



Evaluation of the Agroforestry and Farm Forestry Program

An assessment of benefits - stage 2

**A report for the Rural Industries Research and
Development Corporation**

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Foreword

This report is part of an overall evaluation of the Agroforestry and Farm Forestry Program, a sub-program under the Emerging Industries program. This is the fifth in a series of evaluations and the first at the sub-program level. Given the size of the sub-program and current public interest in replanting Australia, it is timely for the focus of this year's evaluation to be on Agroforestry. It is also an ideal candidate for triple bottom line evaluation as the non-commercial benefits of trees are one of the motivating factors for public interest. Part one of the report compiles a list of all completed and current projects together with an assessment of their expected impact. This part of the report provides a more in-depth assessment of the impacts of the R&D.

Four clusters of projects (covering 25 projects in all) are evaluated. The evaluation method aimed to identify and quantify the environmental and social as well as the economic benefits. The internal rates of return range between 11 and 24 per cent. The relatively low values reflect the long delay between planting trees and reaping some of the more commercial benefits. The net benefit investment ratios (NBIR) which estimate the dollars return to each dollar of R&D invested range from 2 to 26. Overall the net present value of the benefits from the 25 projects sum to around \$100 million for an investment of under \$9 million in R&D.

The benefits from the R&D have accrued largely in terms of additional commercial returns to farmers in terms of wood and projected carbon credit sales. The assessment of environmental outcomes included the reduction in externalities from salinity, biodiversity protection values and aesthetic values. This assessment provided some challenges owing to poor information about biophysical relationships and baseline environmental quality. However, the results suggest that the environmental benefits flowing from the R&D are small compared to the commercial returns. This is partly due to the poor prospects for a large expansion in farm forestry — particularly in low rainfall areas. Generally speaking, a 'critical mass' of tree planting must be achieved before environmental benefits such as salinity control are realised.

The focus on a triple bottom line approach has proved interesting, making clear the need to report both dollar value estimates and other social indicators. Multiple criteria are needed for ranking projects under this triple bottom line approach.

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Simon Hearn
Managing Director
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Contents

Foreword	iii
Glossary	ix
Executive summary	xi
The evaluations	xi
Comparisons with previous RIRDC evaluations	xviii
Lessons from the evaluations	xviii
1 Introduction	1
The Agroforestry program	1
Identifying the benefits from the R&D	2
Overview of the evaluations	5
Comparisons with other project assessments	10
2 Tropical and sub-tropical Cabinet Timbers	13
Project overview	14
Project evaluation	22
Results	30
3 Agroforestry and catchment hydrology	38
Background	38
Projects evaluated	40
Our evaluation approach	45
Results	52
Sensitivity analysis	53
4 Master Treegrower Program	55
Background	55
The Master Treegrower Program	55
Project outcomes	58
Project evaluation	65
Results	72

5	Site and species suitability	78
	Background	78
	Project descriptions	81
	Outputs	82
	Outcomes	88
	Evaluation methodology	92
	Results	101
A	Estimation of indirect benefits	106
	Triple bottom line framework	106
	Direct economic benefits	110
	Indirect economic benefits	112
	Non-market impacts	117
	Social benefits	122
B	Guidelines for triple bottom line reporting	125
	Objective	125
	Why do we need triple bottom line reporting?	128
	A framework for triple bottom line reporting	130
	Classifying triple bottom line outcomes and impacts	132
	The approach used in this report to estimating the value of triple bottom line impacts	138
	References	142
	 Boxes	
	Box A.1 The Choice Modelling technique	119
	 Charts	
	Chart 1 Summary of the results - present value of costs and benefits	xiv
	Chart 2 Benefit distribution from additional high rainfall plantings	xviii
	Chart 3 Comparison of rates of return on projects across the four programs	xx
	Chart 1.1 Mapping from project outcomes to benefits	4
	Chart 2.1 Effect of JVAP Cabinet Timber projects	15
	Chart 2.2 Model methodology	27
	Chart 2.3 Hectares of cabinet timbers, with & without research 2000-2050	29
	Chart 2.4 Wood benefits from cabinet timbers, with & without research 2000-2050	29
	Chart 2.5 Benefits from JVAP cabinet timber research	31
	Chart 2.6 Non-wood benefits from JVAP cabinet timber research	31
	Chart 3.1 Potential impacts of R&D on salinity policy and implementation	44

Chart 3.2 Impact of agroforestry on the future costs of degradation 2000–2020	51
Chart 4.1 Hectares of trees planted with and without MTG	60
Chart 4.2 Tree planting, harvesting and technology adoption rates	62
Chart 4.3 Calculating the benefits of the ‘echo effect’	64
Chart 4.4 Adoption rates of technology with and without MTG echo by farmers who did not attend the MTG	65
Chart 4.5 Flow of inputs, outputs, outcomes and benefits	66
Chart 4.6 Composition of the increase in present value of benefits attributable to MTG	73
Chart 5.1 Site suitability outputs	87
Chart 5.2 Species suitability outputs	88
Chart 5.3 Site and species suitability outcomes and impacts	89
Chart 5.4 Adoption profile	91
Chart 5.5 Model to estimate the benefits of site and species suitability R&D	93
Chart 5.6 Benefit distribution from additional high rainfall plantings	105
Chart A.1 Economic, social and environmental outcomes: a guide for measuring benefits	109
Chart A.2 Impact of agroforestry on the future costs of degradation 2000–2020	116
Chart B.1 Mapping outputs to outcomes to benefits	126
Chart B.2 Measuring benefits – from market based dollars to survey based assessments	131
Chart B.3 Measuring economic impact	137
Chart B.4 Mapping R&D outputs to a triple bottom line	141
 Tables	
Table 1 Results of the evaluations (at 5 per cent discount rate)	xiii
Table 2 Sensitivity of the estimates	xv
Table 1.1 Other evaluation results	11
Table 1.1 Other evaluation results (continued)	12
Table 2.1 R&D project costs, by funds source	19
Table 2.2 R&D project cost, by financial year (2002 dollars)	19
Table 2.3 Results	30
Table 2.4 Economic bottom line	34
Table 2.5 Environmental bottom line	36
Table 2.6 Assumptions for sensitivity analysis	36
Table 2.7 Results from sensitivity analysis	37
Table 3.1 JVAP projects on hydrology and agroforestry interactions	41
Table 3.2 National expenditure on biodiversity and landscape protection	45
Table 3.3 Current and future costs of salinity, turbidity and sedimentation	48

Table 3.4 Per hectare salinity benefit from agroforestry — before implementation costs	52
Table 3.5 Timing of R&D costs	52
Table 3.6 Estimated returns hydrological research	53
Table 3.7 Sensitivity of net R&D benefits (\$ millions NPV) ^a	54
Table 4.1 Costs of R&D	57
Table 4.1 Costs of R&D (continued)	58
Table 4.2 Changing reasons for planting trees	61
Table 4.3 Establishment costs	71
Table 4.4 Outcomes with Master Treegrower Program	71
Table 4.4 Outcomes with Master Treegrower Program (continued)	72
Table 4.5 Results of the benefit cost analysis under varying discount rates	72
Table 4.6 Values used to parameterise the probability distribution of each input variable	76
Table 4.7 Results from sensitivity analysis	76
Table 5.1 Annual research costs for site suitability	79
Table 5.2 Annual research cost for species suitability	81
Table 5.3 Objectives of R&D by site suitability project	82
Table 5.4 Objectives of site suitability R&D projects by Stage	83
Table 5.5 Hectare distribution assumptions	95
Table 5.6 Distribution and growth assumptions - baseline	95
Table 5.7 Use of wood and value assumptions	96
Table 5.8 Harvest and thinning time line	97
Table 5.9 Assumed costs planting and associated costs	98
Table 5.10 Quantifiable benefits from plantations	99
Table 5.11 Scenarios tested	101
Table 5.12 Incremental returns from research	102
Table 5.13 Values used to test the sensitivity of the model	103
Table 5.14 Sensitivity analysis results confidence interval results	103
Table 5.15 Scenario results (5 per cent discount)	104
Table A.1 Estimated carbon sequestration value of farm trees	112
Table A.2 Current and future costs of salinity, turbidity and sedimentation	115
Table A.3 Agroforestry adoption scenarios and impacts - key assumptions	116
Table A.4 Non market value estimates for 20 year outcomes	120
Table A.5 Some benchmark estimates of value	122

Glossary

BCA	Benefit Cost Analysis
BCR	Benefit Cost Ratio
CRRP	Community Rainforest Re-forestation Program
CTM	Cabinet Timbers Model
IRR	Internal Rate of Return
JVAP	Joint Venture on Agroforestry Program
MAI	Mean Annual Increment
MTG	Master Tree Growers
NBIR	Net Benefit Investment Ratios
NHT	Natural Heritage Trust
NLWRA	National Land and Water Resources Audit
NPV	Net Present Value

Executive summary

Agroforestry and Farm Forestry is the largest sub-program in the Emerging Industries program, with an annual budget exceeding \$3 million. The investment in agroforestry R&D is made as part of the Joint Venture on Agroforestry Program (JVAP) which was formed in 1993. This report is the fifth in a series of annual evaluations and is the first report to look specifically at a sub-program. It is also the first to explicitly consider the triple bottom line outcomes of the R&D — the economic, environmental and social outcomes and the benefits they bring to Australia.

This report focuses on the benefits of the R&D outcomes that can be estimated based on market values. These estimates include the flow-on benefits of environmental outcomes such as reduced water treatment costs as well as direct economic impacts such as higher wood volumes from improvements in the growth rates of trees. It also includes the value of protecting biodiversity, and the benefits of improved aesthetics where such benefits can be identified and willingness to pay has been estimated. These market based value estimates capture a lot, but not all, of the benefits. They are unable to reflect some benefits that can flow from R&D such as the value to individuals from greater confidence in their future or greater contentment. A companion report by AgKnowledge / AgInsight considers this part of the triple bottom line.

The evaluations

In order to develop an indicative estimate of the returns to investment generated by the Farm Forestry Program, a sample of projects were selected for 'ex post' benefit-cost analysis. Projects contributing to a common outcome were identified in stage 1 of the evaluation process. In stage 2 four topics were selected for detailed analysis. Individual projects that addressed each topic were identified and grouped together such that the joint outcomes of the cluster of projects were analysed as a whole. In total, 25 individual projects were evaluated. The topics covered by the evaluations, and a brief summary of their benefits, are as follows:

- Agroforestry and catchment hydrology — 4 projects that developed fundamental principles and provided advice on where in a catchment trees should be planted to maximise the cost-effectiveness of salinity mitigation. This advice can substantially improve the return to public investment in trees for salinity mitigation by raising the probability that the trees planted will be effective in reducing the water tables. The research reflects the current

uncertainty that exists in the research community about the effectiveness in many areas and plays an important role in shaping the direction of R&D to improve information for decision making.

- Cabinet timbers — 9 projects that looked at different aspects of the fledgling cabinet timber industry in the sub-tropics of Australia. The work in production aspects of this new sub-industry is already supporting industry growth through improved productivity and has been critical in raising the expected commercial returns.
- The Master Tree Growers (MTG) courses — 2 cycles of funding for a project that has trained almost 800 agroforesters on various aspects from establishment to management and marketing. The courses resulted in an increase in the average area planted to trees and productivity improvements. Although difficult to estimate there is evidence that the MTG pass on some of their knowledge to other farmers creating an echo effect, improving the outcomes for other tree growers. In addition to the environmental benefits of an expansion in the area of trees planted are a number of intangible benefits reflected in improvements in confidence and the knowledge of MTG.
- Site and species selection — 10 projects researched a range of factors influencing tree growth under different site conditions and selected species for particular purposes. The productivity improvements and cost savings in establishment that could be gained are considerable. The impact is highly dependent on adoption rates, which will vary with location and applicability of the research. A conservative estimate of impact is made based on the knowledge improving outcomes for existing and planned plantings. Some of the projects could also form the basis for expansion of farm forestry in low rainfall and saline areas, bringing considerable environmental benefits.

Each of the benefit cost evaluations follow a systematic approach to identifying the collective project outputs and mapping these outputs to measurable outcomes. Given the long time lags involved in many forestry enterprises — and the delays between research and realising the outcomes — it is necessary to build futures scenarios to evaluate the impacts of R&D. Whilst the projects in question have all been completed or in the process of being finalised, in some cases it will take time before the benefits begin to flow through. Thus, the scenarios take explicit account of adoption rates and time lags before new innovations are taken up by industry. Information on expected adoption profiles is sourced from researchers and industry stakeholders. The scenarios also incorporate the uncertainty associated with biophysical systems (for example, salinity projections) and other key parameters using sensitivity analysis.

The aim of the evaluations is to estimate the most likely R&D payoff under a given set of assumptions. Where environmental and social impacts are not fully captured in the analysis, the benefit-cost results provide a ‘first pass’ measure of the pay-off. If this return is less than returns on other investment alternatives the estimates can be used to assess what the intangible benefits would need to be ‘worth’ to make the R&D project competitive.

The benefit-cost results are summarised in table 1. The range of results suggest that there is a fair degree of clustering in terms of the projects selected for evaluation. The range of net benefit investment ratios (NBIR) — the return for each R&D dollar invested — is from 2.4 to 26. The net present value of the four projects sets ranges from \$4 million to \$71 million and the internal rate of return from 11 to 24 per cent.

Table 1 Results of the evaluations (at 5 per cent discount rate)

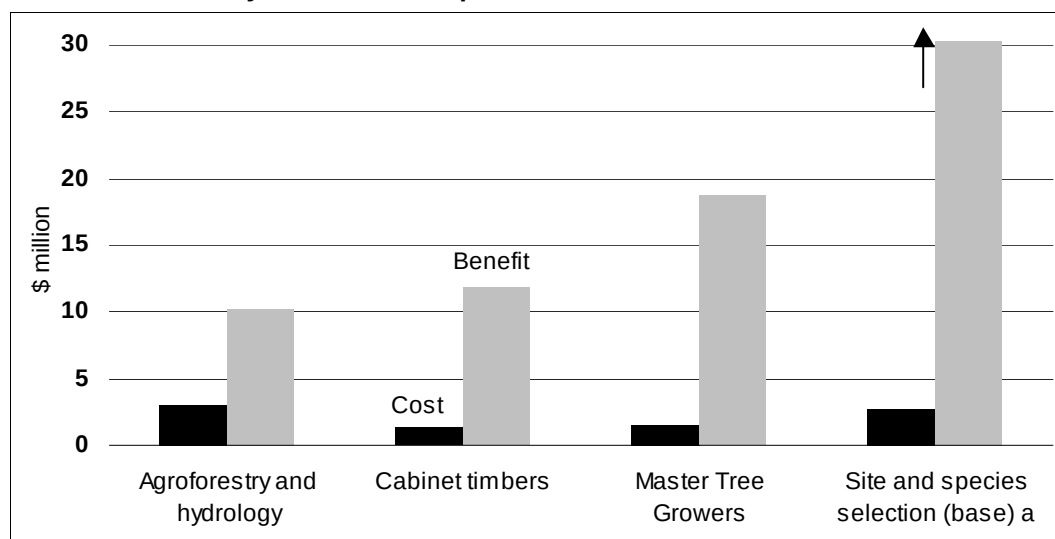
Project	Present value Cost	Net present value	NBIR	IRR
	\$m	\$m		%
Agroforestry and hydrology	3.05	4.1	2.4	21
Cabinet timbers	1.40	10.5	8.4	10.6
Master Tree Growers	1.57	17.2	11.0	15
Site and species selection (base) ^a	2.7	70.7	26.2	23.6

^a The mean estimate is reported from the sensitivity analysis as the assumptions given in the base case are thought to reflect the best case outcomes.

Source: Chapters 2-5

Chart 1 summarises the present value of the cost of the R&D and the present value of the benefits that result.

Chart 1 Summary of the results - present value of costs and benefits



^a The mean estimate is reported from the sensitivity analysis as the assumptions given in the base case are thought to reflect the best case outcomes.

Source: Chapters 2-5

The internal rate of return (IRR) on most of the project sets evaluated is low when compared to previous cost-benefit analyses conducted on RIRDC programs. This is due to the considerable time lag before many of the benefits from planting trees are realised. It is also due to the embryonic nature of the industry and the technical challenges associated with some areas of research. Indeed, agroforestry R&D is dealing with complex systems where many of the biophysical relationships are still unknown.

The baseline expansion of agroforestry is taken to be that set out in *Vision 2020*, with agroforestry remaining a constant share of the plantation estate (currently 6 per cent) into the future. While this projection may not be entirely appropriate for agroforestry, it is to be expected that the adoption of trees on farms will be influenced to a large extent by the commercial attractiveness of forestry and the availability of processing facilities in regional areas. Thus, there is good reason to believe that the adoption of farm forestry will mirror what is happening in the industrial plantation estate. To the extent that agroforestry grows faster than the growth predicted for plantations the results presented here will underestimate the benefits.

The sensitivity of the estimates

Agroforestry is an emerging industry. The National Farm Forestry Inventory provides estimates of the current size of the industry, but little is known about its long term growth prospects. Agroforesters are highly diverse, as are their reasons

for planting farm trees. This makes it difficult to assess the relevance of and access to information and the likely adoption rates of the R&D. The diversity of locations, planting purpose and species selection make modelling the benefit flows a challenge. While we can fairly safely assume that planting for a specific purpose will deliver that benefit, many plantings have multiple purposes. To test the sensitivity of the estimates to these types of uncertainties sensitivity analyses were undertaken on all the benefit cost analysis (BCAs). The results are given in table 2.

Table 2 Sensitivity of the estimates

Project	Lower bound NPV	Upper bound NPV	Lower bound NBIR	Upper bound NBIR
	\$m	\$m		
Agroforestry and hydrology	1.8	12.0	1.6	4.9
Cabinet timbers	2.3	23.7	2.6	17.7
Master Tree Growers	10.9	20.76	8.0	14.3
Site and species selection (base)	46.8	106.4	17.3	39.4

Source: Chapters 2-5

Return on R&D and return on investment in the industry

The NBIR estimates provide a measure of the return on the R&D investment. This return is often contingent on an additional investment being made — in this case in the establishment and management of farm forestry. This investment is reflected in the additional area that is likely to be planted as a result of the improvements in the outcomes from farm forestry due to the R&D. There was an additional investment in all the evaluations except the catchment hydrology projects, as this looked at more effective allocation of existing committed resources. The results of the other three BCAs depend on the viability of these additional investments.

- The cabinet timber BCA found that farmers would get a return of 12.6 per cent on their investment in cabinet timbers, allowing for the opportunity cost of land. This is considerably higher than the return on investments in many other agricultural products, making cabinet timbers an attractive option.
- The evaluation of the Master Tree Growers Course uses survey information from AgKnowledge / AgInsight (2002) to assess the area of tree plantings undertaken by course participants before and after the course. The benefit cost ratio estimated when implementation costs are taken into account is 3.2, reflecting a solid return to the MTG and those who follow their lead.

- The site and species selection BCA did not consider an increase in the area in the base line R&D scenario. However, several scenarios where expansion in area occurred were examined.
 - An expansion in the high rainfall zone resulted in a benefit cost ratio (BCR) on the additional implementation investment of 1.4. The lower value partly reflects the higher opportunity cost of land in this area.
 - An expansion in the low rainfall zone resulted in a BCR on the additional investment of 3.3. This maybe somewhat optimistic as it assumes a high price can be achieved for carbon credits, but there is also a strong element of shade and shelter benefits.
 - An expansion in the saline areas resulted in a BCR of 1.9.

The triple bottom line

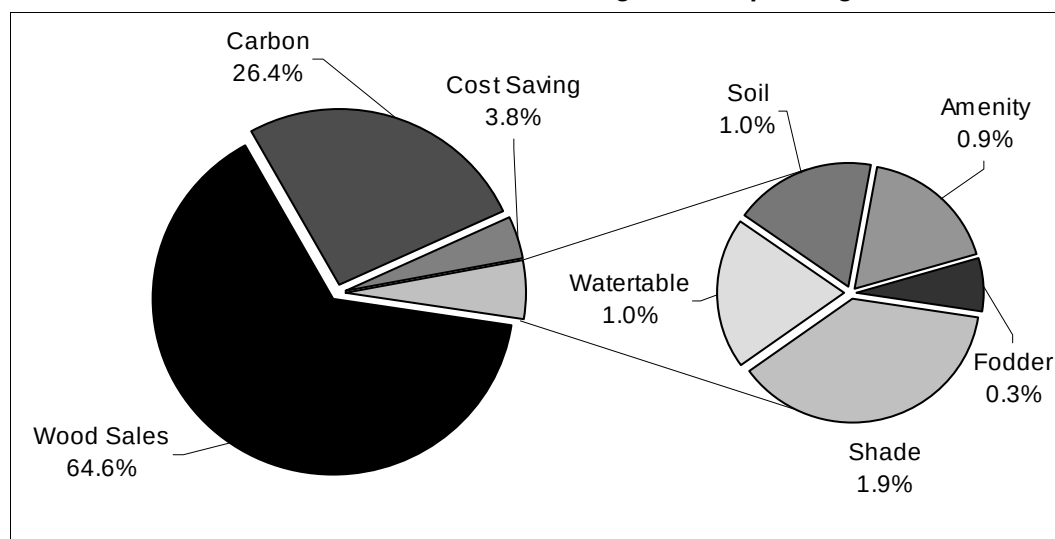
The source of the benefits — economic, environmental and social outcomes varies between the project sets evaluated. As discussed in detail in appendix B, there are benefits that cannot be measured in dollar terms as they do not have a market value metric. The results presented in this report do not include indicators of this kind of benefit. Some indicators are presented in the companion report *AgKnowledge / AgInsight* (2002). This report does include estimates of most of the economic and some of the other benefits that flow from the environmental outcomes of the R&D. The other benefits included are a value on biodiversity and on aesthetics or amenity value. These values are derived from the National Land and Water Resources Audit work (NLWRA, 2002). They represent the Australian community's willingness to trade-off a household environmental levy for particular environmental outcomes.

Commercial benefits from increased revenue from wood sales and carbon credits are the major sources of benefits of all but the hydrology project sets. This should not be surprising as the research has focused on raising the commercial returns to make farm forestry a more attractive option. However, as the section above notes, even with these productivity improvements it is very difficult to raise the return to commercially attractive levels in areas other than high rainfall locations close to existing processing capacity. This finding is consistent with the forthcoming report for JVAP (Buffier and Allen Consulting, 2002). As such, in this evaluation a relatively modest expansion in farm forestry is assumed. This conservative approach explains the comparatively low share of benefits flowing from environmental outcomes.

The distribution of benefits are as follows:

- Agroforestry and catchment hydrology — the benefits all come in terms of having a greater impact on salinity levels and hence lowering the costs associated with salinity including yield losses, infrastructure repair costs and water treatment costs. The potential impact on biodiversity and the value this might generate was not taken into account.
- Cabinet timbers — wood benefits made up 96 per cent of the estimated benefits. Of the remaining non-wood benefits carbon trading made up 2 per cent. The share of the value of other environmental outcomes was very small, with the benefits to biodiversity, fodder and aesthetics being the largest of the remainder.
- Master Tree Growers Course — the main source of gains due to the MTG course (57 per cent) was from the expansion in area and the carbon sink value this delivers. Higher revenues from wood accounted for 32 per cent of the benefits, while the non-carbon environmental outcomes made up less than 1 per cent of the benefits. The echo effect — adoption of new technology by other growers — accounted for 10 per cent of the benefit. This component was all in higher productivity of wood production as the area planted by non-MTG growers was not expected to increase as a result of the MTG. In addition to these largely economic benefits the MTG has had social benefits. These are reflected in the reported increased confidence in the future of agroforestry and agriculture in general (AgKnowledge / AgInsight, 2002). These impacts were not given a dollar value in the analysis.
- Site and species selection — in the base line R&D case the benefits are almost entirely due to productivity improvements in wood production. In the high rain fall expansion scenario 65 per cent of the benefits came from wood, 26 per cent from carbon credits, 3.7 per cent from cost savings in establishment, 2 per cent from shade and shelter, and around 1 per cent each for amenity values, soil erosion control and reduced water tables. As an example, chart 2 shows the distribution of gross benefits from an expansion in the area of farm forestry in the high rainfall zone.

Chart 2 **Benefit distribution from additional high rainfall plantings**



Data source: CIE calculations

Comparisons with previous RIRDC evaluations

The estimates of the returns on agroforestry are similar to the returns in other emerging industries, without the big winners. This is in part due to bundling of the research into larger sets, which incorporates both very good and poorer projects. Chart 1 summarises the results from the past five years of RIRDC evaluations.

Returns agroforestry R&D is noticeably smaller than some other RIRDC programs such as 'Established Industries'. However, this result must be viewed in its proper context. Agroforestry is still at an embryonic stage of development and the research undertaken by JVAP is dealing with complex systems where many of the biophysical relationships are still unknown. The benefits of R&D are contingent on the growth in the industry — which in turn will depend on the ability for farm forestry to be a commercially attractive option in low rainfall areas.

Lessons from the evaluations

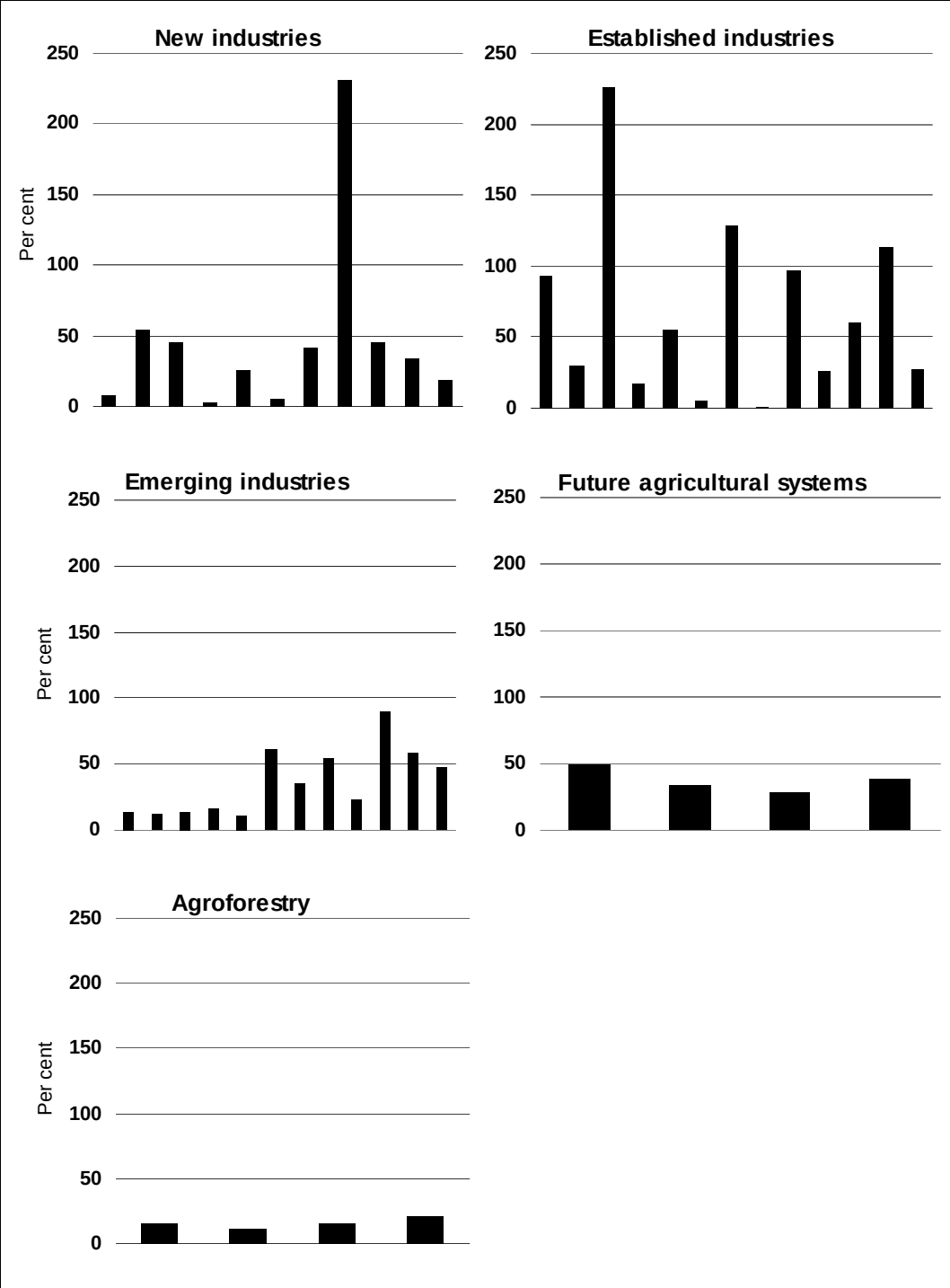
These evaluations have presented considerable challenges due to the lack of hard data on adoption rates and the diversity of the industry. A wide range of opinions was sought in trying to estimate the outcomes of the research and adoption rates that might not be apparent in the text. Most people contacted could only report with any confidence on their specific locality, which explains

the wide range of assumptions that are tested. Given the scope of the exercise it has been necessary to make a number of simplifying assumptions and use broad zone averages in the estimation of outcomes and impacts. As the evaluations focus on the changes brought about by the R&D, the base matters less than when making estimates of the total value of agroforestry, hence we have some confidence in the results presented here.

As always, the most useful part of doing evaluations is the lessons we learn from them. It is hoped that the process of the evaluation will assist researchers in better understanding the likely impacts of their research. Key lessons are:

- The long lag before trees provide a commercial return means that the return on R&D will always be comparatively low, compared with products with annual production cycles.
- It is the commercial returns on agroforestry — in wood and in carbon credits that provide the greatest return, and the main motivation for investment in agroforestry. The research evaluated has focused largely on improving the commercial outcomes.
- There are situations where agroforestry looks like a good complement to other agriculture as with cabinet timber production. However, in many cases the return may be more marginal, and individual values on the outcomes that are not reflected in the market based values used here may need to be high to get the investment over the line.
- While there are environmental outcomes that are valuable, these are not large relative to the commercial returns on the R&D.
- Initial research in new industries can deliver enormous productivity gains. Once this ground breaking research is done it will be harder to deliver such big gains in the future. This means that greater attention to project selection will be needed to identify where the greatest gains are in the future.

Chart 3 **Comparison of rates of return on projects across the four programs**



Agroforestry is an unusual industry in that it has significant spillover effects on the environment and potentially on social outcomes. The concern of industry supporters is that the commercial benefits are not sufficient to grow the industry and bring about subsequent environmental gains. Hence the focus of much of the R&D evaluated here is on raising the commercial returns. The results suggest that significant progress has been made, but the commercial hoop is still out of reach in some areas. The future challenge is to target R&D to make the jump and get the industry onto a widespread commercial footing. And, the environmental outcomes and their value need to be quantified in order for policy makers to determine the appropriate level of public support. JVAP R&D projects are also tackling these issues.

1 Introduction

The Agroforestry program

Agroforestry and Farm Forestry is the largest sub-program in the Emerging Industries program, with an annual budget exceeding \$3 million. Most of the investment is made as part of the Joint Venture on Agroforestry Program (JVAP) which was formed in 1993. JVAP is a partnership with RIRDC, Land and Water Australia (LWA), the Forest and Wood Products Research and Development Corporation (FWPRDC) and the Murray Darling Basin Commission (MDBC). The Commonwealth has provided \$4 million for the research through the Natural Heritage Trust (NHT) and the Farm Forestry Program (FFP). Other agencies such as the Grains Research and Development Corporation (GRDC) and the Australian Greenhouse Office contribute to specific projects. The objective of the Agroforestry and Farm Forestry program is to integrate sustainable and productive agroforestry within Australian farming systems.

This report and a focus on triple bottom line

This report is the fifth in a series of annual evaluations. It is the first to look at a sub-program. Part one of the report provides an overview of the Agroforestry and Farm Forestry program, summarising all the R&D projects that have been undertaken since the inception of the sub-program. This second part reports on the findings of the benefit cost analysis (BCA) undertaken of a selected set of projects. While non-economic outcomes, such as the effect on health and safety, have been taken into account in previous evaluations, this report is the first to explicitly consider the triple bottom line outcomes of the R&D — the economic, environmental and social outcomes and the benefits they bring to Australia.

The report focuses on the benefits of R&D outcomes that can be estimated based on market values. These estimates include the flow-on benefits of environmental outcomes such as reduced water treatment costs as well as direct economic impacts such as higher wood volumes from improvements in the growth rates of trees. It also includes the value of protecting biodiversity, and the benefits of improved aesthetics where such benefits can be identified. A number of benchmark estimates are provided in appendix A. These market based value estimates capture a lot of the benefits but not all. They are unable to reflect some benefits that can flow from R&D such as the value to individuals from greater confidence in their futures, or greater contentment. Appendix B provides a

discussion of the triple bottom line approach taken in estimating the benefits in this report. It recognises the difficulties with including social values that do not have a market value metric in summary estimates of value. A companion report by AgKnowledge / AgInsight considers this part of the triple bottom line for the Agroforestry program.

Identifying the benefits from the R&D

In order to develop an indicative estimate of the economic returns to investment generated by the Farm Forestry Program, a representative sample of projects were selected and subjected to 'ex post' benefit-cost analyses. The projects are analysed as a group, with each group being a different research topic. In total, 25 individual projects across four different research topics are evaluated. It should be noted that these topics form only a portion of the JVAP research program, for example work on potential new products and the contribution of farm forestry to environmental services is not covered by this report. The topics covered are as follows:

- Agroforestry and catchment hydrology — 4 projects that developed fundamental principles and provided advice on where in a catchment trees should be planted to mitigate salinity;
- Cabinet timbers — 9 projects that looked at different aspects of the fledgling cabinet timber industry in the sub-tropics of Australia;
- The Master Tree Growers Courses — 2 cycles of funding for a project that have trained almost 800 agroforesters on various aspects from establishment to management and marketing; and
- Site and species selection — 10 projects that researched a range of factors influencing tree growth under different site conditions and selected species for particular purposes.

The starting point for all the evaluations is to identify the range of potential benefits. Agroforestry provides a wider range of potential benefits than many of the other industries that RIRDC deals with. Trees have considerable scope for spill-over benefits — benefits that accrue to people other than those who plant the trees or are involved in the forestry industry.

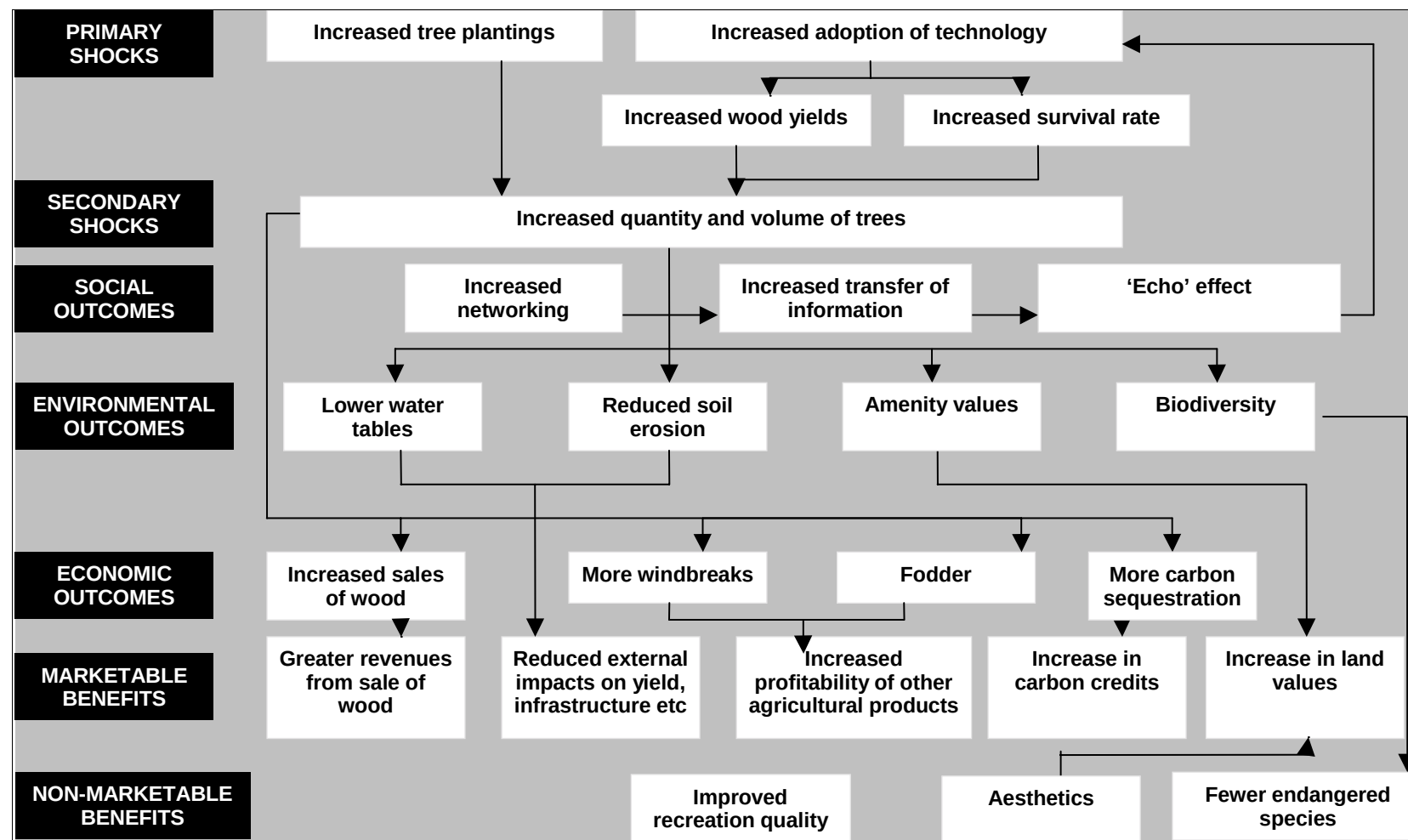
Chart 1.1 summarises the range considered in this report. As discussed above there are other benefits that may flow from agroforestry that are not captured here, but they fall into the category of social values that economics cannot quantify in dollar terms. A more detailed discussion of these benefits, and how to evaluate them, is contained in Appendix A.

The main benefits identified are:

- productivity improvement due to:
 - higher growth rates and shorter rotations;
 - lower establishment costs; and
 - high establishment success rates;
- quality premiums due to silviculture;
- environmental outcomes of lower water tables and hence:
 - yield improvements;
 - reduced infrastructure repair; and
 - lower water treatment costs;
- reduced soil erosion, particularly in riparian zones, lowering control costs;
- enhanced biodiversity; and
- enhanced aesthetics.

The social impact of the R&D at a 'whole of community' level is uncertain, with both positive and negative influences. At an individual grower level, survey results from the MTG survey reflect improvement in various social indicators.

Chart 1.1 Mapping from project outcomes to benefits^a



^a The echo effect refers to the dissemination of skills and knowledge from RIRD's primary recipients of R&D findings into the wider community.

Overview of the evaluations

The four benefit-cost analyses undertaken in this report are briefly outlined below.

Agroforestry and catchment hydrology

Four projects were evaluated together under Agroforestry and Catchment Hydrology. They were:

- CSM-3A Agroforestry and hydrology— a research planning workshop;
- WS967-7 Ground water take-up and salt accumulation by trees over shallow water tables — a workshop to assess the state of knowledge;
- AGS-1A National classification of catchments for land and river salinity control — mapping of catchments by potential for control; and
- CSM-4A Agroforestry design guidelines to balance catchment health with primary production — guidelines on how to plant trees in the landscape to maximise salinity mitigation, while maintaining production.

These hydrology projects have improved our understanding of managing dryland salinity with trees. The major impact is likely to be on shaping government policy and improving the efficiency with which public investment is targeted for salinity control. It is anticipated that around \$1.5 billion a year is being spent by the public and private sector on biodiversity and landscape protection. We assume that 30 per cent of this (or \$450 million) is being spent on tree planting programs. While there is debate about whether this represents good value for money, the purpose of this evaluation is not to determine whether the benefits of this policy exceed the costs. Rather, the evaluation estimates the value of JVAP's research in terms of efficiency improvements per dollar invested.

Approach

The cost of salinity over the next 20 years has been estimated by the National Land and Water Resources Audit as \$2.9 billion. Based on the potential for agroforestry to mitigate these costs we estimate that the annual benefit from a hectare of trees with the R&D is likely to be around \$9.00 per hectare. This compares with an annual value of around \$7.70 per hectare without the research (see table 3.4 in chapter 3). The benefits are estimated based on:

- improved responsiveness of salinity abatement from more effective tree planting programs; and
- a greater number of trees planted per dollar invested. For example, improved survival rates lower the costs of tree establishment and encourage higher adoption of agroforestry.

Results

The present value of the benefits is estimated as \$18.7 million, for a cost of \$3.05 million for the research. This gives a NBIR of 6.1 and an internal rate of return of 88 per cent. While the net benefits are not particularly high, the results show a positive impact of the R&D. The range of possible impacts is large as the results depend critically on:

- the projected future costs of salinity in the absence of salinity control treatments.
- the responsiveness of the salinity cost function to agroforestry treatments; and
- the scale of agroforestry adoption.

A sensitivity analysis around these parameters finds that the NBIR is likely to range between 5.3 and 8.8.

Cabinet timbers

There are nine projects in the project set, covering topics from establishment and nutrition to silviculture to making tree growing consistent with animal production. All support the development of a cabinet timber industry in the sub-tropics. The nine projects are:

- UQ-18A and UQ-41A — Agroforestry with high value trees;
- QDN-1A — production of book 'Commercial timber species doe eastern sub-tropical Australia;
- DAQ-240A — Silviculture of rainforest cabinetwoods;
- QDF-1A — Establishment of tropical rainforest cabinetwood species using artificial tree shelters;
- UNE-34A — Growth in high value trees on farms;
- CSL-6A Demonstration of the potential effects of nurse nutrients on tropical cabinet timbers;

- CSZ-1A — The potential for tropical agroforestry in wood and animal feed production; and
- CSC-58A — Trees for wood and animal production in northern Australia.

Approach

There was a paucity of information on the size of the industry, except from harvest from native forests. The first step was to develop a model to assess the scale and value of the industry. The R&D has contributed to a stronger outlook for the industry in terms of growth, as well as delivering a number of productivity shocks. The impact of the growth in the industry and the improvements in productivity is assessed in the model. The opportunity cost of land and the implementation costs of additional planting is taken into account in assessing the net benefits. The benefits depend on the purpose of the plantings with an anticipated 15 per cent of plantings not being harvested, but left for biodiversity, and other benefits. Given the small volumes of wood and their potential to replace harvest from native forests, downstream processing impacts are not considered.

Results

The present value of the benefits is estimated as \$12 million, for a cost of \$1.4 million for the research. This gives a NBIR of 8.4 and an internal rate of return of 11 per cent. The vast majority of the benefit comes from the productivity improvement in wood production.

The Master Treegrowers Program

Two projects have supported the MTG program.

- UM-34A — The Australian Master Treegrower Program.
- UM-44A — Continuation and expansion of the Australian Master Treegrower Program.

By June 2001 35 MTG programs had been completed and around 800 agroforesters, extension agents and others involved in farm forestry had attended a course.

Approach

A survey had been undertaken before and after the course, which recorded the level and purpose of plantings. After the course the number of trees planted

expanded considerably. As some of this expansion had not doubt been planned prior to the course only 25 per cent of the increase was assumed to be attributable to the course. However, higher adoption of new technology was also indicated. In addition to the changes made by the participants in the MTG program there is expected to be an 'echo' effect — other farmers adopting new technology as a result of the example and informal learning opportunities through MTG farmers and extension services. The benefits of the expansion in area planted, distinguished by purpose of planting, and of higher rates of adoption of new technologies by MTG farmers and others are estimated in a similar manner to the cabinet timber benefit estimates.

Results

The benefits of the projects are estimated as \$23 million for an R&D cost of \$1.6 million. This gives an NBIR of 11, and an internal rate of return of 15 per cent. The majority of the benefits are from additional carbon credits (57 per cent) while improved revenue from wood production makes up 32 per cent.

Site and species selection

There are 10 projects in the site and species suitability evaluation. Site suitability research projects have dealt with the broad question of determining the best location for growing trees in general and specific tree species in specific locations. Species suitability is a broad term used to identify projects that are designed to allocate particular trees species to locations that will result in the best growth rates and qualities. The three site suitability projects are similar in size, while one project (CSF-56A) dominates the work in the species suitability set. The projects are:

- CSF-41A - The effect of soils and climates on Eucalyptus Globulus plantations;
- CAL-4A - Development of an Australian 'Farm Forestry Site Selection Manual'; and
- DAV-129A - Forecasting tree growth and yield and financial returns of key agroforestry species across Southern Australia;
- PIF-1A - Species selection database;
- AGT-4A - An assessment of commercial prospects for planted tree species in the low rainfall zones of Australia;
- RST-1A - Aleppo pine low rainfall farm forestry;
- CSF-57A - Conifers in the dry country;

- CSF-44A - Trees for South Eastern Australia;
- CAL-1A - REX 95-non specialist tree information database; and
- CSF-56A - Seed and information support.

Approach

The projects were considered to all contribute to improving the productivity of agroforestry through:

- Lowering the input costs for tree establishment;
- Raising the growth rate of trees; and
- Increasing the success rate for tree establishment.

The later two outputs result in a higher volume of wood being produced per hectare, while the first output lowers the initial investment cost. The size of these shocks was assessed after extensive discussions with researchers and others involved in agroforestry. Clearly there are significant difference across locations, species and the purpose of planting in these three areas. The model took account of differences between broad species categories and purpose of planting, but took an average across high rainfall locations to establish a without research baseline. The area of agroforestry was assumed to remain a fixed share of total plantations, growth forecasts of which are given by Vision 2020. The results focus on the changes due to the research, so using an average for the baseline will lead, at worst to only second order errors. The base case estimates of the benefits of the R&D focus only on the productivity improvements. A number of scenarios are undertaken that look at the impact if the R&D leads to an expansion in the area under agroforestry.

Results

The base case estimates the return on the R&D investment of \$ 2.7 million is \$74 million. The NBIR is estimated as 26 and the internal rate of return as 24 per cent. The maximum benefit estimated, based on the values of the productivity shocks provided by the researchers put the net present value at \$106 million. The majority of the benefit comes in higher wood production from the existing investment. Under the area expansion scenarios the benefit estimates are higher, although the returns on the additional investment required may not be high enough to provide an incentive for private investment.

Comparisons with other project assessments

None of the Agroforestry projects evaluated display the very high returns that are occasionally found in the other evaluations. There are a number of reasons why this might be the case.

- The production cycle on trees is a lot longer than on most other agricultural crops, and as the discounting used in BCA puts a lower value on benefits that arise a long time in the future, the estimates of benefits are commensurately lower. A five per cent discount rate is used as a standard, and there has been considerable debate about the appropriate rate to use for investments of this nature. We consider 5 per cent appropriate.
- The industry is still very small and at an embryonic stage. R&D has much greater benefits if it can be applied across a large base. The diversity of agroforestry lends itself to highly specialised research that has more local than generic applicability. Widespread applicability could be claimed for some of the projects in the site and species selection set and as a result the returns on this project set are the highest. They are still subdued somewhat as we had to limit the likely relevance of some of the R&D outputs, reducing the expected impact.
- Research undertaken by JVAP is dealing with complex systems where many of the biophysical relationships are still unknown. Indeed, there is still a lack of consensus as to the impact of trees on hydrology. Therefore, a lot of basic research is being conducted in terms of gathering information and identifying false leads. These activities are common in new areas of research.
- Sets of projects rather than individual projects were evaluated as it was not easy to sort out the different contributions to outcomes. By lumping the projects together, particularly by including the earlier projects, we estimate the average returns to the R&D rather than the marginal returns. Marginal return estimates are often higher, especially where it is hard to sort out the marginal contribution. Having these topic based projects sets also prevented picking winners for evaluation.

Not surprisingly these characteristics are reflected more in the new and emerging industries than in the established industries. The results from previous evaluations by CIE and others is summarised in table 1.1.

Table 1.1 Other evaluation results

	NBIR	NPV	Year	IRR	Disc- ount rate	Source
Future Agricultural systems						
		\$m		%	%	
Trade policy	190	136	2000-01	49	5	CIE 2001
Environmental management systems	6.5	8.9	2000-01	34	5	CIE 2001
RAINMAN	6.7	13.7	2000-01	29	5	CIE 2001
Tractor seats	16.4	2.6	2000-01	38	5	CIE 2001
Prospective new industries						
<i>Plants</i>						
Coffee — harvester	4.9	8.60	1999-2000	8.2	5	CIE 2000
Lentils — new varieties	81.6	31.80	1999-2000	54.0	5	CIE 2000
Buckwheat — industry development	9.2	6.40	1999-2000	46.0	5	CIE 2000
Callide Valley — herb and spice			1999-2000			CIE 2000
Cashews — breeding (CSH-43A, CSH-36A, CSH-8A)	0.4	-2.30	1997-98	2.8	5	Chudleigh in CIE 1998
Cashews — pest management (NAB-3A)	20.0	1.60	1997-98	26.0	5	Chudleigh in CIE 1998
<i>Animals</i>						
Crocodiles — research program	1.1	0.13	1999-2000	5.5		CIE 2000
Dairy goats — farm productivity	10.0	1.15	1999-2000	42.0		CIE 2000
Kangaroos — trading manual	36.0	1.52	1999-2000	231.0		CIE 2000
Emu processing and product development (DAW-34A)	5.3	2.40	1994-95	46.0	7	Bathgate and Coyle 1997
Alpaca productivity and marketing improvement (DAS-41A)	4.6	2.20	1997-98	34.0	5	Michael 1998
Emu processing and product development (DAW-34A, DAW-57A)	2.4	1.80	1997-98	19.0	5	Michael 1998
Established rural industries						
<i>Chicken meat and eggs</i>						
Meat - amino acids in feed (US-60CM, US-67CM, UQ-52AJ)	69.0	32.70	1998-99	93.0	5	CIE 1999
Meat and eggs – vaccine for <i>Eimeria</i> sp (DAQ-28E/29CM, DAQ-251A)	20.8	46.10	1998-99	30.0	5	CIE 1999
Eggs – diet post-moult (VCA-4A)	164.0	23.00	1998-99	226.0	5	CIE 1999
<i>Honeybee</i>						
AFB control (DAN-10H)	18.9	10.40	1998-99	18.0	5	CIE 1999
<i>Rice</i>						
Early maturing (DAN-4A)	16.4	9.90	1992-93	55.0	5	Fearn 1994
Aromatic varieties (DAN-72A)	7.0	11.50	1992-93	55.0	5	Fearn 1994
Improving harvester efficiency (KDI-11A, KDI-17A, KDI-18A)	11.8	2.60	1998-99	129.0	5	CIE 1999

(Continued on next page)

Table 1.1 **Other evaluation results** (continued)

	NBIR	NPV	Year	IRR	Discount rate	Source
<i>Horses</i>						
Progestagens in maintaining pregnancy (GEH-1A)	0.8	-0.01	1998-99	1	5	CIE 1999
<i>Fodder crops</i>						
Oaten hay exports (DAW-28A)	20.0	5.40	1994-95	97	7	Bathgate and Coyle 1997
Inoculants for lucerne (DAW-36A)	2.8	0.14	1994-95	26	7	Bathgate and Coyle 1997
Hay and silage management (KDI-6A)	4.2	1.00	1994-95	60	7	Bathgate and Coyle 1997
Project Haymaker (DAN-88A)	11.3	5.10	1998-99	114	5	CIE 1999
<i>Pasture seed</i>						
New varieties (SED-3A, SED-8A)	4.5	2.40	1998-99	28	5	CIE 1999
Emerging industry portfolio						
<i>Wildflowers</i>						
Breeding and selection projects (22 projects)	2.2	9.30	1997-98	14	5	CIE 1998
Geralton wax breeding (UWA-35A)	1.3	0.12	1992-93	12	10	Fearn 1994
Post harvest quality (UWA-15A)	1.4	0.13	1994-95	13	7	Bathgate and Coyle 1997
<i>Essential oils</i>						
Boronia (UT-2A)	2.3	0.46	1997-98	16	8	Brennan in CIE 1998
Boronia (UT-5A)	1.3	0.17	1997-98	11	8	Brennan in CIE 1998
Boronia (UT-10A)	6.8	3.66	1997-98	61	8	Brennan in CIE 1998
Boronia (UWA-16A)	4.8	1.74	1997-98	35	8	Brennan in CIE 1998
	11.3	2.30	1992-93	54	10	Fearn 1994
<i>Tea tree oil</i>						
Breeding (CSF-43A, ANU-11A, DAN-87A)	14.0	19.00	1997-98	23	5	Chudleigh in CIE 1998
Pest control	1.2	21.50	1992-93	89	10	Fearn 1994
<i>Agroforestry</i>						
Farm trees in New England Tablelands (UNE-16A)	10.0	5.90	1997-98	59	5	CIE 1998
<i>Deer</i>						
Alternative-feed (UWA-14A)	2.1	0.10	1994-95	na	7	Bathgate and Coyle 1997
<i>Rare and natural animal fibres</i>						
Measurement of goat fibres (DAW-45A)	29.0	3.40	1994-95	48	7	Bathgate and Coyle 1997

2 Tropical and sub-tropical Cabinet Timbers

Australia's native forests play host to a rich array of high value trees and cabinet timbers. However, past logging and our environmental preference for the protection of these native forests have limited the potential supply of high value timber around the world.

At the same time, Australian farmers are becoming increasingly aware of the many benefits of farm forestry. More than just the financial benefits of producing wood products, agroforestry offers benefits to the farm such as soil conservation, shade and shelter, fodder for animals and protection against salinity and waterlogging. There are also the benefits of nature conservation and improved scenic quality.

These two trends represent an opportunity for increased planting of cabinet timbers on farms to achieve multiple benefits, most especially in the tropics and sub-tropics.

Such an option, while potentially quite beneficial both for the farmer and the general public, has not been explored in much depth in Australia and there is little information on appropriate tree types for various areas and the magnitude of the potential benefits.

It is in this environment that the JVAP have pursued numerous studies into issues surrounding cabinet timbers. JVAP studies have furthered understanding of appropriate cabinet timber species for various areas and how these species affect animal production. These studies have revealed the potential benefits of investing in high value trees and have improved the decision-making tools for farmers interested in cabinet timbers. This in turn increases the likelihood that farmers will invest in cabinet timbers and increases the efficiency of agroforestry as farmers are able to make better decisions.

Considering the cabinet timber industry and the effect of research on the industry is made difficult by the absence of any solid information. In a country of 770 million hectares, with a total plantation industry of 1.5 million hectares (NHT, 2001) – tropical and sub-tropical cabinet timbers on private farms currently make up a little over 1 000 hectares (CIE model). It is not surprising then, that little work has been done to quantify aspects of the industry.

The ‘newness’ of the industry has three primary consequences for this analysis. The first consequence is that this report has had to build up a picture of the industry from scratch – and has had to rely on assumptions mostly derived from field experts, as opposed to previous rigorous studies. The results of this analysis need to be interpreted keeping in mind the lack of solid data.

The second consequence is that it can be difficult in small industries to get large returns from research. The value of research depends critically on the growth rate and size of an industry, as even a doubling of the size of a small industry may not be a significant gain, while relatively small improvements in a large industry can result in large total gains.

Finally, initial R&D investments that act as a catalyst for industry growth should show high initial marginal returns. Research into any new industry is likely to be most beneficial at the early stages, as major breakthroughs are made and fundamental questions can be answered. Future research will continue to refine the benefits and improve industry output, but it is unlikely to have the same quantum of effect that the initial research will have, unless very carefully targeted at highly prospective areas of R&D.

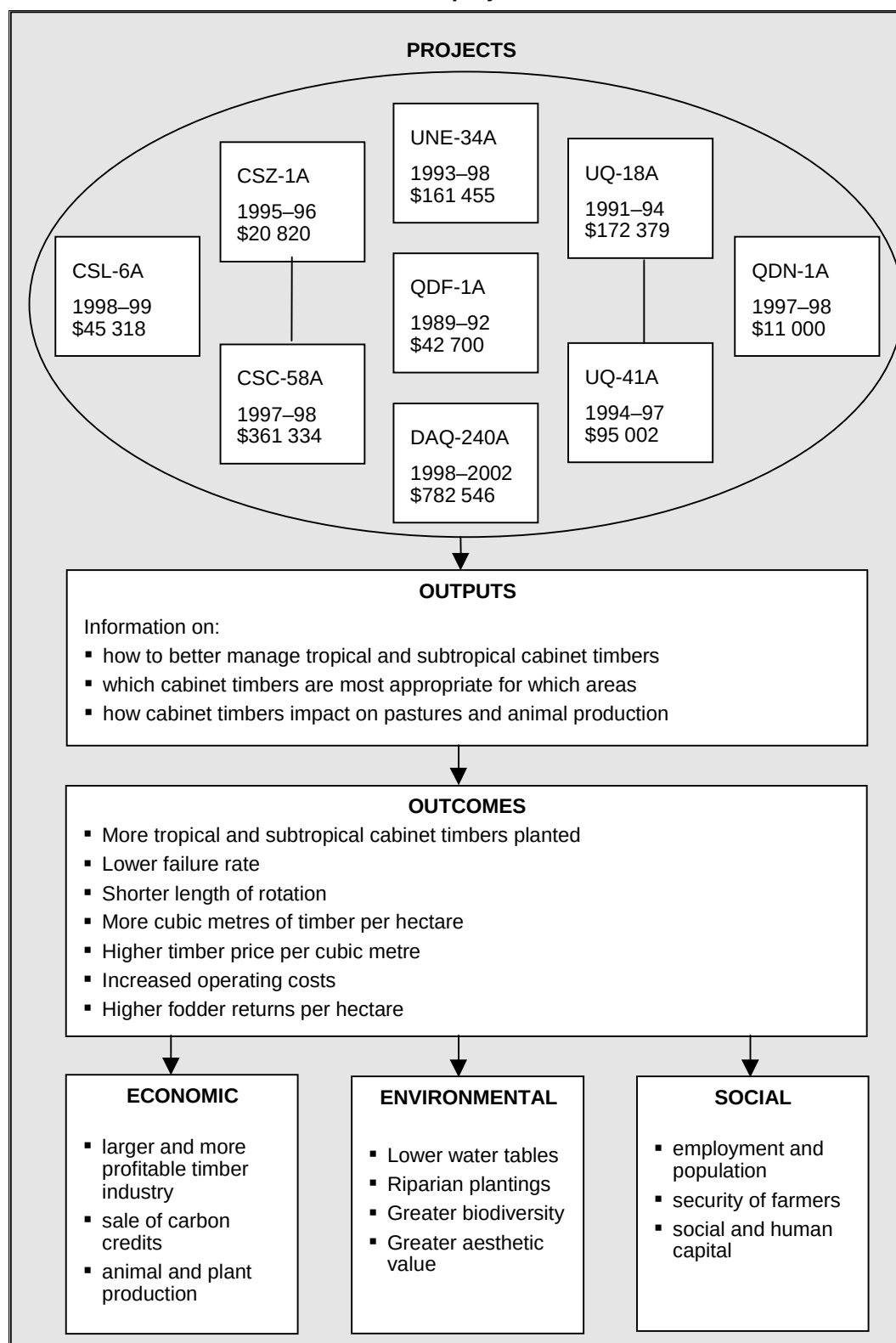
Project overview

Nine JVAP projects covering tropical and sub-tropical cabinet timbers nutrition, multi-products and production systems are included in this calculation.

While the outputs and hence benefits from each project differ markedly, the quantification of benefits and costs will be for the projects in aggregate as it is difficult to separate out the individual project impacts on outcomes. Projects with a particularly high or low effect on the industry outcomes have been discussed quantitatively in the brief descriptions below. It should be noted that UQ-18A and UQ-41A were considered of high value, while CSC-58A and CSZ-1A were of a lower value in terms of the results of this analysis.

Details on the projects included in the analysis, as well as their impact on the cabinet timber market are summarised in chart 2.1 below, followed by a brief description of each project.

Chart 2.1 **Effect of JVAP Cabinet Timber projects**



Description of the projects

UQ-18A and UQ-41A – Agroforestry with High Value Trees

These projects were undertaken between 1991 and 1997, led by Dr David Lamb of the Botany Department of the University of Queensland. The objectives of the project were:

- to assess the growth potential of 16 high value cabinet timber tree species growing in plantation polyculture and to identify species worthy of plantation development; and
- to assess tree and pasture production under a range of tree stocking rates, to assist the development of tree / pasture systems in which both trees and pasture maintain viable productivity.

This study has been successful in increasing the knowledge of the plantation performance of rainforest cabinet timber species, and the results of the trial are widely known in the industry. It is likely that this research project was one of the most important contributors to the results of this analysis (Annandale, Sexton, Warner, Harrison).

QDN-1A – Production of book ‘Commercial timber species for eastern sub-tropical Australia’

The book was written by Ashley Sewell, and the project went from 1997–1998. The book gives details of what are considered the ‘best bet’ 50 commercial species. The focus is on those species found growing in eastern sub-tropical Australia and includes both trees grown for cabinet timbers as well as for other wood products.

While the book provides a good resource of information regarding tree species, the information is basic (2 pages per specie) and of limited use for established tree growers.

DAQ-240A – Silviculture of rainforest cabinetwoods

This project, headed up by Mark Annandale, commenced in 1998 and is expected to be finished in July 2002. This was the single most costly project, with total funding of \$782 536. The objectives of the project are to:

- determine appropriate sites for preferred tropical rainforest timber species;
- increase the rate of successful plantation development of red cedar (*Toona Ciliata*) by development of the most appropriate light environments and establishment procedures;

- develop management prescriptions for spacing, thinning and pruning in single and mixed species plantations of high-value tropical timber species; and
- improve understanding of inter-species interactions in mixed species plantations.

It is expected that a new project 'Mixed Species Plantations: Extending the Science' will commence in the 2nd half of 2002 to build on this project.

QDF-1A – Establishment of tropical rainforest cabinetwood species using artificial tree shelters

Undertaken between 1989 and 1992, the principal investigators in this project were Grahame Applegate and Greg Unwin. The objectives were to:

- demonstrate early growth response of several rainforest cabinetwood species established in the field in artificial tree shelters;
- determine microclimate factors and physiological processes which contribute to the observed growth response of rainforest species established in tree shelters; and
- determine patterns on tree growth and plant environment relations before and after removal of artificial tree shelters.

UNE-34A – Growth of high value trees on farms

This project went from 1993 to 1998 and was headed up by Alison Specht. The objectives were to:

- assess the growth potential of sixteen commercially valuable cabinet timber species grown in a plantation situation on two different soil types in north-east New South Wales and south-east Queensland;
- assess the growth of existing plantations in the same climatic zone; and
- determine species selection and tree establishment strategies and present them in a manner useable by landholders.

CSL-6A – Demonstration of the potential effects of nursery nutrients on tropical cabinet timber trees

Headed up by Mike Webb, this project went from 1998–1999. The project undertook a number of field trials, established in the humid tropics, to demonstrate the benefits to tree growth that can be derived from improving techniques in nutrient delivery to establishing trees.

The results of this project were well publicised and have been the catalyst for some neighbouring countries adopting nursery nutrients on tropical cabinet timber trees (Canberra Times, 1999).

CSZ-1A – The potential for tropical agroforestry in wood and animal feed production

This project, produced by Brian Lowry and Jayne Seebeck, was done between 1995 and 1996. In this study the principal investigators reviewed literature and conducted a survey to assess the potential for agroforestry in Australia's wet-dry tropics based on trees for both wood and animal production. This work was continued in CSC-58A.

CSC-58A – Trees for wood and animal production in northern Australia

Undertaken by Brian Lowry, this project went from 1997–1998, building on project CSZ-1A. The objectives were to:

- demonstrate the feasibility of more sustainable and productive farming systems through the use of trees that promote animal production and also yield a valuable timber crop; and
- produce a manual providing decision support on the use of particular species, a ranking of their suitability for different regions, together with establishment and management information.

While this research succeeded in its goals of showing the fodder benefits of trees, the outcome of higher fodder benefits is a relatively minor result. As stated by the principal investigator Mr Lowry, this project (and CSZ-1A before it) is unlikely to result in significant gains for the industry. However, it should be noted that the final report has not yet been published.

R&D costs

The total cost of the nine research programs is \$1.7 million, of which \$0.6 million comes from RIRDC. Table 2.1 below shows the contributions by RIRDC, industry and other organisations for each project.

Table 2.1 R&D project costs, by funds source

Project Name	RIRDC	Industry	Other organisations	Total cost
	\$	\$	\$	\$
UNE-34A: Growth of High Value Trees on farms	64 431	46 024	51 000	161 455
CSL-6A: Novel nutrient management for improved timber	20 598	18 720	6 000	45 318
CSZ-1A: Potential for agroforestry for the wet-dry tropics	9 973	10 847	0	20 820
CSC-58A: Trees for wood and animal production	119 102	242 232	0	361 334
UQ-18A: Agroforestry with High Value Trees	92 819	49 460	30 000	172 379
UQ-41A: Agroforestry with High Value Trees II	32 900	27 102	35 000	95 002
QDN-1A: 'Commercial timber species for eastern sub-tropical Australia'	11 000	0	0	11 000
QDF-1A: Topical rainforest cabinet wood species	42 700	0	0	42 700
DAQ-240A: Silviculture of rainforest cabinet species	187 670	594 876	0	782 546
Total	581 193	989 361	122 000	1 692 554

Source: RIRDC

To place all the above costs in a consistent and comparable framework we have adjusted all prices to 2002 dollars. Table 2.2 shows the total costs of the projects in 2002 dollars, split by year. The total cost in 2002 dollars is \$1 940 506.

To determine the net present cost in 1990 (the first year of funding for cabinet timber research), the total cost is then discounted at 5 per cent. The net present cost of the research is \$1 401 436.

Table 2.2 R&D project cost, by financial year (2002 dollars)

Year	UNE-34A	CSL-6A	CSZ-1A	CSC-58A	UQ-18A	UQ-41A	QDN-1A	QDF-1A	DAQ-240A	Total
	\$									
1990/91	0	0	0	0	0	0	0	38 089	0	38 089
1991/92	0	0	0	0	69 066	0	0	18 990	0	88 056
1992/93	0	0	0	0	75 915	0	0	0	0	75 915
1993/94	65 049	0	0	0	74 087	0	0	0	0	139 136
1994/95	67 543	0	0	0	0	38 437	0	0	0	105 979
1995/96	65 455	0	24 866	0	0	38 904	0	0	0	129 225
1996/97	0	0	0	99 726	0	35 795	5 730	0	0	141 252
1997/98	0	0	0	211 920	0	0	6 785	0	0	218 705
1998/99	0	51 245	0	98 272	0	0	0	0	241 997	391 514
1999/00	0	0	0	0	0	0	0	0	207 192	207 192
2000/01	0	0	0	0	0	0	0	0	210 010	210 010
2001/02	0	0	0	0	0	0	0	0	174 535	174 535
2002/03	0	0	0	0	0	0	0	0	20 897	20 897
Total	198 047	51 245	24 866	409 919	219 068	113 136	12 515	57 080	854 631	1 940 506

Source: RIRDC

Outputs

The output from the cabinet timbers projects is primarily better information (for example, on new and better technology), which in turn should lead to better decisions. The outputs and their anticipated outcomes are:

- information on how to better manage cabinet timbers;
 - details on stocking rates, appropriate nutrients and better silvicultural practice will lead to improved management of existing trees improving tree quality and growth rates;
 - better decisions made because of this output will result in lower failure rates, shorter rotations, increased cubic metres per hectare and higher prices per cubic metre, but at a higher cost of production and more time spent managing the trees;
- information on which cabinet timbers are most appropriate for which areas;
 - information on site selection and species selection will result in the planting of more appropriate trees for specific environments with resultant higher establishment and growth rates;
 - as with information on better management, better site and species selection will result in lower failure rates, shorter rotations and increased cubic metres per hectare at harvest and from thinnings; and
- information on how high value trees impact on pastures and animal production;
 - information on the fodder benefits from trees will contribute towards increased planting of trees and an increase in the fodder benefit per hectare of cabinet timbers.

This information is passed on to agroforestry ‘information intermediaries’, who in turn pass this information onto landholders. A prominent information intermediary, especially in the 1990s, was the Community Rainforest Re-forestation Program (CRRP) and its manager, Gary Sexton. Gary is an important source of information for this report, along with Mark Annandale (principal investigator of DAQ-240A) and David Lamb (principal investigator of UQ-18A and UQ41-A). A complete list of people consulted can be found in the References.

Mark Annandale outlined seminars, field days and publications as prime vehicles for spreading information, with 10 per cent of farmers having a quick response to new information, 75 per cent having a moderate response rate, and around 15 per cent either not responding or responding with a considerable lag.

The total impact of the projects was a significant increase in the information set regarding cabinet timbers. It must be understood that very little information was available prior to these projects, and these projects have introduced a base level

of understanding necessary to build a viable cabinet timber industry. As David Lamb and Geoff Borschmann explained in 1999: ‘the current state of knowledge of the plantation performance of rainforest cabinet timber species with production potential in sub-tropical Australia is underdeveloped’ (Borschmann and Lamb, 1999, pp. 108-112).

If the information provided by the projects leads to the establishment of a significant industry, then provided the industry is more profitable than the alternative uses of the land, labour and capital, the benefits should be considerable.

Outcomes

The information that comes from the cabinet timber projects leads to seven identifiable outcomes.

- The failure rate of tree plantings would have been 5 per cent higher without the research.
 - Source: Gary Sexton and David Lamb. As discussed later, while Dr Lamb disagreed with the *level* suggested by Mr Sexton, he agreed with the magnitude of change due to the research. This is true also for the length of rotation and average cubic metres of wood per hectare.
- The length of rotation would have been 8 years longer without the research.
 - Source: Gary Sexton and David Lamb.
- There would have been 10 per cent less trees planted without the research. One reason for this is that the additional research decreases the risk associated with planting trees and increases the expected returns.
 - Source: Gary Sexton and David Lamb.
- Average wood per hectare would have been 40 cubic metres less without the research.
 - Source: Gary Sexton and David Lamb.
- The price per cubic metre would have been 10 per cent less without the research.
 - Source: Gary Sexton and David Lamb.
- The ongoing costs would have been \$500 in the 2nd year without the research, compared with \$1 000 in the 2nd year with the research. For all future years the ongoing yearly cost would have been \$20 without the research, compared with \$100 with the research.

- While better tree management will result in greater revenue from tree sales, more intensive management and silvicultural practices will also take more time and money.
- Source: David Lamb.
- The fodder benefit would have been at the lower end of the range identified in Appendix A (\$3 per hectare per year) without the research, compared with an upper estimate of \$10 per hectare per year with the research. (See appendix A for more details on fodder benefits.)

There are other variables that have been influenced by the research, however the impact is considered marginal and difficult to quantify. It is considered likely that the above effects will encompass most of the influence of the research.

Project evaluation

Triple Bottom Line reporting

The Triple Bottom Line (TBL) — economic, environmental and social — consequences of the outcomes are analysed.

The economic impacts include increased value from the cabinet timber production as well as other non-wood benefits including fodder benefits, shade and shelter benefits when trees act as windbreaks and the benefits from selling carbon credits. The total economic impact must also take into account the opportunity cost of agroforestry.

Environmental outcomes include the effect on salinity and waterlogging, soil conservation, biodiversity and aesthetic improvements. Estimates of the benefits focus on the economic value from reduction in salinity and water tables and from riparian plantings. Willingness-to-pay based values are used to estimate the value of biodiversity and aesthetics (see appendix A).

Social impacts include the impact on employment and population in rural and regional Australia, the security of the farmer, the effect on neighbours as well as human and social capital. However, as discussed in appendix A it is difficult to project the changes in these indicators so they are not included in this analysis.

More detail on triple bottom line reporting can be found in appendix B.

Method of analysis

This study looks at the impact of the projects on the tropical and sub-tropical cabinet timber industry. The starting point is to develop a model of the cabinet timber industry. Apart from uncertainty over the future growth rate of the industry a key question is the extent to which the R&D program has contributed to this growth. The other benefits result from the higher productivity and improved quality of trees and the enhanced fodder value as described above.

To understand the effects of the research we need to firstly understand how the industry works. Due to a lack of comprehensive data on cabinet timbers, such an analysis has required the production of an Australian Cabinet Timbers Model (CTM).

The benchmark scenario of the model assesses the current projection of the industry and already incorporates the benefits of the research ('with research' scenario). We can use the model to make some preliminary judgements about the future of the tropical and sub-tropical cabinet timber industry. Unless the industry offers high returns to the farmer, there will be insufficient incentives for the industry to grow, and the assumptions of an increase in plantings will be without basis.

Once we understand the current trends in the cabinet timber industry we can then change the assumptions to see how different parameters would lead to different outcomes in the industry. As the benchmark scenario assumes the research has been carried out, the alternative scenario is a 'without research' scenario. That is, if we did not get the outcomes from the research, then what would the industry look like? This allows us to compare these two scenarios to determine the impact of the research.

The below sections will:

- outline the CTM, including the baseline assumptions;
- discuss the viability of the Cabinet Timber Industry; and
- briefly discuss the 'without research' scenario.

This information will then be used to assess how the projects effect the economic and environmental bottom line.

Cabinet Timber Model

This model relies on many variables, which are uncertain due to the small size of this industry. The size of the Australian cabinet timber industry on private land has never been surveyed and there is very limited literature on the industry. The assumptions are based on advice from field experts including people involved in cabinet timber research and promotion. (A list of conversations with field experts can be found in the reference page.)

The assumptions for the base model are:

- There was little tropical and sub-tropical cabinet timber trees on private farms before the CRRP.
 - Source: Mark Annandale and Gary Sexton.
- During the CRRP, 200 hectares of cabinet timbers were planted every year on private farms (1992–93—1997–98).
 - Source: Gary Sexton.
- Once the CRRP ended – plantings slowed to 50 hectares a year.
 - Source: Gary Sexton.
- This rate of tree plantings will grow to 100 hectares per year in 2003, 200 by 2005 and 500 by 2010.
 - Source: Gary Sexton and David Lamb.
- There is a 22 year average rotation, which includes thinning at age 10 and 15, however a minority of cabinet timbers are not harvested until they are 30 years old.
 - Source: Gary Sexton. It should be noted that there is some disagreement about this assumption, most especially from David Lamb. However, for the purpose of determining the effect of the research, it is the *change* in the rotation that is most important – and on this issue Mr Sexton and Dr Lamb are in broad agreement.
 - This and the other areas where opinions vary probably reflects different priors about species and plantation approaches.
- A total of 350 cubic metres of wood is produced from one hectare – with 25 cubic metres being harvested at 10 years, 100 cubic metres being harvested at 15 years and 200 being harvested at the end of the average rotation (22 years) and 25 hectares being harvested after 30 years.
 - Source: Gary Sexton and David Lamb. Once again, there was some disagreement between Mr Sexton and Dr Lamb – with the above assumption more closely representing Mr Sexton’s assessment. As with the above assumption, the difference was regarding the *level* and not the

change due to research, and so does not adversely affect the conclusions of this study.

- Eighty per cent of all tree plantings will come successfully to harvest, 5 per cent will fail and 15 per cent will grow successfully, but not be brought to harvest (being kept for reasons other than wood production).
 - Source: Gary Sexton. Again, there was some disagreement and alternative success rates offered by Dr Lamb and Mr Annandale. However, again, these were mostly differences in *level* and not in the *change* due to research.
- One cubic metre of cabinet timber will sell for \$90 until the research is adopted, and then will sell for \$100.
 - Source: Gary Sexton, David Lamb, Mark Annandale and Andy Warner.
- The production costs of cabinet timbers are \$2 500 for the first year, \$1 000 for the second year and \$100 for every year after.
 - Source: David Lamb.
- The results of the research are adopted in 2000, with the impact on harvest not occurring until trees planted in 2000 or later are harvested, and the impact on price occurring 15 years after adoption.
 - Source: David Lamb.

Additional assumptions have been made for the non-wood benefits. The values of the benefits per hectare per year are outlined in appendix A. Gary Sexton supplied estimates for the percentage of relevant land. The assumptions are:

- the shade/shelter benefit from cabinet timbers is \$17 per hectare per year, and this applies to 15 per cent of all cabinet timber hectares;
- the fodder benefit from cabinet timbers is \$10 per hectare per year, and this applies to 15 per cent of all cabinet timber hectares;
 - note that this is at the high end of the estimates provided in Appendix A, due to the greater fodder benefits flowing from the research;
- the benefits from carbon trading is \$300 per hectare per year and applies to all cabinet timbers which are not going to be harvested;
- the benefits from lower water tables and less salinity is \$10 per hectare per year, and applies to 60 per cent of the total area of cabinet timbers;
 - the benefits are derived from preventing future deterioration, and not from actually reversing previous deterioration. While Queensland does not currently suffer from a salinity problem, it is expected that 145 000 hectares of land in Queensland will have yield constraints due to saline soils by 2020 (NHT, 2002). Further, by 2050 it is estimated that 3.1 million

hectares of Queensland land will have a high potential to develop dryland salinity (NHT, 2000);

- the benefits from riparian plantings is \$2 per hectare per year and applies to 15 per cent of the total area of cabinet timbers;
- the benefits from greater biodiversity is \$22 per hectare per year and applies to 30 per cent of the total areas of cabinet timbers; and
- The benefits from greater aesthetics is \$15 per hectare per year and applies to 70 per cent of the total areas of all cabinet timbers.

Based on the assumptions, the model estimates the total cubic metres of cabinet timbers harvested every year, the total amount of cabinet timbers in the industry by hectare (split by trees to be harvested and trees kept for non-wood related reasons), the total gross operating revenue and operating costs (and subsequently the gross operating profit) and the total non-wood benefits from the industry.

Methodology

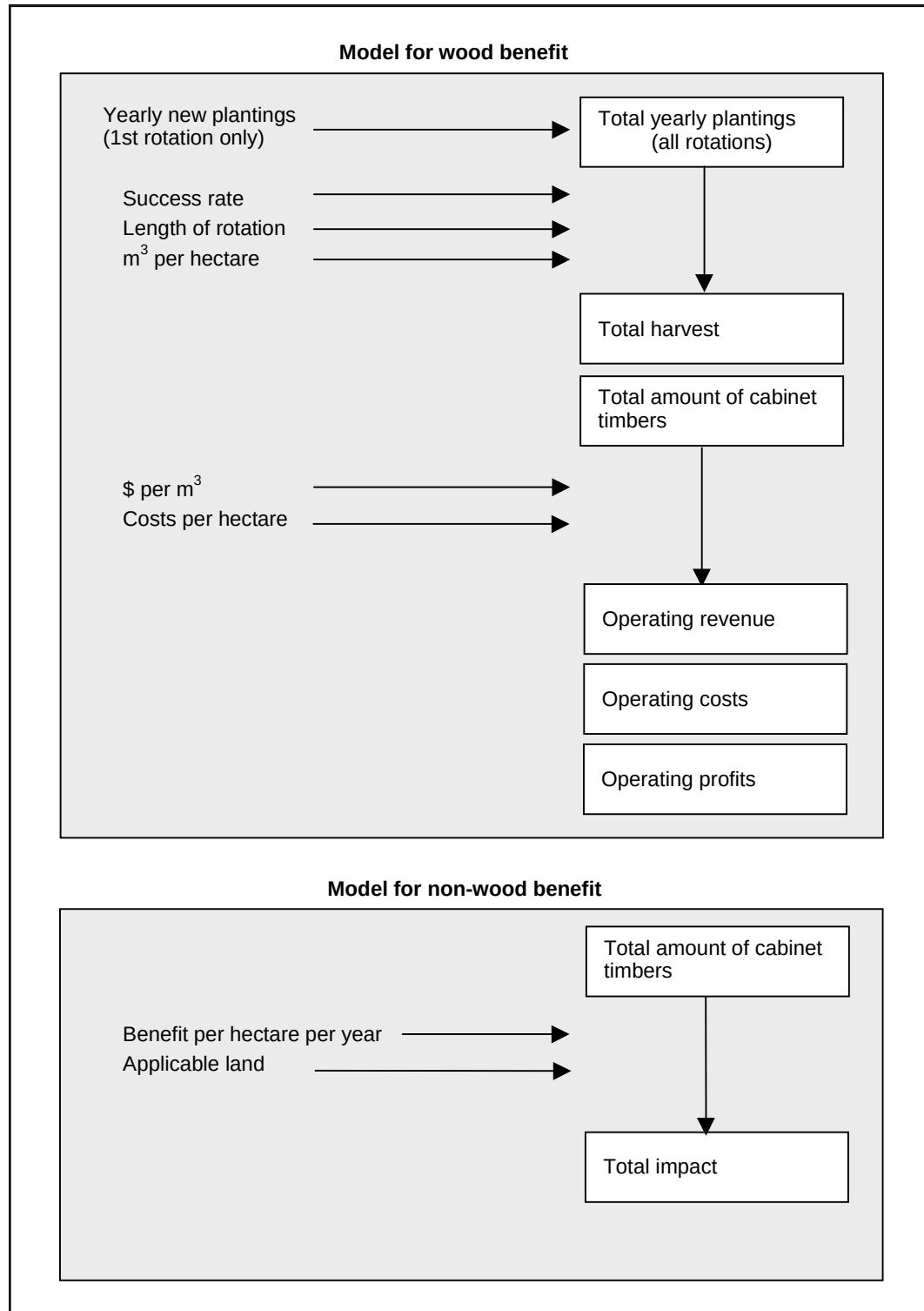
The methodology used for evaluating the size of the tropical and sub-tropical cabinet timber industry is outlined in chart 2.2.

The ‘non-wood’ methodology is used to determine the benefits from fodder, shade and shelter, biodiversity, aesthetics, lower water tables, riparian plantings and carbon credit trading. It should be noted that no benefits were assumed from trading carbon credits until 2008. Further details on non-wood benefits can be found in appendix A.

The viability of the industry

The total amount of cabinet timbers in 2002 is estimated to be 1 160 hectares, which is expected to rise to 2 775 by 2010 and then to about 10 000 by 2025.

Chart 2.2 **Model methodology**



In 2002 there will be no revenues in the tropical and sub-tropical cabinet timber industry as trees are still too young to harvest, while costs are estimated as

\$261 750. While a revenue stream should become apparent near 2010, operating losses will remain until 2020. By 2023, revenues should pick up substantially and there will be an operating profit of \$3.9 million (in 2002 dollars). By 2032 this is expected to increase to \$10 million, and then to \$20 million by 2054.

The net present value of the operating profit over the next 90 years (which is the extent of the model), calculated with a 5 per cent discount rate, is \$87 million. Factoring in the opportunity cost of the land, this is a rate of return of 12.6 per cent on the investment in plantations by the farmers. Given this, farmers have an incentive to make the investment on the returns on wood alone.

In 2002 there is a small amount of non-wood benefits being received by farmers, and the wider community, including about \$12 000 in aesthetic value, \$8 000 due to increased biodiversity and \$3 000 from windbreaks.

The net present value over the next 90 years of future benefits are \$9.4 million from carbon credit trading, \$1.8 million from greater aesthetic value, \$1.1 million from greater biodiversity and \$1 million due to lower water tables. Other 90 year net present value benefits included \$430 000 due to the benefits of windbreaks, \$250 000 in fodder benefit and \$50 000 from riparian plantings. The net present value of all non-wood benefits totalled \$14 million with the majority due to carbon credits and hence providing another direct source of income for the farmer.

The net present value of the opportunity cost of the land totalled \$9.4 million. The total net present value over the next 90 years of all benefits, net of the opportunity cost is \$91.6 million – due mostly to the benefits from the timber industry.

When considering these estimates it should be remembered that these result are informed by assumptions made without the benefit of a comprehensive survey or market data.

‘Without research’ scenario

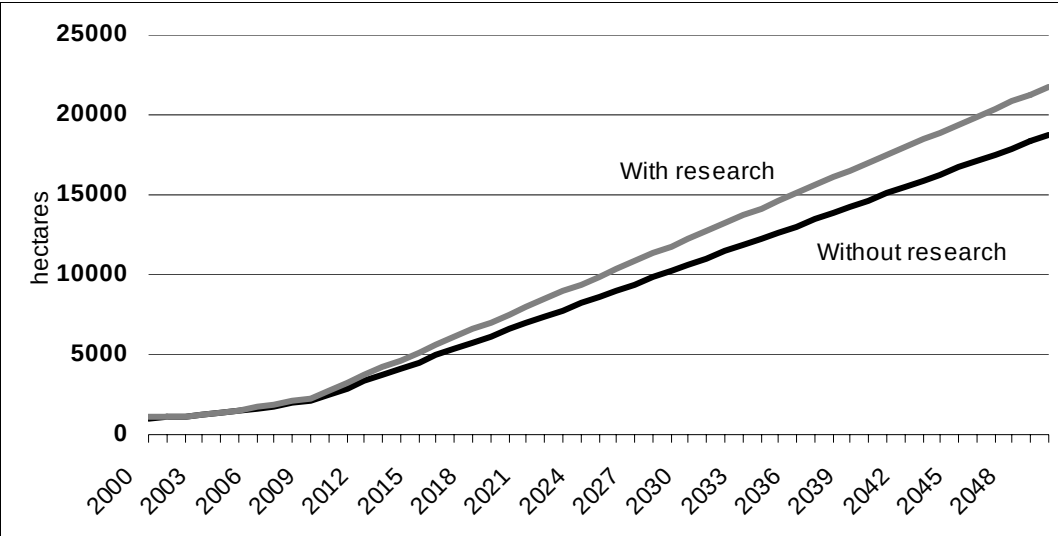
To evaluate the effects of the nine cabinet timber research projects, the changes that occurred in this small industry due to the research need to be identified.

To achieve this we must compare the benchmark scenario (as described above) with a ‘without research’ scenario, and compare the outcomes to determine the impact of the research.

The ‘without research’ scenario modifies the assumptions in line with the outcomes of the research – as outlined in the ‘outcomes’ section earlier in this chapter.

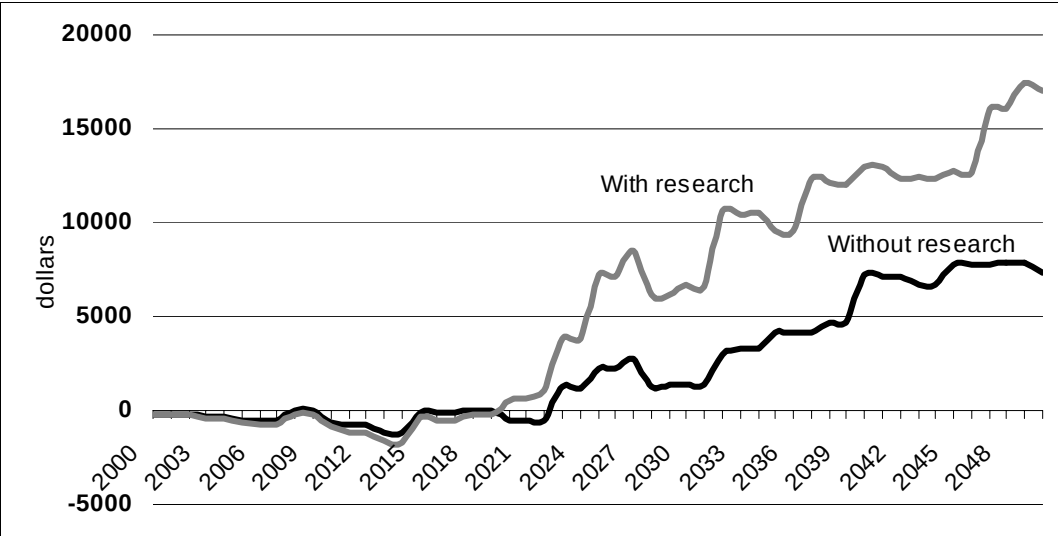
The differences between the benchmark and the ‘without research’ scenarios can be seen in chart 2.3 and 2.4 below. Chart 2.3 shows the growth in the total hectares of cabinet timbers under both scenarios, while chart 2.4 shows the expected operating profit for both scenarios.

Chart 2.3 Hectares of cabinet timbers, with & without research 2000-2050



Data source: CIE model

Chart 2.4 Wood benefits from cabinet timbers, with & without research 2000-2050



Data source: CIE model

The differences between the two scenarios will be analysed below to determine the total net benefit of the JVAP research projects.

Results

Bringing together the economic, environmental and social bottom lines – and comparing the net influence of the research on these areas compared with the total R&D costs, reveals that this research is expected to provide a substantial benefit to Australia.

Table 2.3 below shows that the total net present value is \$10.4 million for the time period 1990–2039 (using a 5 per cent discount rate). The internal rate of return is nearly 11 per cent and the NBIR is over 8:1.

Table 2.3 **Results**

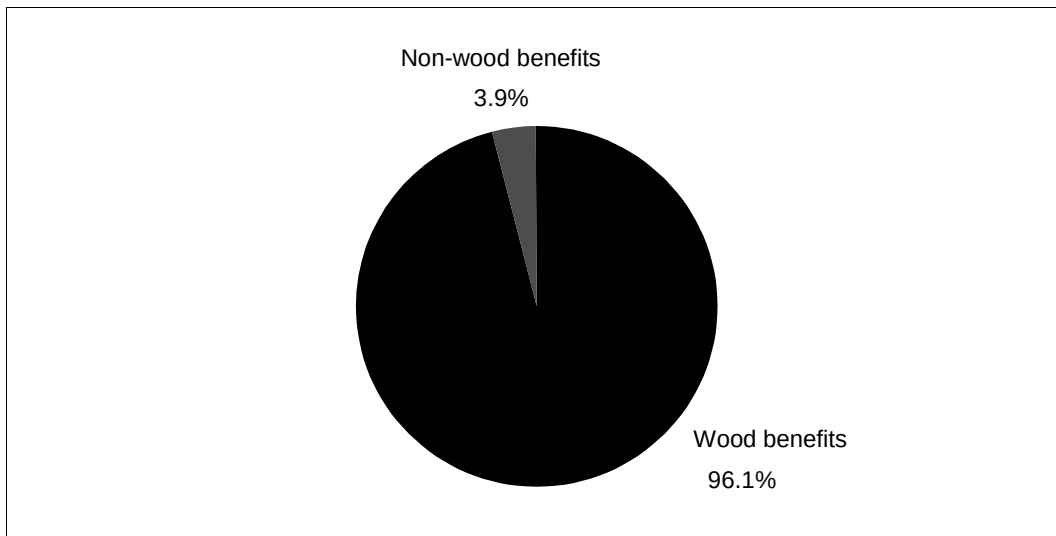
Discount rate	NPV ^a				NBIR	IRR
	<i>Project costs</i>	<i>Environmental benefits</i>	<i>Economic benefits</i>	<i>Net benefit</i>		
	\$m	\$m	\$m	\$m	Ratio	%
0 per cent	1.94	0.90	95.28	94.24	49.1	10.6
5 per cent	1.40	0.15	11.71	10.46	8.4	
10 per cent	1.05	0.03	1.39	0.37	1.3	

^a Estimates are in 2002 dollar terms, recorded as net present value as of 1990, when the first research project started.

Source: CIE estimates

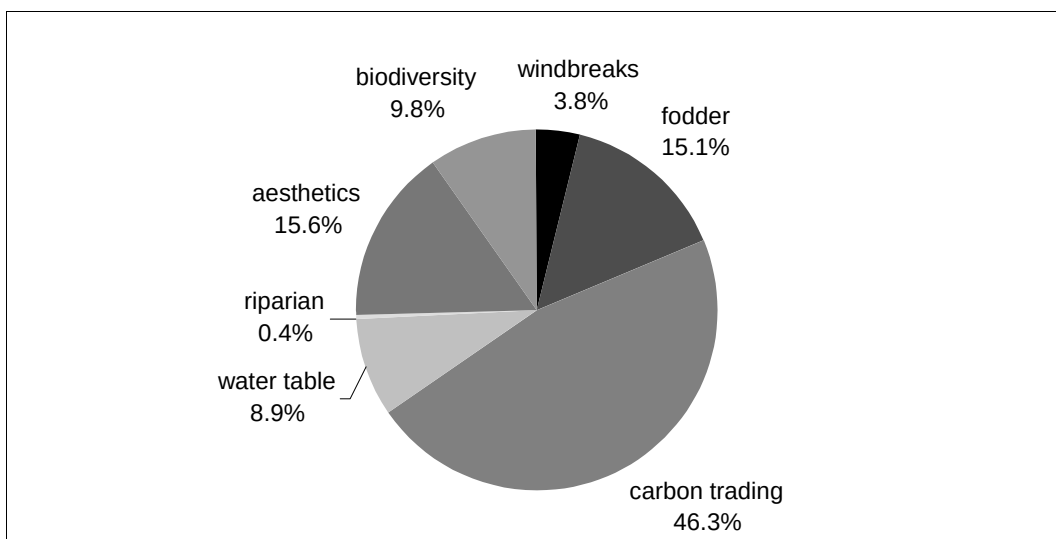
As can be seen in chart 2.5 below – the prime driver of this high value is the benefits from wood production (making up 96.1 per cent of the benefits). Of the non-wood benefits (shown in chart 2.6 below), trading carbon credits is the largest expected benefit, making up 46.3 per cent of all non-wood benefits.

Chart 2.5 **Benefits from JVAP cabinet timber research**



Data source: CIE model

Chart 2.6 **Non-wood benefits from JVAP cabinet timber research**



Data source: CIE model

More detail on the economic and environmental benefits will be outlined below. Due to the inherently subjective and qualitative nature of the social impact of the JVAP research, we did not derive a quantitative net social benefit. Further information on the social impacts can be found in appendix A.

Economic bottom line

The economic benefits from JVAP's cabinet timbers research is derived primarily from the increased quantity and efficiency of cabinet timber production, leading to higher profits from wood products.

For a complete economic evaluation, we must also consider the effects of more trees on animal and plant production through their role as a windbreak and fodder source, as well as the economic benefits from future carbon credit trading. The total economic benefit must be offset against the opportunity cost of using the land.

The below analysis shows that, analysed over a 50 year period (1990–2039), the present value of the economic benefits from the JVAP research is \$11.7 million. This value (as with all NPV values used below) is the NPV of the project assessed at 1990 (the first year of funding for the research projects), using 2002 dollars.

Wood products

The direct economic benefit through the production of cabinet timbers is equal to \$11.8 million. This is a significant benefit – and is by far the most high value benefit derived from the research. One reason for this is that the benefits apply to all the plantings, not just additional plantings stimulated by the research.

This positive result is due to several of the project outcomes. A shorter rotation and a greater amount of cubic metres per hectare improved the Mean Annual Increment from 10.3 to 15.9 – leading to greater efficiency of timber production. The lower failure rate and greater number of hectares planted meant that this greater efficiency was applied to a bigger number of trees. Finally, the higher price (a result of better management leading to higher quality timber) increased the return.

These benefits are somewhat offset by the increase in operating costs, however the net impact of the above changes is a significant future positive. With a competitive the mean annual increment (MAI) and high price, the tropical and sub-tropical cabinet timber industry looks to be in a sound position for expansion.

This then leads back into the original assumptions of the CTM and justifies the high rate of tree plantings assumed for future years.

Carbon credit trading benefit

Another benefit from tree production is the potential for trading in carbon credits. This applies to trees planted for reasons other than harvest (such as riparian plantings). For trees planted for harvest, as carbon credits will have to be purchased to harvest the trees, the benefits are counted only at the time of first planting. The benefits from trading in carbon credits are only incorporated after

2007, following an assumption that a carbon credit trading system will be in place by 2008.

The greater benefit derived from such trading as a result of the JVAP research has been estimated to be about \$200 000 in net present value.

Impact on animal production

There are potential benefits and costs on other animal and plant production that go along with farm forestry. Most especially, benefits could come from the use of trees as a windbreak and the production of fodder.

The greater benefit derived from using trees as windbreaks as a result of the JVAP research has been estimated to be about \$16 000, while the increased benefits from fodder have been estimated at about \$65 000.

These are not significant numbers, due to the fact that the benefits mostly accrue several decades into the future, and the present value of future benefits are not as high as the present value of current benefits.

Economics costs

In addition to the business costs involved in tree production, which are included in the evaluation of wood benefits above, there is also the opportunity cost of the factors of production that must be considered. That is, what benefits would have been received if a farmer had chosen to plant an alternative crop where they planted trees?

The total economic cost is simply the size of the tree crop times the average opportunity cost of using that land for alternative production. It is assumed that the research projects have not changed the productivity of alternative farming choices – so the only variable that will lead to a change in economic cost is the change in the number of hectares being used for cabinet timbers.

The total increase in economic costs due to the JVAP projects is about \$355 000.

Total economic bottom line

As shown in table 2.4 below, the combined effect of wood products, carbon credit trading, other animal and plant benefits and the economic costs result in a net benefit of \$11.7 million.

Table 2.4 **Economic bottom line**

Benefits/costs	\$
Wood benefits	11 781 295
Benefits from windbreaks	16 468
Benefits from fodder	65 433
Carbon trading	200 687
Opportunity cost of land	(356 797)
Net economic bottom line	11 707 086

Source: CIE model

Environmental bottom line

Environmental issues include the effect on salinity and waterlogging, riparian plantings, nature conservation and the aesthetic value of agroforestry. The benefits of trees with regards to carbon sequestration are included in the economic benefits on the assumption that a carbon credit trading system will be established in 2008.

Each of the environmental benefits of trees will be enhanced by the research to the extent to which the research leads to a greater number of trees being planted. As the increase in the area is relatively small in the short to medium term, the benefits are commensurately low. Further details on the benefits used can be found in appendix A.

Salinity and waterlogging

Trees are effective in preventing rising water tables, and subsequently reducing problems caused by waterlogging, flooding and salinity. The benefit per hectare per year is assumed to be \$10, which applies to 60 per cent of all cabinet timbers. It should be noted that this benefit is a result of preventing future degradation and not reversing previous damage.

The increased number of trees is estimated to result in a benefit of around \$39 000 due to lower water tables.

Riparian plantings

The value of riparian plantings is estimated to be \$2 per hectare per year and is assumed to apply to 15 per cent of cabinet timbers planted.

The increased number of trees is estimated to result in a benefit of around \$2 000 from riparian plantings.

Biodiversity

More trees can result in an improved landscape health, which encourages diverse plant and animal life and may help prevent the extinction of some species. The biodiversity benefit of an additional hectare of trees per year is estimated at \$22, which applies to 30 per cent of all cabinet timbers.

The increased number of trees is estimated to result in a benefit of around \$43 000 due to greater biodiversity.

Aesthetic value

Trees add value to land through improved aesthetics. Often, tree plantations replace otherwise unattractive land, and especially with tropical and sub-tropical cabinet timbers not planted in a monoculture, are considered preferable to most alternative crops in terms of aesthetics. This aesthetic benefit is estimated at \$15 per hectare per year and applies to 70 per cent of cabinet timbers.

The increased number of trees is estimated to result in a benefit of around \$68 000 due to improved amenity value.

Total environmental bottom line

As shown in table 2.5 below, the combined effect of lower water tables, riparian plantings, increased biodiversity and greater aesthetic value result in a net benefit of \$150 000.

This number is considerably smaller than the benefits derived from wood sales. The lower relative benefit is partly explained by the fact that most environmental benefits are received several decades into the future (when there is a significant increase in hectares planted), and the present value of future benefits are not as high as the present value of current benefits. It is also important to note that much of the research achieved things that do not have an impact on the environmental – such as faster growth times for trees and the amount of wood produced per hectare.

Table 2.5 **Environmental bottom line**

Benefits	\$
Salinity and waterlogging	38 747
Riparian plantings	1 937
Biodiversity	42 622
Aesthetics	67 808
Total environmental bottom line	151 114

Source: CIE model

It must also be remembered that this measure does not reflect the total environmental benefit gained by tropical and sub-tropical cabinet timbers, but only the marginal increase in the benefit due to additional expansion in the area of trees resulting from the JVAP research projects.

Sensitivity analysis

As explained earlier in this chapter – this assessment has been reliant on the advice from various field experts as little concrete data was available about such a young industry. Subsequently, it is vital to perform a sensitivity analysis to see how beneficial the JVAP research projects are under different assumptions.

Table 2.6 below shows the different assumptions made for the optimistic and pessimistic scenarios, compared with the assumptions made for the baseline scenario.

Table 2.6 **Assumptions for sensitivity analysis**

Variables	Baseline scenario	Optimistic scenario	Pessimistic scenario
Failure Rate	5 per cent	5 per cent	10 per cent
Length of rotation	22 years	20 years	24 years
Trees planted	Base case	+ 5 per cent	- 5 per cent
Cubic metres per hectare	350	370	330
\$ per cubic metre	\$100	\$110	\$95
Ongoing costs – 2 nd year	\$1000	\$800	\$1200
Ongoing costs – future years	\$100	\$80	\$120
Fodder benefit	\$10	\$12	\$8

Source: CIE assumptions

It should be noted that, by changing the assumptions regarding the length of rotation and the cubic metres per hectare, we are effectively changing the assumption regarding MAI. The MAI for the baseline scenario is 15.9 cubic

metres per hectare per year, while the MAI for the optimistic scenario is 18.5 cubic metres per hectare per year and the MAI for the pessimistic scenario is 13.8 cubic metres per hectare per year.

Using the above revised assumptions we can determine an optimistic set of results and a pessimistic set of results, as shown in table 2.7 below.

Table 2.7 Results from sensitivity analysis

	NPV	NBIR	IRR
	\$m	ratio	Per cent
Benchmark scenario	10.5	8.4	10.6
Optimistic scenario	23.7	17.7	14.9
Pessimistic scenario	2.3	2.6	7.6

Source: CIE model

- The optimistic scenario concludes with an NPV of \$23.7 million, a NBIR of 17.7 to 1 and an IRR of 14.9 per cent.
- The pessimistic scenario concludes with an NPV of \$2.3 million, a NBIR of 2.6 to 1 and an IRR of 7.6 per cent.

It is important to note here that, while the pessimistic scenario does not offer a very strong result, the NPV remains positive.

3 Agroforestry and catchment hydrology

Dryland salinity is a significant economic problem in rural Australia. The National Land and Water Resources Audit (NLWRA) estimates that salinity is causing \$187 million of damage to dryland agricultural production and \$89 million of damage to infrastructure each year (NLWRA 2002). In addition, increasing water salinity imposes costs on irrigators, households and industrial users. There are also non-market impacts on the environment — many of which affect the whole community (see appendix A for details).

Revegetation of the landscape with trees and woody shrubs has been shown to lower the water table and offer control over dryland salinity. But planting trees is not a guaranteed solution to salinity as some catchments are more responsive than others to tree planting treatments. The hydrological processes underpinning salinity are complicated by the heterogeneity of the Australian landscape and underlying geology.

There is an urgent need to develop a better understanding of the interactions between trees and the hydrology of different landscapes so that scarce public resources can be targeted to regions and catchments that are likely to yield the greatest return on investment.

Over the last six years JVAP has undertaken several projects that focus on developing guidelines for classifying catchments according to their susceptibility to salinity and responsiveness to revegetation treatments. Approximately \$3 million of R&D effort has been invested in four projects managed by JVAP. This chapter examines the outputs and outcomes of this work and estimates the potential dollar returns on the R&D expenditure.

Background

In recent years substantial amounts of public funds have been directed towards salinity management. In 1997 funds from the part sale of Telstra were used to establish the NHT. Over the period 1997 to 2002 approximately \$1.5 billion was spent by NHT across a range of land conservation programs, averaging \$250 million per annum. In the 2001 Federal Budget, the Government announced an additional \$1 billion for the Trust, extending the funding for five more years. The

National Action Plan for Salinity and Water Quality will deliver a further \$1.4 billion for salinity management over seven years.

These Commonwealth Government programs have a strong focus on funding community-based conservation projects and promoting ‘on-ground’ works, including tree planting. But a difficult policy dilemma is where to target the support funds to achieve the highest social return at the margin. Key questions are:

- where should trees be planted to be most effective at delivering salinity benefits;
- what scale of planting is required;
- what is the most cost-effective planting design; and
- what is the impact of trees on surface water run-off and water yield?

Until these issues are better understood, there is a risk that salinity management resources will be misdirected and poorly allocated.

JVAP and the national research effort

JVAP has taken a lead role in coordinating research into the impact of agroforestry systems on lowering the water table and controlling salinity. It has managed several projects that pull together research findings from various sources and has organised workshops that have brought together scientists to develop a consensus about what is known and unknown.

The JVAP work complements a larger research effort being undertaken in Australia. Other institutions involved in hydrological survey and modelling include:

- Commonwealth Government agencies – the Bureau of Resource Sciences, CSIRO and the Australian Geological Survey Organisation;
- Universities and Cooperative Research Centres;
- State Government agencies; and
- Land and Water Australia.

The National Land and Water Resources Audit — an NHT program — has recently compiled salinity data from each State and produced projections of future salinity trends (NLWRA, 2000). Part of this study has utilised findings from research initiated by JVAP to classify different catchment types according to their susceptibility to salinity and responsiveness to agroforestry treatments. The

Audit report is currently being used to shape policies to deal with salinity. Furthermore, results from JVAP funded work on catchment characterisation are being used to identify priority areas for salinity mitigation under the National Action Plan for Salinity and Water Quality.

Projects evaluated

JVAP has made significant in-roads to understanding the way salinity develops in different catchment types. The four projects assessed in this BCA are summarised in table 3.1. The first four projects listed are workshops and involve relatively minor expenditures by JVAP. These initial workshops helped to guide the direction of future research. The workshops formed a basis for project CSM-4A, which was a major study that examined the interaction between farm forestry and hydrology.

Research outputs and outcomes

The hydrology projects have improved our understanding of groundwater flow systems in Australia and how best to manage dryland salinity with trees. The findings have provided a systematic approach to classifying different types of catchments according to their hydrological characteristics. In particular, AGS-1A has been influential in that it has provided a framework for conceptualising how salinity evolves in different regions (Coram 1998). For instance, we now know that there are three generalised types of catchments systems.

- Local flow systems are characterised as having discharge and recharge areas close together and, consequently, are relatively responsive to revegetation treatments. The systems tend to occur in areas of higher relief and are generally confined.
- Intermediate flow systems tend to occur in foothills and valleys, with discharge and recharge sites separated over a horizontal scale of five to ten kilometres. The time lag before revegetation has an impact on reversing a rising watertable in these groundwater systems is much longer than for local flow systems — up to 50 or 100 years.

Table 3.1 **JVAP projects on hydrology and agroforestry interactions**

Project	Description	Year completed	Cost
CSM-3A	Agroforestry and hydrology: What do we need to know' ▪ Workshop and proceedings	1996	\$6 000
WS967-7	Groundwater uptake and salt accumulation by trees over shallow water tables ▪ Workshop and proceedings	1997	\$16 000
AGS-1A	National classification of catchments for land and river salinity control ▪ Workshop and proceedings	1998	\$32 000
CSM-4A	Agroforestry design guidelines to balance catchment health with primary production ▪ measurement and prediction of tree water use under optimal conditions; ▪ review and measurement of tree water use under stressed conditions; ▪ measurement and prediction of the competition between trees and crops for water in different agroforestry systems; ▪ application of a catchment model to key sites and run model scenarios to optimise catchment health with tree productivity; and ▪ production of guidelines to support land managers to optimise tree productivity with crop/pasture productivity and catchment health.	2002	\$2 901 000

Source: RIRDC

- Regional flow systems are characterised by large horizontal distances between recharge and discharge areas – therefore the time lags between planting trees and observing a salinity benefit are considerable. These systems are the least responsive to revegetation treatments.

This classification system was developed from detailed studies of individual catchments. The NLWRA (2000) report has used the framework to classify landscapes throughout Australia. The system assists resource managers to understand the likely responsiveness of different regions to tree planting without having to conduct expensive surveys to obtain detailed data on the region of interest.

Other outputs from the research projects include extension materials for farmers and extension officers including decision aids, workshop proceedings and manuals detailing the type of data that must be collected for salinity monitoring

(for example, the publication *Trees, Water and Salt*). The process of building hydrological models — conceptual and empirical — has improved our understanding of what data needs are required for ongoing monitoring of the impacts of trees on the water balance.

Policy implications

JVAP research, in conjunction with hydrological studies undertaken by other organisations, has started to influence government policy. For example, a report by a Salinity Taskforce commissioned by the Western Australian government which drew heavily on JVAP research has been influential in prioritising the government's funding allocation to salinity (WA Salinity Taskforce, 2001).

As depicted by chart 3.1, information on hydrological processes feeds in at each level of the planning and implementation process.

Policy development and planning

Research outputs from JVAP are helping to improve the cost effectiveness of salinity management policies by allowing on-ground works to be prioritised by region or catchment. Good hydrological information is critical for the setting of end-of-valley water quality targets or revegetation targets. In the absence of knowledge about the biophysical relationships between agroforestry and salinity response, there is potential for significant amounts of public resources to be wasted on ill-conceived tree planting programs. Information coming out of the JVAP work is helping resource managers to understand the time lags between revegetation and water table response at a regional scale.

Policy instruments and administration

In addition to assisting with target setting and the allocation of resources, information on hydrological relationships is a prerequisite if market based instruments such as salinity credit trading and vegetation offset schemes are to be used to implement salinity policies.

Trading schemes are a potentially valuable tool for implementing landscape changes because they circumvent the need for information about each farmer's enterprise structure and costs. Even within a relatively small region there is a great deal of diversity across different farm properties with respect to enterprise mix and farm business structure. Therefore, imposing a uniform policy on all landholders — such as a minimum area of land to be revegetated — will

disadvantage some farmers more than others. A trading scheme has the potential to reduce the total costs of a meeting salinity targets by allowing farmers who find it costly to meet the target to trade with those who are willing to plant a larger proportion of their farm to trees.

However, a drawback of salinity credit trading is that it requires a reasonably accurate hydrological model to predict the impact of tree planting on water quality or land salinisation. The work undertaken by JVAP is a start towards the development of hydrological models that are capable of forecasting the impacts of different land use changes on recharge and salinity. Without such models it will not be possible to establish salinity trading markets.

On-ground implementation

The main focus of the JVAP work was to provide management guidelines at a macro or regional level. However, part of project CSM-4A involved case studies of salinity at the paddock level from which management principles were drawn. This culminated in the production of a set of guidelines that are readily accessible to farmers (*Trees, Water and Salt*). These guidelines are assisting extension officers and growers to improve the siting of trees for maximum control benefits. For instance, it has now been established that planting trees in discharge areas is generally not a wise decision because there is a high risk that trees will become salted out and will have minimal impact on lowering the water table.

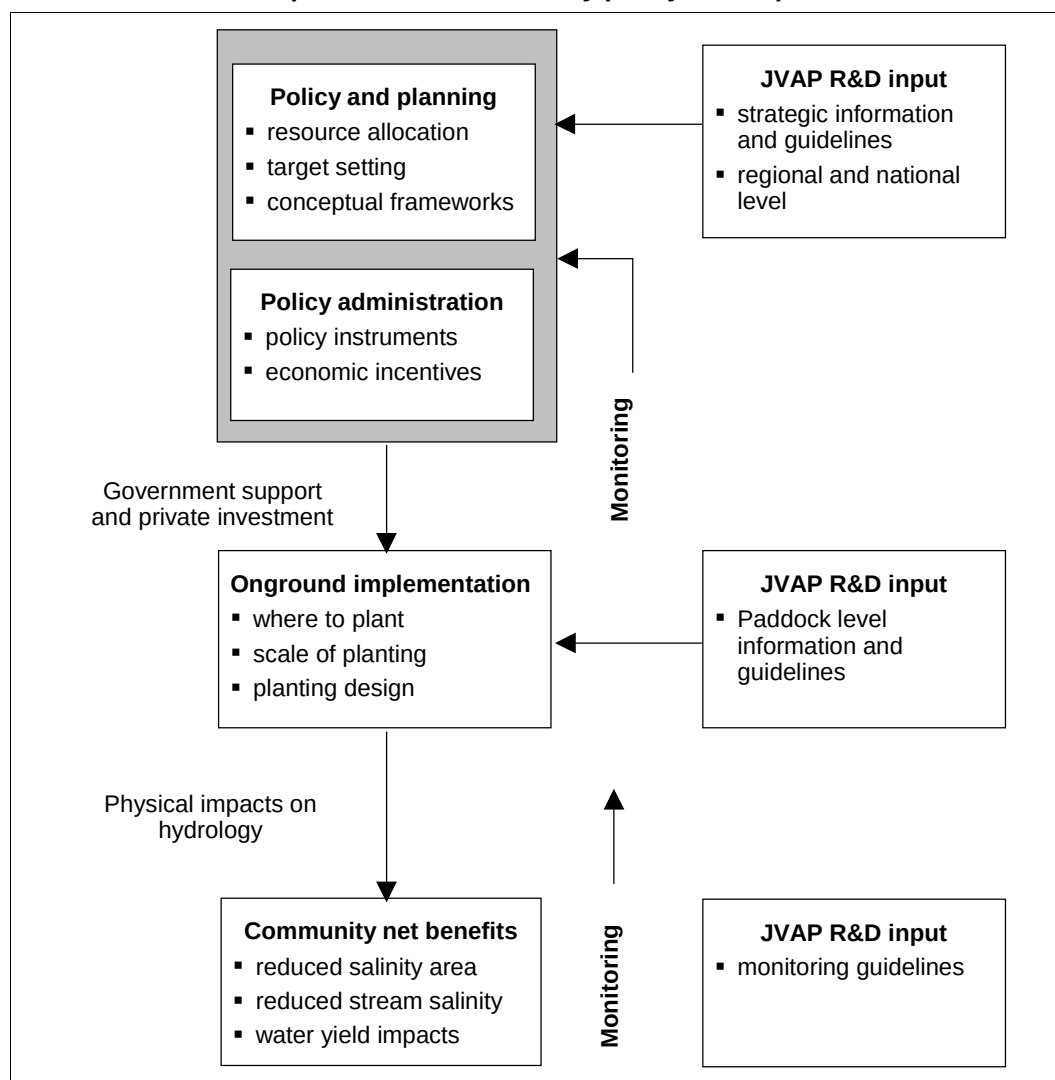
Monitoring

The R&D projects have sharpened our understanding of what variables need to be monitored to provide feed back to regional planning and management. There is a better knowledge of what needs to be monitored, where and how often. The hydrological models developed by JVAP are useful for avoiding unnecessary data collection and can be used to develop cost effective monitoring systems.

Research direction

The body of research being evaluated here — particularly project AGS-1A — has reshaped the research agenda and directed R&D funds to more fertile areas of work with greater prospects of producing high returns on investment.

Chart 3.1 Potential impacts of R&D on salinity policy and implementation



Data source: CIE

Salinity management expenditure

During the mid 1990's the ABS (1999) estimates that Australia was spending approximately \$1 billion per annum on biodiversity and landscape protection in rural areas (table 3.2). This estimate includes both public and private sector investment and has taken into account Landcare taxation concessions. Of this expenditure, we assume that 30 per cent would have been targeted to tree planting for salinity management.

Environmental protection expenditure statistics have not been collected since 1996–97. But it is expected that annual expenditure on tree planting for conservation purposes has risen since 1997 due to NHT funding. In the period 1997 to 2002, \$1.5 billion was spent by the NHT across a range of programs,

averaging \$250 million per annum (ABS, 2001). In the 2001 Federal Budget, the Government announced an additional \$1 billion for the Trust, extending the funding for five more years. Substantial funds will also be made available under the National Action Plan for Salinity and Water Quality, which is a seven year program commencing 2003. This program has a total budget of \$1.4 billion or \$200 million per annum.

Given these boosts to environmental funding, it is reasonable to expect that public and private expenditure on biodiversity and landscape protection could be \$1 500 million annually from 1998 onwards. In our analysis we assume that 30 per cent of this (or \$450 million) is for on-ground salinity management.

Table 3.2 National expenditure on biodiversity and landscape protection

	1995–96	1996–97
	\$m	\$m
Government ^a	929	1 057
Private (agricultural industry)	79	73
Total	1 008	1 130

^a Includes Landcare tax concessions

Source: ABS (1999)

Our evaluation approach

We equate the benefits of JVAP's hydrology research to two main impacts:

- improved cost-effectiveness of planting trees for salinity control through better targeting of trees in the landscape, more informed catchment planning, better designed policy instruments and more effective monitoring; and
- a greater number of trees planted per dollar invested. For example, improved survival rates lower the costs of tree establishment and encourage higher adoption of agroforestry.

It is fair to assume that substantial amounts of public and private funds will continue to be invested in tree planting for salinity control over the coming decades. While there is debate about whether this represents good value for money, the purpose of this evaluation is not to determine whether the benefits of this policy exceed the costs. Rather, the evaluation estimates the value of JVAP's research in terms of efficiency improvements per dollar invested. Therefore we assume an ongoing fixed level of expenditure on tree planting (\$450 million per year) and estimate the expected payoff to this investment with and without R&D.

Estimating the likely pay-off

While the benefits from farm forestry are numerous (see Appendix A) this evaluation concentrates on the extent to which R&D will increase the expected payoff from using trees as a salinity control strategy. Ancillary benefits such as erosion control and reduced waterlogging are excluded from the analysis because these benefits are not critically dependent on understanding hydrological processes. That is, the positioning of trees in the landscape is important for salinity control but less critical for managing other forms of degradation.

The net salinity benefit from farm forestry is equivalent to the value of ‘salinity damage prevented’ over time. To estimate this payoff we need to know the current and future costs imposed by salinity and the expected reduction in salinity costs per unit of agroforestry adopted (termed the salinity response function).

JVAP’s research is expected to improve the responsiveness of the water table to trees such that for every hectare of trees planted, there will be greater prospects for salinity costs to be prevented. It is also expected to reduce the cost of tree planting programs so that more trees can be established per dollar invested. This evaluation estimates the combined impact of these changes in dollar terms. The evaluation draws on salinity cost estimates from the literature and salinity response functions are specified based on the best available information about the impact of trees on saline water tables.

Salinity costs

Dryland salinity and saline water imposes a variety of costs on society, including:

- yield losses in dryland agricultural production;
- costs to irrigators;
- in-situ damage to infrastructure (roads, buildings, railways and bridges);
- ex-situ damage to plumbing, machinery and water supply infrastructure; and
- environmental damage (recreation, aesthetics and biodiversity).

Several studies have attempted to estimate these costs at a national or regional level. Unfortunately there are some inconsistencies in the methodologies used to quantify the costs and in some cases poor methods have been employed. Two recent studies are the National Land & Water Resources Audit (NLWRA 2002) — which estimates costs at a national level — and a study by Ivey ATP / Wilson

Land Management Services (NDSP 2002) which focuses solely on the Murray Darling Basin.

National Land & Water Resources Audit study

The NLWRA study estimates the cost of dryland salinity and water quality decline at a national level (table 3.3). These cost estimates indicate, to an order of magnitude (to the nearest number of zeros), the potential benefits that could be realised if salinity could be prevented. Admittedly, the Audit estimates are not comprehensive because they do not include impacts on irrigated agriculture and the environment (for example biodiversity, recreation and aesthetics). But they do provide a starting point for examining the economic significance of the problem.

The cost estimates for salinity are based on the Audit's assessment of current and future trends in the area of saline land. The current extent of salinity — defined as areas where salinity is causing yield losses — is estimated to be 3.1 million hectares or 0.7 per cent of agricultural land. By 2020 this area is projected to increase to 4.4 million hectares. This projection is based on the assumption that existing agricultural practices continue and there is no change to the current area of agroforestry.

The value of current yield losses caused by salinity is estimated to be \$187 million per year (measured in terms of a reduction in profit at full equity). However, of more interest to policy makers is the future cost of additional land becoming saline, which is estimated to be \$558 million in net present value terms over the next 20 years. This figure is perhaps the most relevant for RIRDC because it is questionable whether the current extent of salinity can be reversed by agroforestry (Western Australia Salinity Taskforce 2001). If this position is accepted, then the \$558 million figure provides a measure of the potential economic gains to agriculture from preventing future salinity damage.

Dryland salinity also damages infrastructure such as roads, buildings, railways and bridges. The Audit estimates that at the current extent of salinity, this annual damage cost is approximately \$89 million. The net present value of future increases in salinity damage over the next 20 years is estimated to be \$341 million.

Other forms of degradation examined by the Audit were the cost of increasing water salinity to downstream infrastructure (for example, corrosion in household and industrial plumbing and machinery) and the future cost of worsening levels of water turbidity and sedimentation. If the current levels of water salinity,

turbidity and sedimentation were to increase by 10 per cent over the next 20 years, the cost is estimated to be \$1958 million in net present value (NLWRA, 2002). The 10 per cent figure is perhaps conservative as the Murray Darling Basin Salinity Audit (MDBC 1999) estimates that the average salinity of the Murray River at Morgan in South Australia will increase by 17 per cent by 2020.

Adding up all the impacts measured by the NLWRA, the total cost of future increases in salinity over the next 20 years is \$2 857 million (NPV).

Table 3.3 **Current and future costs of salinity, turbidity and sedimentation**

	Current cost	Cost of further degradation 2000-2020
	\$ m per year	\$ m NPV
Dryland salinity		
Agricultural yield loss	187	558
Damage to infrastructure	89	341
Water quality deterioration		
Salinity	not estimated	1021
Turbidity	not estimated	814
Sedimentation	not estimated	123
Total cost		2857

^a Assumes 5 per cent discount rate

Source: NLWRA (2002)

Murray Darling Basin Study

This study by Ivey ATP and Wilson Land Management services examines the current cost of dryland salinity and saline water in the Murray Darling Basin (MDB), however it does not estimate future costs based on salinity projections. Nor does it estimate the cost of saline water to irrigated agriculture or environmental damage. For eight catchment management regions examined in the MDB, total costs are approximately \$217 million per annum (NDSP 2002). Given that this figure only applies to the MDB, the survey methods used in this study appear to be producing higher cost estimates than the NLWRA study.

Salinity costs to irrigators

Only sketchy information is known about the potential future costs of salinity to irrigated agriculture. This is mainly because there is uncertainty about the likely increase in water salinity due to the effects of dryland salinity. The threshold salinity concentration for irrigated crop and pasture damage is approximately 1500 EC units. The MDB Salinity Audit forecasts that within 100 years some

tributaries of the Murray River will experience salinity levels above this threshold (MDBC 1999). However, at Morgan in the lower reaches of the Murray, salinity levels are not expected to exceed 1500 EC. Because irrigation water is drawn from the Murray and its tributaries at various locations, the impacts of rising salinity will be unevenly distributed through the MDB. On the best available information, current costs of water salinity to irrigators in terms of lost production is \$30 million per annum and this cost is estimated to increase by approximately \$100,000 per EC unit increase in salinity (MDBC 1999).

Salinity response function

Deriving an estimate of the salinity control benefit of trees is problematic because there is no readily identifiable relationship between the area of agroforestry and the amount of salinity response. For example, it is not clear what area of agroforestry is required to deliver salinity benefits or the time lag between planting the trees and realising the benefits. Some hydrological models predict that 30 to 70 per cent of farmland may need to be converted to alley forestry to be effective in preventing the upward trend in salinity (NLWRA, 2002).

Our approach is to assume a simple linear relationship between the future costs of salinity and the proportion of broad-acre farmland converted to agroforestry (chart 3.2). The cost of salinity over the next 20 years (expressed as a net present value) is assumed to fall with increasing area of agroforestry. Currently less than 0.1 per cent of broadacre farmland is under farm forestry — representing an area of 90 000 hectares. At this level of agroforestry (the business as usual scenario) it is assumed that increases in salinity over the next 20 years will cost between \$2857 million to \$4000 million in present value terms. The lower bound estimate is based on the NLWRA (2002) study and the upper bound figure allows for additional cost items not included in the NLWRA assessment. For illustration purposes the response functions in chart 3.2 are based on the NLWRA estimate.

Future salinity costs could be substantially reduced if, on average, 20 per cent of all broadacre farmland was converted to agroforestry. For the purposes of establishing a response function we assume that NPV costs could be reduced to \$700 million, representing a reduction of 75 per cent on the NLWRA estimate of \$2857 million. With JVAP research it is expected that the salinity response function will be more responsive to tree planting strategies. We assume that, costs could be reduced to \$100 million NPV at the 20 per cent level of agroforestry, which equates to a reduction of 96 per cent.

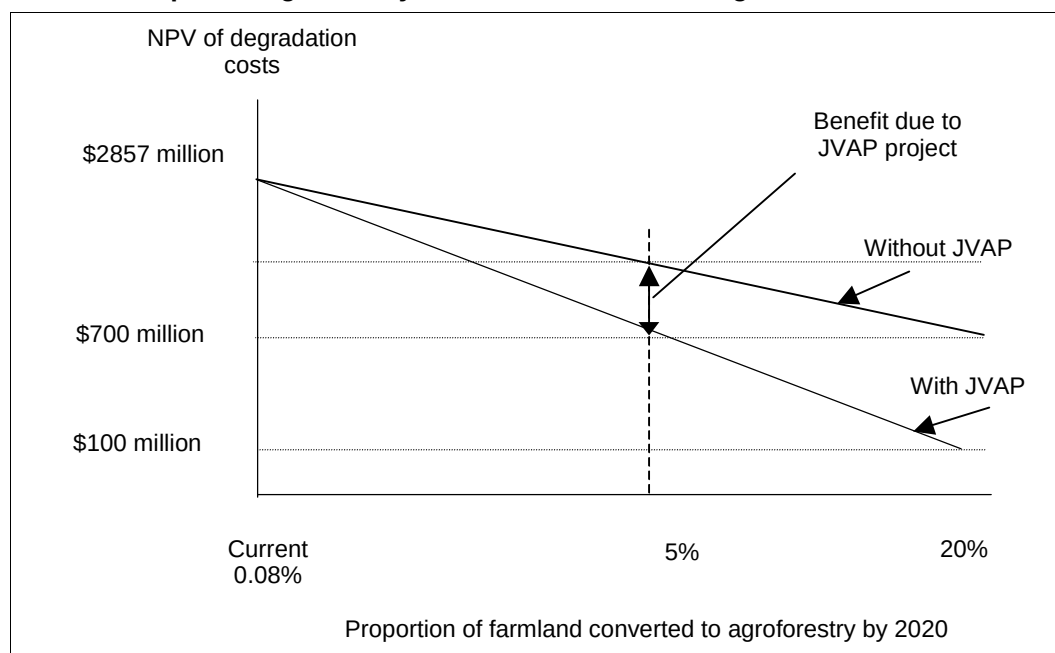
Agroforestry adoption level

Agroforestry on 20 per cent of broadacre farmland represents a very large increase in the area of farm forestry. The current area of farm forestry is approximately 90 000 hectares or less than 0.1 per cent of broadacre farmland. In contrast, 20 per cent of all broadacre farmland equates to 23.4 million hectares (the total area of broadacre farms in the wheat-sheep and high rainfall zones is 117 million hectares — ABARE 1997). Given the low base from which we are starting, it is most unlikely that the 20 per cent average could be achieved without very significant increases in public and private investment in tree planting.

A more realistic adoption level is 5 per cent of broadacre farmland, which could be reached by 2020 if 0.3 million hectares of agricultural land was converted to agroforestry each year. This is considered to be feasible if the current levels of investment in tree planting extend into the future.

The analysis does not factor in any potential increases in adoption level due to the catchment hydrology R&D. This is because we have assumed a fixed level of private and public investment in agroforestry establishment over the next 20 years. Further expansion (due to JVAP or other influences) would require additional implementation costs — which are not included in the analysis. Importantly, the analysis is evaluating the treatment efficiency improvements achieved per hectare planted for a given level of investment rather than the increase in area planted.

Chart 3.2 Impact of agroforestry on the future costs of degradation 2000–2020



Data source: CIE

Per hectare benefits of agroforestry

The slope of the salinity response function is used to estimate the salinity benefits per hectare of agroforestry. The formula for this calculation is as follows:

$$(\text{Cost A} - \text{Cost B}) / (\text{Area B} - \text{Area A})$$

where;

- Cost A is the present value cost of future salinity at the current area of agroforestry;
- Cost B is the cost of salinity at the 20 per cent adoption level;
- Area A is the current area of agroforestry (0.09 million hectares); and
- Area B is the area of agroforestry corresponding to 20 per cent of broadacre farmland.

The per hectare salinity benefits from agroforestry ‘with’ and ‘without’ JVAP are summarised in table 3.4. Two sets of benefit estimates are shown. One set is based on the NLWRA (2002) estimate of future salinity costs (\$2857 million) and the other is based on an upper cost estimate of \$4000 million.

Table 3.4 Per hectare salinity benefit from agroforestry — before implementation costs

	Without JVAP		With JVAP	
	\$/ha NPV	\$/ha/year	\$/ha NPV	\$/ha/yr
<i>Future salinity cost under business as usual for period 2000–2020</i>				
Scenario 1: \$2857 million NPV	101	7.70	118	9
Scenario 2: \$4000 million NPV	129	9.9	165	12.6

Source: CIE calculations

R&D expenditure

The schedule of costs for the four projects are shown in table 3.5. In the analysis these costs are converted to 2002 present values.

Table 3.5 Timing of R&D costs

Project	1996–97	1997–98	1998–99	1999–00	2000–01	2001–02
	\$	\$	\$	\$	\$	\$
CSM-3A	6 000					
WS967-7	16 000					
AGS-1A		32 000				
CSM-4A						2 901 000
Total	22 000	32 000				2 901 000

Source: RIRDC

Results

The benefit cost analysis shows a positive return on R&D investment (table 3.6). This standard set of results is based on the NLWRA (2002) estimate of future salinity costs (\$2857 million). The present value of R&D benefits at a five per cent discount rate is estimated to be \$4.1 million. The research yields a NBIR of 2.4 and an internal rate of return of 21 per cent. The IRR is high relative to the NBIR because the benefits from more efficient planting designs to control salinity are spread evenly through time rather than being concentrated at the end of the planning horizon. This is unlike the other BCAs where benefits from tree harvesting are not realised until the end of the planning horizon.

The net benefits should be regarded as a lower bound estimate of potential returns because only the salinity benefits associated with preventing agricultural yield loss, infrastructure damage and the off-site effects of poor water quality were evaluated. The impacts on biodiversity — particularly wetlands threatened

by salinity — were not evaluated because not enough is known about these potential threats to determine a value estimate (see appendix A).

Table 3.6 **Estimated returns hydrological research**

<i>Discount rate</i>	NPV (\$ million)			NBIR	IRR
	R&D cost	R&D benefits	Net benefits		
0%	3.05	10.9	7.9	3.6	21%
5%	3.05	7.2	4.1	2.4	
10%	3.05	5.1	2.1	1.7	

Source: CIE calculations

Sensitivity analysis

Two key parameters affect the size of net benefits flowing from this R&D.

First, the results are sensitive to the projected future costs of salinity in the absence of salinity control treatments. The standard set of results presented above are based on the NLWRA (2002) estimate of \$2857 million over the next 20 years. In this sensitivity analysis, an upper bound estimate of \$4000 million is used in the cost-benefit model.

Second, the R&D benefits are dependent on the responsiveness of the salinity cost function to agroforestry treatments. The sensitivity of results to this parameter is examined by varying the slope of the salinity response function. Three different levels of responsiveness are specified (low, medium and high). The response function is varied by using different assumptions about the extent of salinity cost reductions when 20 per cent of farmland is converted to agroforestry. The ‘with JVAP’ response function is fixed at \$100 million (a 96 per cent reduction on \$2857 million), while the cost reductions ‘without JVAP’ are varied between 65 per cent and 82 per cent. The 65 per cent assumption represents a high response because there is a big gap between this figure and the 96 per cent reduction used for the ‘with JVAP’ scenario. Correspondingly, the 82 per cent assumption represents a low response.

Results of the sensitivity analysis are summarised in table 3.7. The analysis shows that net benefits flowing from JVAP’s hydrology research range from \$1.8 million to \$12.0 million in present value terms.

Table 3.7 Sensitivity of net R&D benefits (\$ millions NPV)^a

Future salinity cost under business as usual for period 2000-2020	Responsivity of salinity cost function to agroforestry treatment		
	Low	Medium	High
\$2857 million	1.8	4.1	7.9
\$4000 million	3.7	7.1	12.0

^a Assumes a 5 per cent discount rate

Source: CIE calculations

4 Master Treegrower Program

Background

There is encouragement from many sectors to increase the amount of plantation forestry in Australia for economic and environmental reasons. Economic reasons include the dwindling supply of native timber for forest products due in part to Regional Forest Agreements, the projected increase in demand for wood and wood products in the Asia-Pacific region and the potential for use of plantations as carbon sinks. Environmental reasons include salinity control, promotion of biodiversity, cleaner air and protection of native and old growth forests.

Vision 2020 (MCFFA 1997), a program developed by government and industry to expand the plantation industry by removing impediments and increasing incentives, set a target of 3.3 million hectares of plantation forestry by the year 2020, up from around 1.1 million in 1995 when the program started. Encouraging farm forestry is part of this strategy. Farm forestry is defined by the National Farm Forest Inventory as plantations that are owned outright by individuals with total plantation estates less than 10 000 hectares. Many of these plantations are owned by farmers of crops or livestock who are looking to diversify their income stream or achieve indirect benefits from trees.

Investing in plantation forestry is a risky venture, since harvest does not occur for anywhere between 5 to 30 years after the initial investment. Achievement of alternative farm forestry goals, such as reducing salinity or improving the amenity value of a farm while maintaining a profitable outcome, depends on the farmer's knowledge and ability to design a plantation that best suits the farm's needs.

The MTG aims to reduce the risks undertaken by farmers engaging in agroforestry. This educational program is designed to help farmers and the wider community realise the economic, social and environmental benefits of trees on farms by providing information encouraging the successful uptake of agroforestry for whatever purpose a farmer requires.

The Master Treegrower Program

The Master Treegrower Program is an educational course involving eight days of seminars, workshops, practical exercises, industry tours and farm visits aimed at

educating farmers and other practitioners involved in farm forestry about the potential benefits of engaging in farm forestry and methods of establishment, managing and marketing of trees and forest products. Funding comes from a wide range of areas, including RIRDC, and LWRRDC, FWPRDC and industry sources.

MTG is the best known farm forestry education and extension program in Australia and has received numerous awards, including:

- Allen Stom Eureka Prize for Environmental Education Program 2000; and
- Institute of Land and Food Resources (University of Melbourne) Award for excellence in outreach, 2001.

Two thousand copies of *The Farmer's Log* have been distributed, as have 600 copies of *Design Principles for Farm Forestry*. These publications provide agroforesters with a guide to maximising economic and non-economic benefits of agroforestry based on the particular requirements of their farm.

The Master Treegrower Program is designed and delivered by the University of Melbourne.

Objectives

Two RIRDC projects have funded and supported the Master Treegrower Program.

The initial project, the Australian Master Treegrower Program, received \$143 860 from RIRDC, \$36 200 from industry and \$252 340 from other research organisations. It commenced on the 10 July 1997 and was completed on the 30 June 1999. Its objectives were to:

- assemble a Master Treegrower Committee to help in the development of the program;
- provide a minimum of eight courses in regional areas across Australia;
- prepare course material including signs, folders and a practical working guide to agroforestry design and management;
- encourage landowners to prepare their own agroforestry project plans and /or plans for other landowners within their region;
- encourage landowners to play a more active role in the management of regional agroforestry networks and programs by providing the knowledge that instills confidence; and

- establish a group of ‘Master Treegrowers’ in each region that can support each other and play an active role in regional extension and development programs.

The follow-up program, Continuation and Expansion of the Master Treegrower R&D Program, commenced on 10 February 1999, and was completed on the 30 September 2001. It received \$280 158 from RIRDC, \$864 000 from other research organisations and \$209 026 from industry. The objectives of the second program were to:

- stimulate the active involvement of farmers in the establishment, management and marketing of trees and forest products;
- encourage greater landholder participation in regional and national farm forestry research and extension; and
- develop and implement a course delivery model which satisfies participant’s needs.

Costs of the Master Treegrower Program

The MTG program charged participants between \$50 and \$100, so \$75 was selected as an average cost for participation. The number of participants at each program is around 20, based on a total of 795 participants at 39 programs. The cost of the R&D programs amounted to a little over \$1.5 million over six years. Table 4.1 shows the additional costs of R&D, and the cost of taking part in the program.

Table 4.1 Costs of R&D

Program	Financial year	RIRDC	Industry	Other R&D	Total
		\$	\$	\$	\$
	1996/97	35090	0	0	35090
	1997/98	26840	10900	62210	99950
The Australian Master Treegrower Program	1998/99	10000	7200	63960	81160

(Continued on next page)

Table 4.1 **Costs of R&D** (continued)

Program	Financial year	RIRDC	Industry	Other R&D	Total
		\$	\$	\$	\$
	1998/99	88174	79914	288000	456088
	1999/00	162032	106552	460800	729384
Continuation and expansion of the Australian Master Treegrower Program	2000/01	14976	22560	115200	152736
	2001/02	14976	0	0	14976

Source: RIRDC database

Project outputs

By June 2001, 35 MTG programs were completed and four more due for completion by the end of the year. When the final program is completed 795 people will have graduated as Master Treegrowers. South Australia is the only state in which a MTG program has not been conducted. The primary output for this project is the Master Treegrower course.

Project outcomes

Three broad potential outcomes of the MTG program are:

- an expansion in farm forestry by those undertook MTG;
- better knowledge for farmers who have decided to take up farm forestry, encouraging better species and site selection, more productive farm forestry practices and so forth; and
- the flow on or echo effects as MTG participants educate others involved in farm forestry to adopt new technologies and / or expand the area committed to farm forestry. The benefits of the MTG course will depend critically on the extent of this 'echo effect'.

Farmers are expected to conclude the course with a greater ability to plant, care for and harvest trees in a manner best suited to their individual situation. This could enhance the outcomes which include:

- profits from additional timber planted, and higher quality or better marketed wood or wood products;
- windbreak benefits from reduced crop and animal loss and soil degradation;
- savings on animal fodder costs; and
- the potential value of carbon credits.

These economic outcomes may be reflected in higher land values as well as income. Perhaps less tangible are the benefits from:

- reductions in salinity and waterlogging problems;
- amenity value;
- biodiversity; and
- establishing networks and relationships with other farm foresters.

The last outcome is of both social value to the individual and community and is instrumental in encouraging the expansion of farm forestry. The success of the MTG program will depend critically on the ‘echo effect’ — the transfer of beneficial information from the MTG program to other farmers, especially those who are not MTG graduates. Little is known about the extent of this ‘echo effect’, and its benefits are difficult to measure accurately.

Estimating the magnitude of these outcomes

The Master Treegrower Program causes four types of changes to the agroforestry businesses of participants and to the industry generally:

1. an increase in the number of trees planted;
2. an increase in the adoption rates of productivity–boosting site and species selection technology among Master Treegrowers;
3. the ‘echo effect’ — agroforestry technology is transferred from MTG participants to other agroforesters by example and other knowledge transfer; and
4. changes in the reasons that farmers plant trees.

Surveys were conducted by an independent team of anthropologists led by Dr Tim O’Meara before and after MTG programs, asking participants a variety of questions including the number of trees they had planted, the reasons why they plant trees, their opinion of the program and so forth. The results of these surveys are referred to in Reid and Stephen (2002) and have been used to construct ‘with MTG’ and ‘without MTG’ scenarios. It is important to note that the initial survey was written and completed by 458 participants and the follow up survey was conducted over the telephone with 98 participants — different results over time may be a result of statistical factors rather than a change in attitudes.

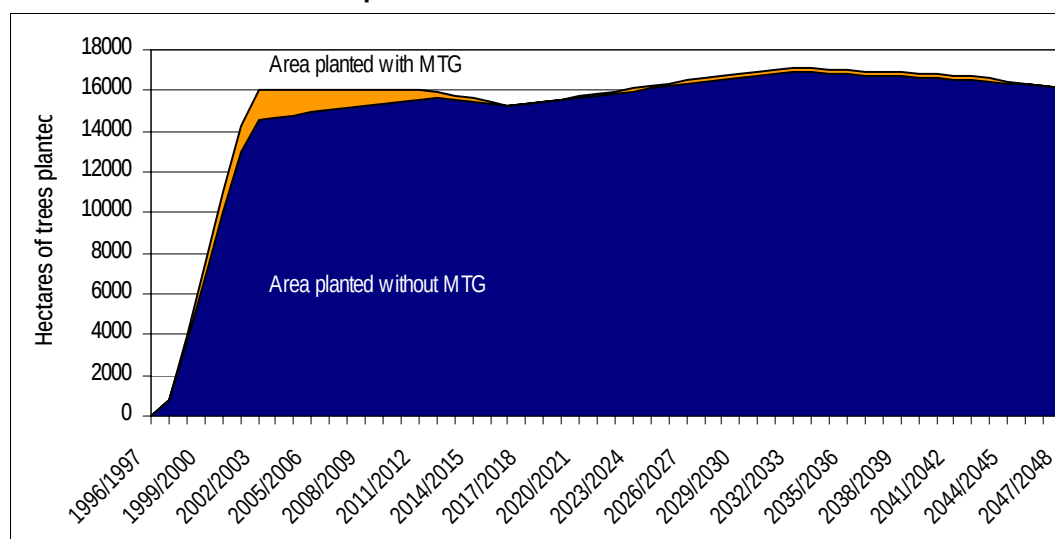
Increase in tree planting

The MTG survey found that, for each participant who planted trees in the year before MTG, an average of 6 244 trees were planted, and the year after, an average of 19 997 trees were planted. Assuming an average planting density of 1 000 trees per hectare, this implies an increase in the average area planted from 6.2 hectares before to 20 hectares after MTG. It is assumed that only 25 per cent of this increase in plantings can be attributed to MTG; the other 75 per cent may have already been planned or is attributable something other than MTG. Some of this increase is due to the acceleration of existing plans for adoption of agroforestry and some is due to addition of trees that would never have been planted in the absence of MTG.

After MTG, fewer participants indicated that they were planting trees. Prior to MTG, 79 per cent said they planted trees; after MTG this figure dropped to 74 per cent. A few participants indicated that the MTG allowed them to make an informed decision not to take up agroforestry.

Based on these assumptions, chart 4.1 shows the projections of total area planted with the MTG program and in its absence.

Chart 4.1 Hectares of trees planted with and without MTG



Note that although the two scenarios tend to converge in terms of area planted, the volume of wood extracted under the 'with MTG' scenario will be greater due to the higher success rate of plantations.

Purposes of tree planting

Usually trees need to be planted for a specific purpose for the target benefits to be realised. For example, windbreak benefits are only achieved if the farmer plants trees in a windbreak pattern. Participants' reasons for planting trees before and after MTG were used as an indication of the proportion of farmers reaping

certain types of benefits from trees, for example windbreak or salinity benefits. After MTG, the importance of each benefit in tree planting changed. Table 4.2 shows how the proportions of farmers planting trees for each reason changed after participation in the MTG. If the MTG was the reason for these changes, it tended to encourage more planting for wood production and environmental reasons than for windbreaks. Note that the changes are fairly small. The main reasons for planting trees are listed below, however some farmers listed other reasons for planting trees that are not assessed in this analysis.

Table 4.2 **Changing reasons for planting trees**

Reason for planting trees	Farmers planting trees for this reason	
	<i>Before MTG</i>	<i>After MTG</i>
	%	%
<i>Economic</i>		
Financial/wood production	27	31
Windbreaks	13	9
Fodder production	1	1
<i>Environmental</i>		
Lower water tables/reduced salinity	7	8
Reduced soil erosion	14	16
Biodiversity	14.5	15
Amenity value	7.5	8

Source: Reid and Stephen (2002)

Impact of site and species selection technology

MTG increases the productivity of plantations by accelerating the rate at which agroforestry R&D reaches farmers and increasing the adoption rate of such research. This transfer of knowledge does not merely affect MTG participants; as it provides agroforesters with the ability to provide better advice to others on agroforestry.

- The survival rate for trees, amongst other things, is a function of the adoption rates of site and species selection knowledge. Adoption of this knowledge can increase survival rates for trees from 73 per cent to 90 per cent.
- The MAI of trees depends on the adoption rates of this site and species selection technology that enhances the growth and survival rates of trees. Researchers claim that adoption of this technology has the potential to increase average MAI from 18.1 cubic metres per annum to 23.5 cubic metres per annum in high rainfall zones or by around 30 per cent. It is important to note that trees grown in saline soil have slower growth rates than those in non-saline soil. It is assumed that farmers who plant trees in saline areas will achieve half the MAI of trees planted in non-saline soil.

These figures are from the site and species suitability analysis (chapter 5).

Adoption of the new technology

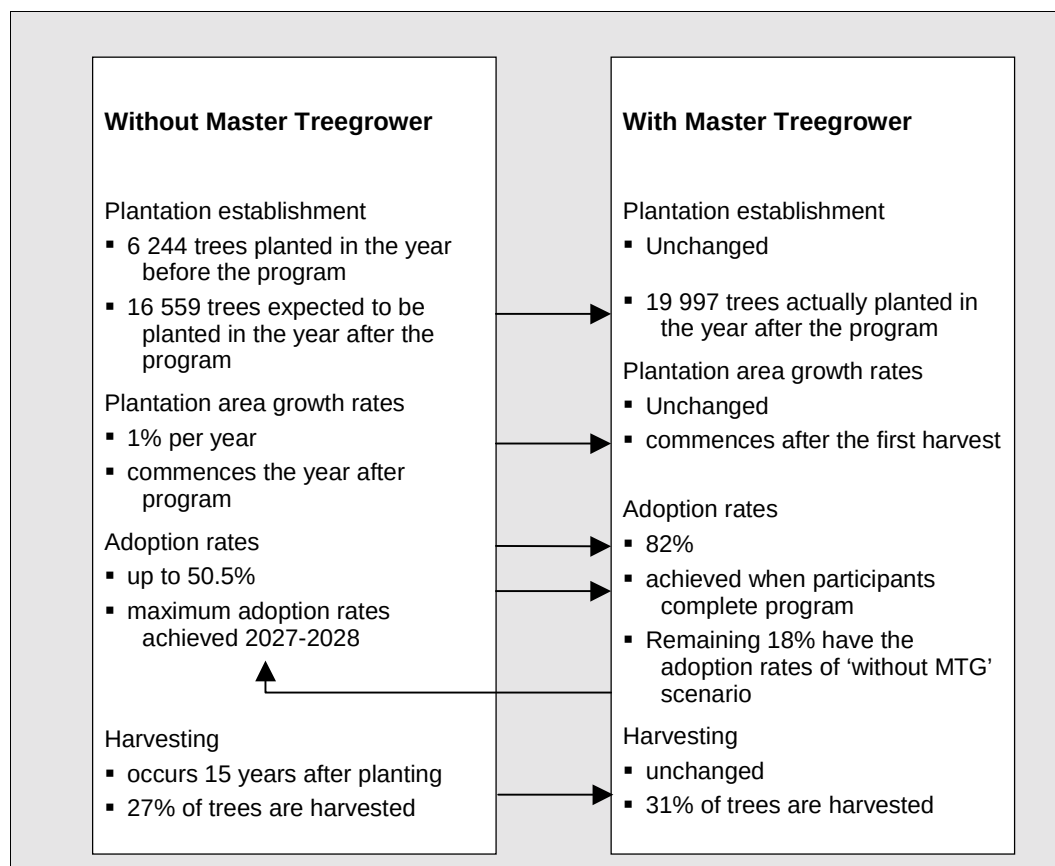
In the absence of MTG, the adoption profile of site and species technology is assumed to peak at adoption rates of 50.5 per cent. This will be achieved in 2027–2028.

The Master Treegrower Program is assumed to increase the adoption rates of this technology by participants, as the course teaches site and species technology, amongst other things. Eighty-two per cent of participants surveyed said their knowledge increased as a result of MTG. Of the remaining 18 per cent it is assumed that 50.5 per cent (the same rate as the non-MTG agroforesters) would end up adopting the technologies so the total adoption rate among MTG participants is assumed to be 91 per cent. It is 40.6 per cent higher than among the general population, assuming that there is no echo effect.

Summary of the estimated changes for participants in the MTG program

Assumptions regarding tree planting, harvesting and technology adoption rates are presented in chart 4.2.

Chart 4.2 **Tree planting, harvesting and technology adoption rates**



The ‘echo effect’

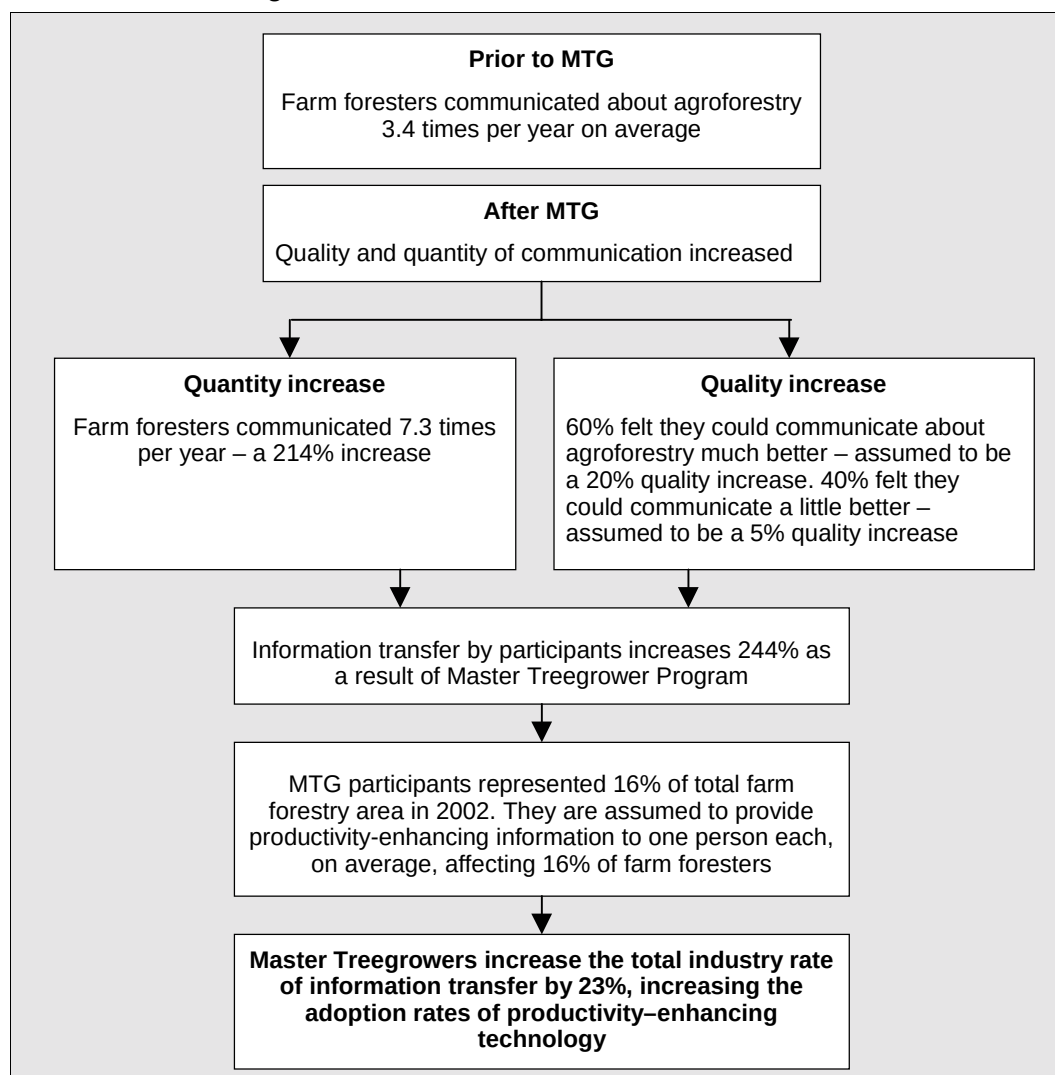
An indirect benefit of MTG is that participants will establish social networks, increasing the word of mouth transfer of agroforestry information. Many of the 14.9 per cent of participants who did not own a farming property took part in the program because they were in the business of passing farm forestry information onto others, such as nursery owners, government farming advisers and private consultants. The MTG course, according to comments from these respondents, improved the quality of information they pass onto clients. This has the potential to lead to increased benefits as the value of the service they provide increases, both in terms of economic advice given and methods of obtaining other goals.

The main effect of this increase in transfer of information is higher adoption rates of new productivity enhancing techniques, as a greater number of people hear of these new methods. This is called the ‘echo effect’ of the MTG program.

AgKnowledge conducted a faxback and phone survey of MTG participants to determine the extent to which participants felt that MTG had improved networking and farm forestry discussion; and increased feeling of security about participant’s farming future. The survey found that 39.3 per cent of participants would communicate with others about farm forestry at least monthly and 21.5 per cent would do so at least quarterly (AgKnowledge 2002). After the program, participants reported that they felt more comfortable discussing farm forestry issues, less isolated in their farm forestry activities and inclined to catch up again with other MTG participants (Reid and Stephen 2002).

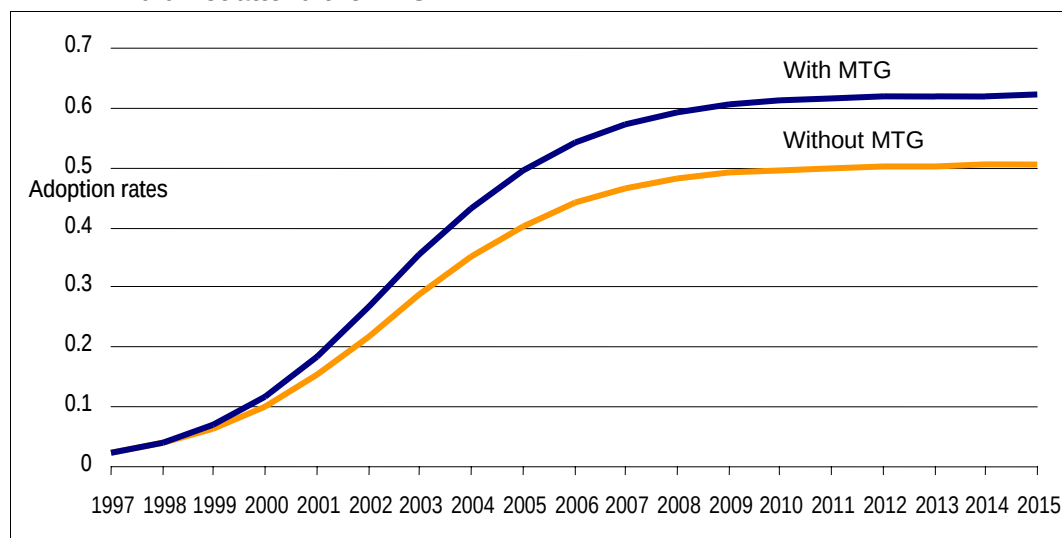
It is important to note that networking has social benefits as well as the potential to produce economic and environmental benefits. The focus in this evaluation is on the latter benefits. The social benefits are discussed in the AgKnowledge report. Chart 4.3 shows the method used to calculate the increase in the transfer of information as a result of MTG.

Chart 4.3 Calculating the benefits of the 'echo effect'



The increase in information transfer as a result of the Master Treegrower Program is estimated to have the long-run effect of increasing adoption rates 23 per cent above the 'without MTG echo' level. This is represented in the difference between the two lines in chart 4.4. Unfortunately this rough estimate cannot be verified as the survey data does not pick up this effect.

Chart 4.4 **Adoption rates of technology with and without MTG echo by farmers who did not attend the MTG**



Project evaluation

To measure the impacts of the project we compare the return to MTG participants from farm forestry with the projected returns if the MTG program had not been undertaken.

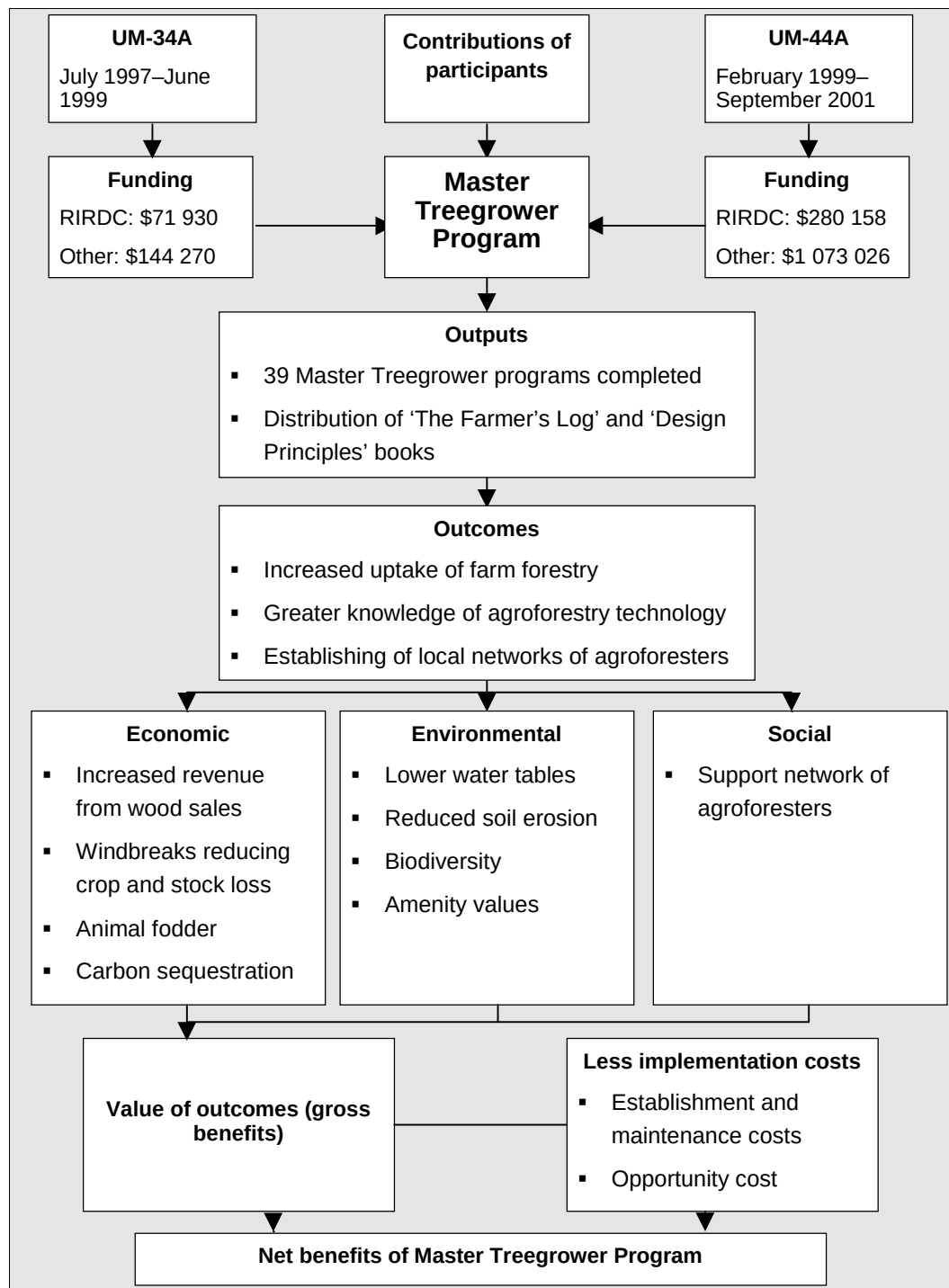
The benefit-cost analysis takes account of two of the ‘triple bottom line’ dimensions; that is, the economic and environmental benefits of the project are assessed. Such an analysis is appropriate as farm foresters tend to place less emphasis on the easily measurable economic benefits from forestry than industrial plantation owners do. As well as the returns from the sale of logs, farm foresters are also interested in the benefits from incorporating farm forestry into their overall farming system. Such benefits can flow from establishing windbreaks, reducing salinity and providing amenity values.

An MTG participant may, as a result of the program:

- decide to engage in agroforestry when he or she would not have otherwise;
- increase the quantity of a planned plantation;
- receive, and hence act on, agroforestry information earlier;
- receive information that would not have been received otherwise; or
- share agroforestry information with other agroforesters leading them to make similar changes.

Chart 4.5 shows the flow of inputs, outputs, outcomes and benefits attributable to the Master Treegrower Program.

Chart 4.5 Flow of inputs, outputs, outcomes and benefits



Parameter assumptions

The following assumptions form the framework with which the costs and benefits of the MTG program were evaluated.

Revenues from wood production

The most obvious economic benefit from MTG is the increase in the volume of wood available for sale. This is due to several factors:

- an increase in the number of trees planted;
- an increase in the adoption rates of technology, leading to:
 - increased wood yields;
 - increased survival rates of plantations; and
- a greater percentage of farmers planting trees for wood sale.

There is no single set of costs and benefits associated with tree planting and harvesting due to the range of options that farm foresters can incorporate into their farming systems. Trees can have a very short rotation with lower costs and sooner but smaller revenues (for example a 15 year rotation of *Eucalyptus globulus* for woodchips can provide a stumpage price of \$15-\$25 per cubic metre with little need for pruning) or a long rotation with high prices for high quality timber, but higher management costs and a longer lag (for example a 30 year rotation of *Acacia melanoxylon* requiring pruning and thinning, can provide a stumpage price of over \$100 per cubic metre).

The net benefit estimates of the costs and revenues are based on a fairly low cost, low-rotation, low-revenue plantation. Returns on the sale of wood were calculated as the number of hectares successfully planted multiplied by the MAI, rotation period, stumpage price and the proportion of people planting trees for the sale of wood. A low-medium stumpage price was selected to go with the low-medium estimates of tree cost, establishment and rotation. The average stumpage price is expected to be \$20 per cubic metre.

It is also important to note that profits from harvest are not the sole or primary motivation for most farmers in planting trees, so trees may be deliberately selected or planted in a manner that does not maximise profits from the sale of wood. For example, mean annual increments are greatly reduced if a tree is planted in saline soil; but this will not deter a farmer whose goals are more diverse such as managing salinity or planting for biodiversity. Trees used for windbreaks, aesthetic value, biodiversity and soil preservation are often widely spaced or established as mixed species plantations, in the later case reducing

mean annual increment per hectare, and trees used for fodder may be damaged by animals in a way that reduces their yield. For this reason it was assumed that the potential yield levels of around 27.1 cubic metres per hectare suggested in the site and species selection analysis would rarely be achieved.

A significant proportion of farmers did not indicate a desire to plant trees for profit from the sale of wood. Only those who wished to profit from the sale of wood were assumed in this analysis to harvest their trees. Those who harvest their trees were assumed to replant the area.

Carbon sequestration benefits

The role of trees in carbon sequestration and the associated benefits depend on the existence of formal markets for carbon credits. This in turn depends on government policy on CO₂ emissions. Farm forestry trees reduce carbon in the atmosphere, an environmental benefit. There is potential for this to become an economic benefit if Australia ratifies the Kyoto Protocol, creating markets for carbon sequestration and giving trees an economic value for their ability to store carbon. However, this value depends on how trees are treated as carbon sinks. Current guidelines consider the sequestration value destroyed when the trees are harvested. It is assumed for this analysis that the protocol will be ratified and that farmers will be able to sell carbon credits from 2008 onwards. Carbon trading and the Kyoto Protocol are discussed further in appendix A.

The increase in trees planted and the reduction in failure rates leads to a greater potential source of revenue from the sale of carbon credits. With carbon credits predicted to provide between \$250 and \$510 per hectare per year, the increase in benefits can be expected to be substantial. An average benefit of \$380 per hectare per year was used in this analysis.

Other economic outcomes from farm forestry

The proportion of farmers planting trees for fodder did not change as a result of MTG, but the increase in total plantation area suggests an increase in the number of trees planted for fodder. The fodder value of trees is an estimate of the amount saved on feed for stock during the summer-autumn months. Farmers may use certain trees for fodder, reducing the amount they must spend on feed. The value of trees used for fodder is estimated to be \$3 per hectare per year. (See appendix A for details.)

The publication *Design principles for farm forestry* estimates that the return for trees established as windbreaks is \$17 per hectare per year, based on a reduction of crop and stock losses from winds and chill. The proportion of farmers planting trees for windbreaks declined after MTG from 13 to 9 per cent. The benefits of

windbreaks are measured by the reduction in loss of crops or stock due to the windbreak.

Environmental outcomes

The benefits sought by farmers planting trees altered slightly, as shown earlier in table 4.2. Slightly more farmers were planting trees for environmental reasons than prior to the MTG. Often, to achieve a particular environmental benefit such as biodiversity, the plantation must be designed with that benefit in mind. The increase in the proportion of farmers planting trees for environmental reasons provides an increase in environmental outcomes.

Note that the some of the benefits of the increase in environmental outcomes are economic in nature. The benefits of lowering the water table and reducing soil erosion are the reduced loss of future agricultural production and damage to infrastructure, while amenity values are measured as positive effect that trees have on land values. The only true environmental benefit estimated is from enhanced biodiversity and even this may have an economic benefit for example by sheltering habitat for predatory insects or birds which keep crop eating insects under control.

The environmental outcomes of planting trees provide a range of benefits; predominantly environmental and economic in nature. The sources of the value estimates are explained in the appendix A.

- Trees reduce soil erosion, retaining the fertility of the soil for agricultural purposes. The benefits of reduced soil erosion are valued at \$8.30 per hectare of trees. This is an estimate of lost production avoided by the planting of trees.
- Lowering water tables and reducing salinity by planting trees reduces the area of agricultural land lost to salinity. The future agricultural value of land saved from salinity and the benefits in reduced infrastructure damage by one hectare of trees is estimated at \$10 per hectare of trees per year.
- Increased biodiversity comes from trees providing habitat for native flora and fauna. Some stands of trees have more biodiversity value than others; for example monoculture stands, especially of exotic species, may have little biodiversity value, while a mixed stand of native trees can potentially have a high biodiversity value. For the purposes of this analysis, the biodiversity outcomes are valued at \$22 per hectare per year.
- Trees beautify landscapes and provide amenity values. The amenity value of one hectare of trees is estimated to be \$8 per year. This estimate comes from a

real estate agent's estimate of the increase in land value from an extra hectare of trees on a property.

The environmental benefits were calculated by multiplying the total area planted, the proportion of farmers planting trees for that reason and the benefits per hectare per year of planting trees for this reason.

Costs

Establishment costs

Costs of farm forestry establishment and maintenance are based on estimates provided for a sample plantation in the Farmer's Log. These figures were for a mixture of commercial species (*E. nitens*, *E. globulus*, *E. obliqua* and *Acacia melanoxylon*) and indigenous species planted for sale of timber, windbreaks, protection of soil and waterways, biodiversity and aesthetic values. The cost of establishing a such a plantation includes costs of fencing, spray for trees, planting costs and fertiliser, and is \$1 640 per hectare in the planting year. Maintenance costs of \$20 per year include aftercare, pruning and thinning. Note that the figure of \$20 per year is an average of costs over the life of the tree, such maintenance usually only occurs two or three times in the tree's life. These costs are based on an assumption of a labour cost of \$20 an hour. Rotations were assumed to be 15 years.

The opportunity cost of agroforestry considers the marginal value of agricultural land rather than the average value as it is assumed that if land is highly productive when used for wheat or grazing, farmers are unlikely to use this land for forestry. Farmers are assumed to plant trees on land which is providing the lowest returns for pasture or crops. The opportunity cost of marginal land is estimated as \$65 per hectare (Reid, R. Melbourne University, personal communication, 24 April 2002.) ABARE surveys (Wilson and Tran, 1995) found that only 76 per cent of farm forestry trees are planted on arable land, so this is taken into account.

Table 4.3 shows the per hectare costs of establishing and maintaining plantations, and the opportunity cost of farm forestry.

Table 4.3 **Establishment costs**

Cost	Cost per unit	Total units	Period in which costs occur	Source
Tree establishment	\$1640/ha	Hectares of trees planted	Year of planting	The Farmer's Log
Tree maintenance	\$20/ha/yr	Hectares of trees established	Annually from planting to harvest	The Farmer's Log
Opportunity cost of agroforestry	Value of marginal agricultural land - \$65	Proportion of trees planted on arable land	Annually	Rowan Reid, ABARE (1995)

Summary of the impacts

Additional trees planted

The environmental outcomes from trees, lower water tables, reduced soil erosion, biodiversity and amenity values are dependent on the number or area of trees planted. An increase in the number of trees planted increases the total level of environmental benefits as well as the economic benefits. The increase in trees planted is confined to MTG participants as there is no survey data to suggest that the echo effect encourages tree planting among non- MTG participants.

Increased adoption of new technology

The increase in adoption rates of new technology results in increased survival rates of trees and higher growth rates. The financial benefits of increased yields and higher survival rates for MTG participants and as a result of their communications — the 'echo effect' — were calculated and these benefits can be attributed to the MTG program. Table 4.4 shows the parameters for the calculation of benefits received from the MTG program.

Table 4.4 **Outcomes with Master Treegrower Program**

Benefits	Measure of benefit	Proportion of farmers affected		Year benefits commence	Source
		Without MTG	With MTG		
<i>Economic outcomes</i>					
Revenue from wood sales	\$20 per cubic metre	27%	31%	15 years	Reid and Stephen
Windbreaks	\$17/ha/yr	13%	9%	Year of planting	<i>Design principles for farm forestry,</i> Reid and Stephen

(Continued on next page)

Table 4.4 **Outcomes with Master Treegrower Program** (continued)

Benefits	Measure of benefit	Proportion of farmers affected		Year benefits commence	Source
		Without MTG	With MTG		
Animal fodder	\$3/ha/yr	1%	1%	Year of planting	Reid and Stephen
Carbon sequestration	\$380/ha/yr	100%	100%	2008	ABARE (2002)
<i>Environmental outcomes</i>					
Lower water tables	\$10/ha/yr	7%	8%	Year of planting	NLWRA, Reid and Stephen
Reduced soil erosion	\$8.3/ha/yr	14%	16%	Year of planting	<i>Design principles for farm forestry</i> , Reid and Stephen
Biodiversity	\$22/ha/yr	14.5%	15%	Year of planting	NLWRA, Reid and Stephen
Amenity value	\$8/ha/yr	7.5%	8%	Year of planting	<i>Design principles for farm forestry</i> , Reid and Stephen
Increased adoption rates of technology	17% lower failure rate, MAI increases by 5.3m ³	50.5%	91%	Gradual increase, plateauing in 2028	AgKnowledge survey, CIE projections

For further information on the sources of these assumptions, see appendix A.

Results

The net benefits accruing from the ‘without MTG’ scenario were subtracted from the net benefits accruing from the ‘with MTG’ scenario, to find the benefits accruing from the Master Treegrower Program. The NBIR is the ratio of the net benefits of the outcomes of the project to the amount invested in the project. The BCR is calculated as the ratio of gross benefits of the project to the sum of implementation costs and R&D costs.

Benefits and costs are measured from the 1996–97 financial year to the 2047–48 financial year. The results are shown in table 4.5.

Table 4.5 **Results of the benefit cost analysis under varying discount rates**

Discount rate	Project costs	Implement- ation costs	Benefits	NPV	NBIR	BCR	IRR
	\$m	\$m	\$m	\$m	ratio	ratio	%
0 per cent	1.87	16.69	91.99	75.30	40.27	4.96	15
5 per cent	1.57	5.58	22.79	17.21	10.96	3.19	
10 per cent	1.32	2.89	7.53	4.64	3.52	1.79	

Source: CIE calculations

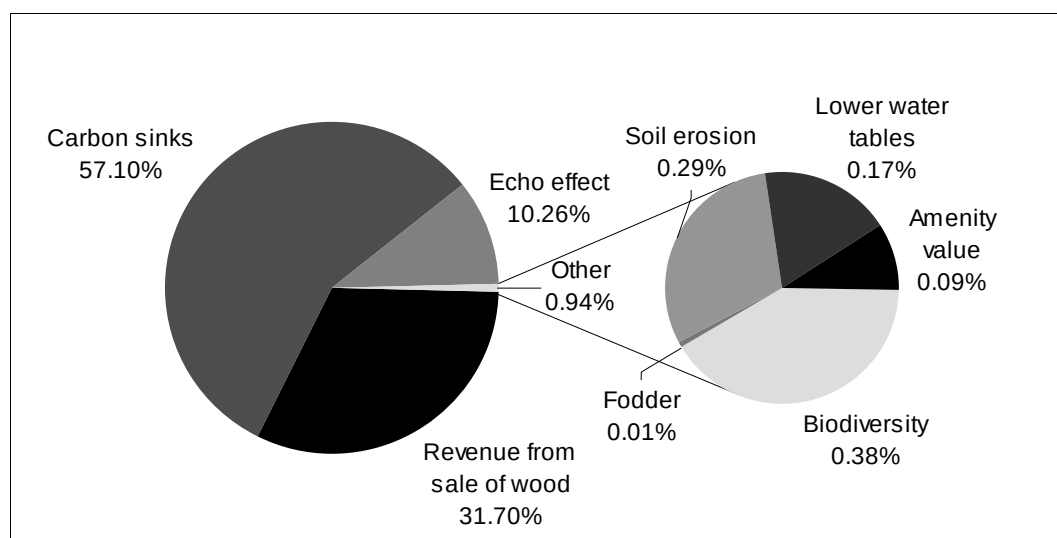
These results suggest that the Master Treegrower Program is a clear success. The expected net present value of the program is \$17.2 million at a 5 per cent discount rate, and the net benefit investment ratio is 11, implying a return of \$11 for each one dollar invested in R&D. These results indicate a strong return on investment. These strong returns are primarily due to:

- the increase in area of trees planted leading to increased sales of carbon credits;
- the increase wood sales due to increased area planted, lower failure rates and higher growth rates; and
- the echo effect.

Benefits by category

Chart 4.6 shows the proportion of present value benefits contributed by each benefit of MTG. The benefits from windbreaks are not shown in the chart as the impact on windbreaks turned out to be negative as the area planted declines as a result of the MTG.

Chart 4.6 Composition of the increase in present value of benefits attributable to MTG



Summary of the benefits of the MTG program

Increased returns from the sale of wood

The increased volume of wood available for sale naturally leads to increased revenues. The present value of this increase in benefits is estimated as \$5.408 million.

Increased sales of carbon credits

The increase in trees established as a result of MTG is expected to yield an estimated increase in the present value of carbon credit sales of \$9.742 million over 50 years. This is due to an expansion in area under permanent farm forestry.

Reduced costs of fodder

Increased area planted as a result of MTG leads to an increased number of trees planted for fodder, which saves on costs of feed for stock. The present value of the benefits from this increase is very small due to the low share of trees used for fodder. It is estimated nationally at \$1 500 reflecting the very small increase in area planted for fodder purposes as the research did not claim to enhance fodder values.

Increased returns from other agricultural products

The reduced area of trees planted for windbreaks has the effect of reducing windbreak benefits, as fewer windbreaks increases losses of crops and animals due to wind and chill. The present value of this increase in loss due to MTG is \$111 941.

The increased use of trees to lower the water table and reduce soil erosion have environmental benefits that have been measured in economic terms, namely the prevention of loss of future agricultural production and damage to infrastructure. The increase in trees planted for the lowering of water tables as a result of MTG is expected to save \$29 730 in future agricultural production in present value terms. The increase in trees planted to reduce soil erosion as a result of MTG is expected to save an extra \$49 352 of future agricultural production.

Increase in land values

The measure used to estimate the amenity value of additional trees on farms is the increase in property values, as trees beautify the landscape and provide a benefit that property purchasers are willing to pay for. The increase in amenity values as a result of MTG is \$16 034.

Non-market estimates of benefits

The increased benefits from biodiversity cannot be easily given a per hectare value (see appendix A). These values are non-market estimates of benefits based on citizens' willingness to pay, as a reduction in the number of species becoming extinct or endangered is not marketable. Given the estimates discussed in the appendix, the increase in biodiversity as a result of MTG is valued at \$64 029. It is assumed that only trees planted with the objective of biodiversity will achieve these benefits.

The echo effect

Networks established as a result of the MTG program result in transfers of information that increase the adoption rates of productivity-enhancing technology among non-MTG graduates. This allows farmers who have not completed the MTG course to improve their trees' growth and survival rates by raising the adoption rate of new technology. Based on a technology transfer to an additional 16 per cent of the area under agroforestry, the estimated present value of this benefit is \$6.233 million.

Sensitivity analysis

There are considerable uncertainties surrounding certain assumptions in this model. A sensitivity analysis was undertaken to determine the effects of variations in the assumptions on the outcome of the model. Three parameters were varied around their assumed mean values and the estimates recalculated to identify the sensitivity of the results to these changes. The parameters varied were:

- the increase in tree plantings attributable to MTG;
- the impact of the echo effect;
- stumpage price; and
- the value of carbon credits.

These parameters were selected for sensitivity analysis as most of the return to farmers from planting trees comes from the sale of wood, carbon credits and the echo effect. The average number of trees planted after MTG is unlikely to remain constant over every year the program is run, there is a substantial degree of uncertainty surrounding the proportion of the increase in plantings that is attributable to the MTG. These assumptions are highly uncertain, so a sensitivity analysis is prudent to provide a measure of confidence about the evaluation results. Table 4.6 shows the mean around which the inputs were allowed to vary, the maximum and minimum values, and the standard deviation.

Table 4.6 Values used to parameterise the probability distribution of each input variable

Input variable	Unit	Minimum	Maximum	Mean	Standard deviation
Percentage of tree planting increase due to MTG	%	0	50	25	10
Impact of echo effect	%	0	32	16	5
Stumpage price	\$/m3	10	30	20	2.5
Carbon credits	\$/m3	250	510	380	50

The program @RISK was used to conduct this sensitivity analysis. The sensitivity of the net present value and the net benefit investment ratio to changes in these variables were measured. Due to the high level of variability in the input variables tested and their strong impact on the outcome of the analysis, the range of possible results is very large. The results from the sensitivity analysis are presented in table 4.7.

Table 4.7 Results from sensitivity analysis

	NPV	NBIR
	\$m	ratio
Minimum	6.53	5.17
Maximum	27.05	18.27
Mean	15.64	10.99
95 per cent confidence interval	10.9 – 20.76	7.95 – 14.25

^a Assumes a 5 per cent discount rate

Source: CIE estimates

These results suggest a clearly positive return on investment. Table 4.7 shows that the range of possible net benefits ranges from \$6.53 million to a maximum of \$27.05 million, with a 'best-bet' mean value of \$15.64 million. The 'best-bet' net benefit investment ratio is 11, while the range is a minimum of 5 and a maximum of 18. There is a 95 per cent chance that the net present benefit lies between \$10.9

million and \$20.76 million, and that the net benefit investment ratio lies between 8 and 14.

The Master Treegrower Program has been well-received by farm foresters, due to the opportunity for networking with other farm foresters in addition to increasing their knowledge base and ultimately, increasing farming returns. The return based on the assumptions of a moderate echo effect on technology transfer shows a good return on R&D investment. Unfortunately the size of the echo effect is not known. If it is much higher than assumed in the analysis the return on the projects would be considerably higher. The other uncertainty is the value of carbon credits which only apply to new areas that will be under permanent rotation. Recent development with Japan ratifying the Kyoto Protocol bring these potential benefits closer to a reality.

5 Site and species suitability

Background

The JVAP administered through the RIRDC has invested significant amounts of money into techniques and analyses intended to aid farm forestry decision making. One aspect of the funding has been targeted at species and sites for planting that would optimise investments made by land owners who have chosen to plant trees on their farms.

The context for the research is the anticipation that farmers are looking to revegetate after years of clearing trees for agricultural purposes. In addition, the demand for agroforestry products such as sawn soft and hard woods, pulpwood and other by-products such as biomass or oils is anticipated to increase into the future (ANU, 2002). Similarly there are other economic reasons for planting farm trees such as wind protection, reduced soil degradation and improving crop and stock yields.

Total plantation growth anticipated in *Vision 2020* is 3.3 million hectares (MCFFA, 1997), a proportion of which will be in agroforestry. This growth, combined with any new farm plantings made attractive through the potential for greater benefits, makes the impact of JVAP research potentially significant. The information in the research projects being evaluated, combined with the myriad other research projects conducted through JVAP, aims to help farmers maximise environmental and other benefits from plantings and the cost effectiveness of wood production. The question is whether the JVAP research has generated social, economic and environmental benefits that outweigh the cost of the research.

Defining site suitability

Site suitability research projects have dealt with the broad question of determining the best location for growing trees. The identification of an appropriate location for tree species means that farm foresters can be more certain of a particular outcome – production or otherwise. Some of the factors that have been considered in the ‘site suitability’ research cluster include rainfall, other climate factors (temperature), soil types and the ground quality or usability (salinity and watertable for example).

There are three RIRDC projects in the site suitability project cluster. These projects are:

- CSF-41A - The effect of soils and climates on Eucalyptus Globulus plantations;
- CAL-4A - Development of an Australian 'Farm Forestry Site Selection Manual'; and
- DAV-129A - Forecasting tree growth and yield and financial returns of key agroforestry species across Southern Australia.

Each of these projects is classified as stage II research meaning that they go beyond basic research and are taking concepts into a development phase, which is prior to extension and adoption. The total research cost for these three projects is \$785 732 of which RIRDC has contributed \$328 822, industry has contributed \$232 770 and research organisations have provided \$224 140. The annual expenditure profile for these projects is displayed in table 5.1. The collective research time line for these projects started in 1990 with CSF-41A and is not completed at this stage because CAL-4A has not been finalised.

Table 5.1 Annual research costs for site suitability

FY end	CSF 41A	DAV 129A	CAL 4A	TOTAL
1991	\$179 388			\$179 388
1992	\$92 552			\$92 552
1993	\$14 500			\$14 500
1994				
1995				
1996				
1997		\$65 957		\$65 957
1998		\$127 914		\$127 914
1999		\$76 600	\$217 450	\$294 050
2000			\$2 000	\$2 000
2001			\$9 371	\$9 371
TOTAL	\$286 440	\$270 471	\$228 821	\$785 732

Source: RIRDC files

Defining species suitability

Species suitability is a broad term used to identify projects that evaluate the performance of tree species in a range of environments and sites. Poor species selection, like poor site selection, may mean that investments in agroforestry do not yield the type of outcome required. That is farm foresters can be more confident in returns from trees planted for whatever reason – whether it is shade,

wind protection or commercial returns from the sale of timber. In addition, species selection can be used to identify tree species that may be grown in areas not considered viable in the past, such as low rainfall regions or high saline soil regions.

The purpose of the research is to find the optimal type of species relevant to a particular area or site, thereby maximising the productivity of whatever agroforestry investment is made. The optimal choice should enhance or build incomes for farm foresters, whether directly through the sale of raw wood products, or indirectly through choice of species that provide superior wind protection or salt absorption. Classification by RIRDC and the CIE identified seven projects in the species suitability project cluster. These projects are:

- PIF-1A - Species selection database;
- AGT-4A - An assessment of commercial prospects for planted tree species in the low rainfall zones of Australia;
- RST-1A - Aleppo pine low rainfall farm forestry;
- CSF-57A - Conifers in the dry country;
- CSF-44A - Trees for South Eastern Australia;
- CAL-1A - REX 95-non specialist tree information database; and
- CSF-56A - Seed and information support.

Each project has been classified according to the relevant stage of research with the first four considered stage I (identification), the fifth in stage II (development) and the final two in stage III (extension or commercialisation). The total expenditure on the seven projects has been \$2 816 539, of which RIRDC has contributed \$1 623 310, industry has contributed \$1 146 907 and other research organisations account for the final \$46 322. It should be noted that a bulk of that funding was in CSF-56A that contained fourteen subprojects. Table 5.2 profiles the payments by project and year. The collective timeline for these projects begins in 1992 with both CAL-1A and CSF-44A and is not yet completed because CSF-56A is not yet finalised.

Table 5.2 Annual research cost for species suitability

FY end	PIF 1A	AGT 4A	RST 1A	CSF 57A	CSF 44A	CAL 1A	CSF 56A	TOTAL
1993					\$142 200	\$125 310		\$267 510
1994	\$25 600							\$25 600
1995								
1996								
1997			\$116 100					\$116 100
1998		\$35 000						\$35 000
1999		\$28 000		\$65 300			\$500 485	\$593 785
2000				\$40 000			\$872 804	\$912 804
2001							\$642 784	\$642 784
2002							\$222 956	\$222 956
TOTAL	\$25 600	\$63 000	116 100	\$105 300	\$142 200	\$125 310	\$2 239 029	\$2 816 539

Source: RIRDC files

Combining site and species suitability

While each project in the two research clusters has different objectives and outputs, it was difficult to consider the effects of species and site suitability separately. Without adequate site suitability and selection criteria, trees may have a high failure rate regardless of whether the species is suitable for the region. The corollary is that regardless of how adaptive or suitable a species is to a region, a further step needs to be taken to identify the appropriate range of sites to plant. So the two clusters will have marginally different outcomes but assessing the combined impact gives a more appropriate picture of the total value of the research.

Project descriptions

Each project within the species and site suitability clusters has separately identifiable objectives but all contribute to the broad objective of an appropriate tree location and growth.

Site suitability

Table 5.3 provides a summary of the objectives of each project in the site suitability cluster. What this table shows is that while each project has individual objectives, the overarching goal is the desire to optimise the productivity of tree species production through the appropriate deployment of tree types to suitable sites.

Table 5.3 Objectives of R&D by site suitability project

Stage II		
CSF-41A	CAL-4A	DAV-129A
- Adapt an existing process based model of tree growth and apply it as a tool for evaluating potential productivity of Eucalyptus Globulus plantations in south west WA; - Develop spacing and thinning strategies to alleviate constraints on the productivity of plantations on farmland.	- Produce a farm forestry site selection manual; - Evaluate current site selection practice in farm forestry; - Identify priorities for future farm forestry site selection R&D; - Increase sustainability and profitability of farm forestry.	- Improve the reliability of forecasting tree growth and yield of agroforestry species on cleared agricultural land across Southern Australia; - Investigate the relationships between tree growth rates and site factors, and construct models of tree growth that could be incorporated into financial models such as FARMTREE; - Improve landholders knowledge of the relative economic returns and benefits from adopting different agroforestry regimes.

Source: RIRDC database

Species suitability

Underlying each project in the species suitability cluster is the broad objective of selecting appropriate species for appropriate growing conditions to ensure maximum agroforestry productivity. Each project however has separate and defined objectives. These objectives have been classified by stage of research and are presented in tables 5.4.

Outputs

The output of each project is the tangible product produced as a result of the research. The output is mainly better information on better technology for use in enhancing the selection of sites and species for planting, outlined in products including reports, databases and information seminars.

Total outputs can broadly be classified as technological tools and information that will lead, with varying degrees of success, to farm foresters achieving better growth from particular sites and species. The primary market for the information is extension officers and agroforestry agents. The impact depends on their effectiveness in communication and the degree to which the information is easy to adapt to on the ground applications and hence adoption. Translation to on-farm outcomes is the key parameter influencing the impact of these projects and is discussed later in the report. The first step is to assess the outputs to identify the likely impacts if the output is adopted.

Table 5.4 Objectives of site suitability R&D projects by Stage

Stage I			
PIF-1A	AGT-4A	CSF-57A	RST-1A
▪ Compile species performance data from research trials for incorporation into a national database MPTDAT; ▪ Enable research access to this database so improved species recommendations can be made.	▪ Assess commercial opportunities for growing a range of tree species in the medium to low rainfall areas of Australia; ▪ Establish priorities by commercial product and species to assist resource allocation in R&D funding by the JVAP committee	▪ Identify conifer species which have potential to grow in low rainfall areas of Australia and outline potential uses; ▪ Provide information on wood properties and growth; ▪ Identify conifers that have commercial potential in the 400-600mm rain zones.	▪ Evaluate the potential of the Aleppo pine group for profitable low rainfall farm forestry; ▪ Evaluate the suitability of sawn and treated round Aleppo timber for structural uses; ▪ Promulgate findings to landholders and investors
Stage II			
CSF-44A			
▪ Augment the existing TREEDAT/MPTDAT data set to provide a sound basis for selection of appropriate tree species for farm planting in South Eastern Australia			
Stage III			
CAL-1A	CSF-56A		
▪ Develop, evaluate and market a tree information database for non specialist users; and ▪ Tap existing technical databases as an information source.	▪ Deliver information to farm forestry groups in a range of packages, including advisory services, field days, training workshops, a national register of trial, climatic profiles, an information directory (commercial trees), handbook of guidelines to assist species selection, enhanced TREEDAT databases and supply seed for regional demonstration plantings.		

Source: RIRDC database

Site suitability projects

CSF-41A produced an adaptation of an existing physiologically based model of tree growth (BIOMASS) to evaluate the effect of soil and climate on the productivity of *E. Globulus* in five southwest Western Australia sites. The project also developed spacing and thinning strategies for better productivity. The combination of these outputs should have a positive impact on joint venture agroforestry and farm forestry, particularly in Western Australia, and other areas with similar Mediterranean climates. The information however is highly technical and not completely new as it has adapted an existing model, so the relative impact on decision making may be high, but the duration to adoption might be a while off in farm forestry.

DAV-129A produced a report analysing six Eucalyptus species in terms of the correlation between tree growth rates, the height of remnant vegetation and the

chemical composition of soil. The output is designed to improve the reliability of tree growth forecasting, particularly through adapting the information for use in the FARMTREE productivity prediction tool. The information seems to have achieved its objective of forecasting tree growth, however the review of the project by RIRDC states that, while some of the information was new, 'there are no new techniques described in this report...' (Davis 2000a). The information is highly technical and while it may have an impact in predicting yields, the likelihood of extension and adoption is seen as low.

CAL-4A will produce a manual for on-farm use to assist in selecting appropriate sites for agroforestry plantings. When completed it will be a suite of information that pulls together available site selection data and then use it for site selection modelling. The project is part of a wider series being published separately. The report has been held off from publication because it required significant editorial work. However in draft form the research has received some media and academic coverage, which may enhance its probability of being adopted. The spread of adoption should be quite high because the information developed has focussed on many regions around Australia.

Species suitability projects

Given the large number of projects and subprojects in this research cluster each of the outputs will be summarised according to the classifications allocated in the Stage I report. These impacts have been allocated by RIRDC and the CIE as high, low or uncertain impacts on the potential for more effective farm forestry.

High impact outputs:

- AGT-4A produced an investigative report on the economic viability of a range of hard and soft wood low rainfall species. The evaluation focussed on a wide range of products and concluded that the highest commercial potential for low rainfall species was fodder, eucalyptus oil and electricity produced from residues. The poor performance of plantings for sawn wood production was confirmed by an independent review of the report (Borough 1999). This report has reduced the range of options farm foresters might consider when planting for reasons other than purely economic reasons and should reduce the potential for losses.
- CSF-44A produced a report on tree performance data to augment the existing database for the selection of tree species and was a precursor to CSF-56A, which is a very useful project. Extension officers in Queensland use the TREEDAT database already, and the new data is for sites where trials had not previously taken place. This project therefore is seen as having a high probability of adoption directly, and indirectly through its augmentation into the CSF-56A suite of information.

- The suite of projects carried out under the CSF-56A research contract created outputs including the establishment and monitoring of species trials, maintaining a register of trials, identification of species and climatic profiles, a manual on species selection, an update of the Trees for Saltland book, augmentation of the TREEDAT database, an advisory service for the term of the project and identification of a range of new products with potential for development in Australia. The information is targeted at a wide range of possibilities for agroforestry and in terms of site and species suitability has the most valuable information from all of the projects. Therefore it is considered to have a very high possibility of being extended and adapted to on farm practice, particularly where the reason for planting is commercial returns.

Low impact outputs:

- PIF-1A established a species selection database from 61 research trials at 47 sites around South Australia. The information should be highly valuable for other research projects but in terms of adoption at the on farm level the impact is likely to be relatively low. The researchers state that 'the data base is not designed to be interrogated for general species recommendation'.
- RST-1A tests the profitability of Aleppo pine dryland farm forestry in low rainfall areas using selected plant stock and optimised maintenance regimes. RIRDC concluded that the project was poorly executed and the report is less informative than others in this cluster, so is determined to have a low likelihood of achieving an impact.
- CAL-1A produced the Rex 95 (revegetation expert) software system, which was subsequently updated as the Rex 96 system. The software uses TREEDAT input to assist farmers in making decisions on types of species for particular sites. The CD is difficult to navigate without training, and 'the information is not detailed enough...to base final decisions upon and some of it needs updating' (Lloyd 2001). Thus while potentially very useful, in its current form this project is considered to have low potential for adoption.

Uncertain impact outputs:

- CSF-57A produced a report looking at trials of imported coniferous species to identify those with the ability to grow in the drier areas of Australia. The report identified five species with the best opportunities for commercial growth based on a range of internal rate of return and net present value outcomes. Returns will only be positive if wood yields are high or alternative uses are taken into account, for example windbreaks. The impact of this project is uncertain due to its speculative nature, and thus the potential for adoption is hindered by uncertain outputs.

The combined outputs of the research into species and site suitability can be summarised as:

- a higher degree of confidence in performance of site, species and climate conditions for particular rainfall and soil type zones across the whole of Australia;
- better information provided to extension officers to enhance the quality, and potentially quantity, of agroforestry plantations;
- seed stock from a variety of trials that will help with the cost effective development of agroforestry;
- extension officer, public and on farm access to highly specialised technology products focussed on agroforestry specifically; and
- identification of a range of uses for the wood produced in areas that either would have been used for agroforestry or that might not have previously been seen as areas with commercial potential because of a lack of product opportunities.

Charts 5.1 and 5.2 show how these project outputs are classified between the different projects in the site and species suitability clusters.

Chart 5.1 **Site suitability outputs**

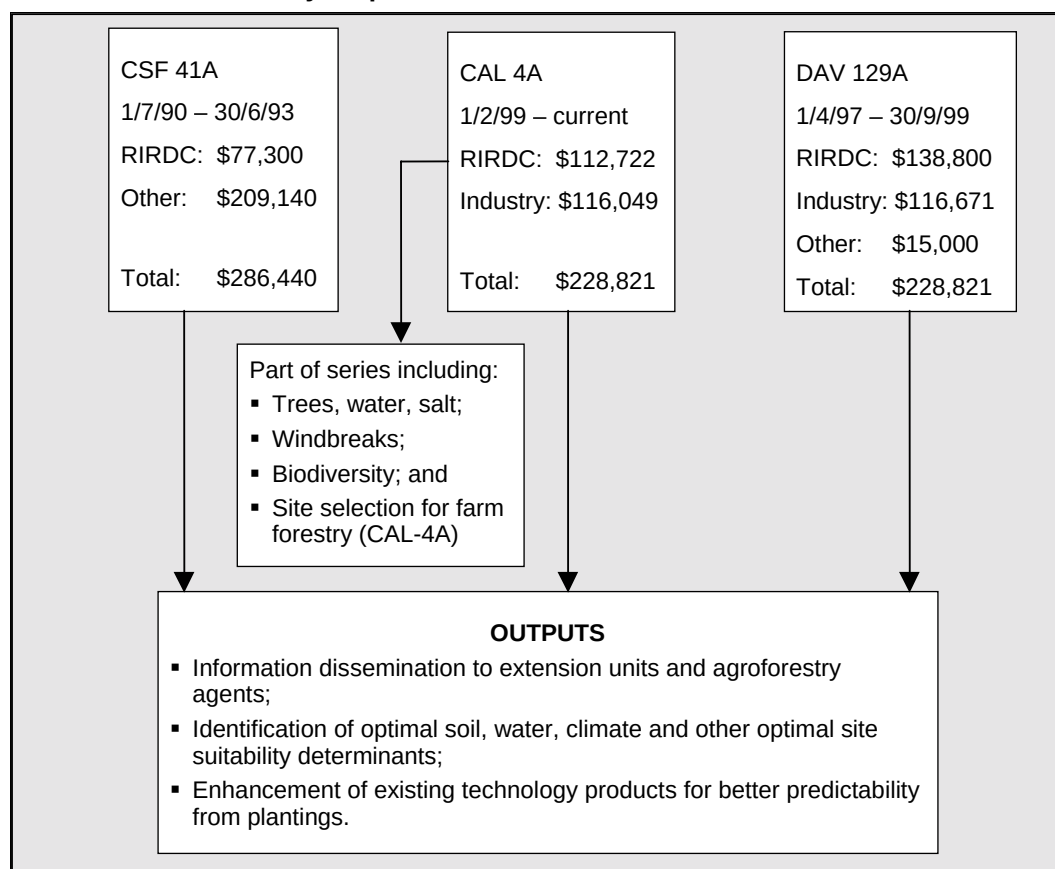
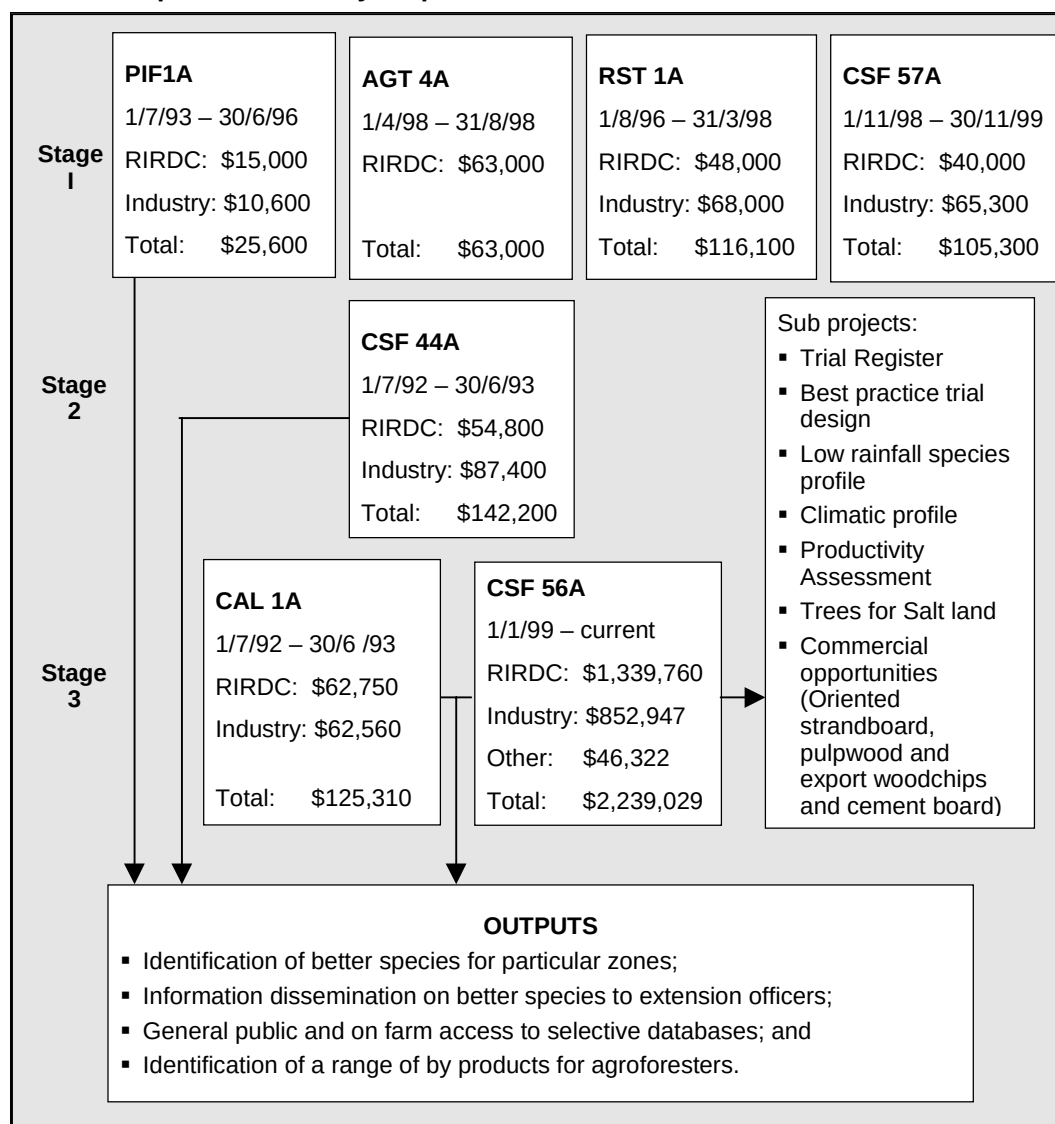


Chart 5.2 **Species suitability outputs**



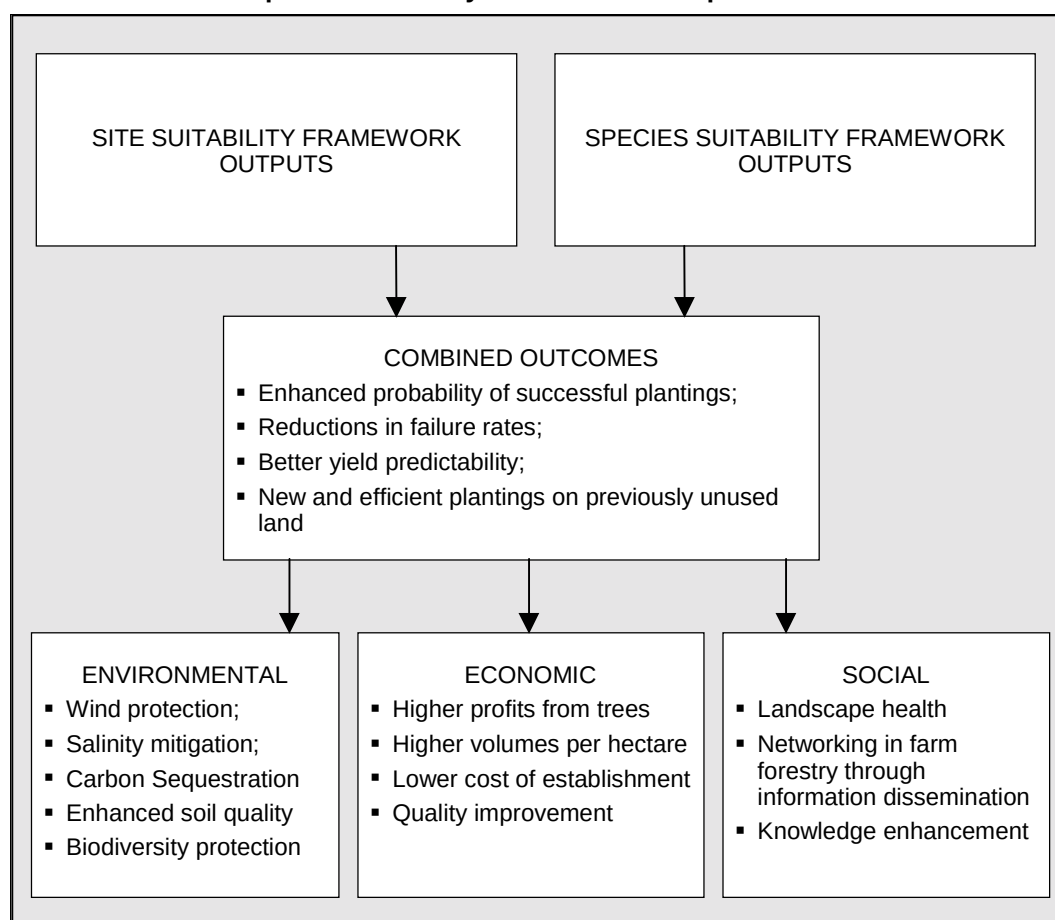
Outcomes

The important outcome from the collective outputs is 'better trees'. The outcome is achieved through appropriate site and species matching. 'Better trees' in commercial terms have a higher productivity per hectare and higher quality product than if planted without the research. 'Better trees' also means greater predictability of performance for range of commercial and non commercial reasons. Importantly, an additional outcome may be an increase in plantings above what might be anticipated from *Vision 2020*. Thus the outcomes generally are more and better trees.

The impact of additional plantings is very difficult to assess. Farm forestry projections under *Vision 2020* are mainly in the high rainfall zone relatively close to processing facilities. Much of the research, particularly on species suitability, has tried to identify opportunities for farm forestry in the lower rainfall zones and in salinity affected areas. Expansions in these areas is contingent on the economic viability of the activity. This will include value from shade and shelter benefits and carbon credits. Expansion in the area planted is tested in a ‘what if’ type scenario because little is known about future expansion beyond the *Vision 2020* projections.

Chart 5.3 summarises the anticipated outcomes from the project outputs. The outcomes are classified as economic, environmental and social. The assessment methodology focuses on assessing the impact of the first two types of outcomes. It is important to note that those outcomes identified in these charts as environmental may generate economic benefits and costs, and have been modelled in this fashion.

Chart 5.3 Site and species suitability outcomes and impacts



Quantifying the outcomes

Estimates of research induced change

The primary impacts of the combined outcomes generated by the research are:

- an increase in the growth rate of trees planted in farm forestry;
- an improved establishment success rate from plantings; and
- a reduction in the costs of planting trees on farms.

The estimates of the potential magnitude of these changes are based on discussions with researchers involved in both the site and species suitability cluster (*pers comm* Vercoe, Booth, Wong, Harper and Reid). The estimates are the average or actual response to the question ‘how will better site and species suitability information affect agroforestry plantations?’ The estimated changes are:

- an increase in the MAI (growth in wood volume) per hectare of 30 per cent over the first five years increasing to 50 per cent after the fifth year (*pers comm* Vercoe and Wong);
- an increase in the establishment success rate of 20 per cent. There was little agreement on the success rate as it varies considerably by planting types, location and so on. However, on average, the R&D is assumed to raise the establishment success rate by around 20 per cent; and
- the cost of tree establishment, excluding fencing, but particularly ground preparation, fertilisers and watering, will fall by an average 30 per cent from a range of 20 to 40 per cent.

The potential for improvement depends on current farm forestry practices – these estimates are the potential improvements by changing from ‘average’ practice to ‘best’ practice.

Adoption rates

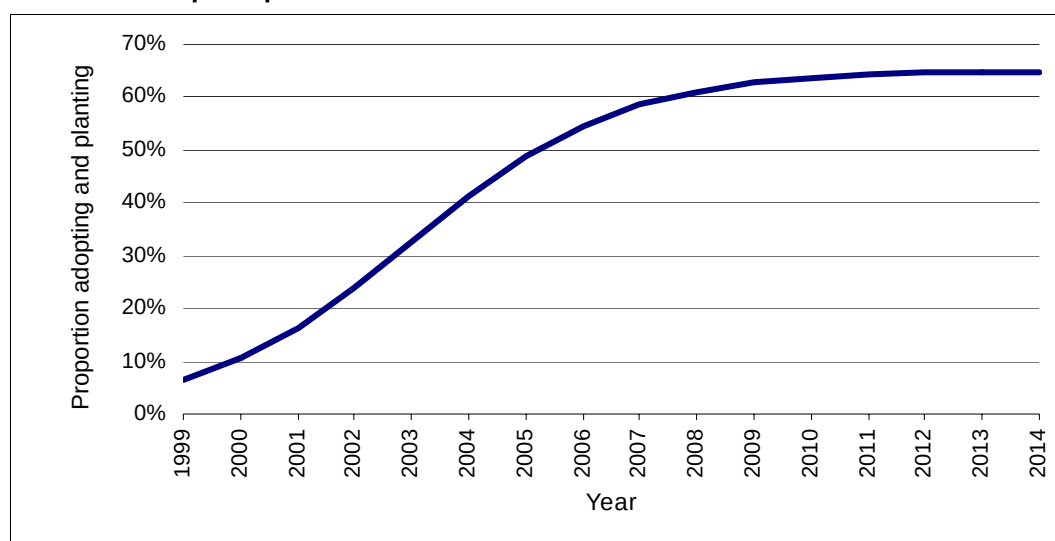
Research in itself does not create value without adoption of the information discovered. For example knowing the best site in Australia to grow a particular species of Eucalyptus is useful knowledge in a general sense, however if agroforesters know nothing of the research then the expected return from the research is zero.

A critical parameter is the expected proportion of agroforesters who have or will adopt the information on the farm. Unfortunately adoption rates have not been measured and given the fragmented nature of the industry, are very hard to measure. In order to make an assessment of the adoption rate researchers were

asked — if a room of 100 farmers was assembled for extension officers to present the information, all of whom were interested in farm forestry already, what proportion would use the research when deciding on making an agroforestry investment? Response estimates ranged from 50 to 100 per cent, with 65 per cent being the average response and hence the chosen maximum adoption rate (*pers comm* Varcoe, Wong, Harper and Booth). This response has been employed as a proxy for the area of agroforestry plantations that are affected by the research impacts. The sensitivity of the results to this parameter is tested in the sensitivity analysis.

The timing of the adoption determines when the benefits start accruing from the research. Adoption is assumed to have commenced in 1999, which is when a large amount of the information would have become available to extension officers. The adoption rate is assumed to start at around 6.5 per cent in 1999, increasing to the full 65 per cent rate by 2007. Chart 5.4 displays the adoption profile used in the model.

Chart 5.4 **Adoption profile**



Data source: Discussions with researchers and CIE calculations.

Identification of outcomes

Despite the differences across locations and plantings in the high rainfall zones the percentage potential improvement in productivity and in adoption are assumed the same. The baseline growth rates (MAI), rotations and stumpage prices are different for each type of planting and broad species level.

Identifying the types of benefit and costs of the site and species suitability project outcomes once adopted has been difficult. The key difficulty is that there is limited information on how the research will impact on farmers' decision making

and how the information might be used in a practical sense. A survey of farmers expectations of the likely outcomes and hence their willingness to invest in agroforestry would have made identification more robust. The difficulties mean the quantum of costs and benefits derived and the results of the analysis should be treated as indicative rather than absolute.

A general model of how the research impacts on agroforestry was developed with the primary assumption being that farmers are going to plant the same number of trees with or without the research. With this in mind, the benefits of the research estimated will be the productivity changes due to higher growth rates, higher establishment success rates and reduced costs. These changes may induce additional plantings by farmers who perceive benefits from tree planting, but in this analysis additional plantings are treated as a ‘what if’ type scenario, rather than taken as a certainty. The effects of the research will be a function of the probability of adoption of the information produced.

Evaluation methodology

The approach adopted is to compare two scenarios— the ‘baseline’ in terms of the volume and value of agroforestry without research and a ‘with research’ scenario. The ‘with research’ scenario differs from the baseline only in terms of economic outcomes because for a change in environmental outcomes an increase in the area planted is required. A number of scenarios are considered for an increase in area planted in high rainfall, low rainfall or highly saline areas. These area expansion ‘what ifs’ will lead to both economic and environmental outcomes.

A similar process based on hectares planted, rather than volume per hectare, is used to determine the environmental outcomes. All indirect economic, environmental and social benefits that can be reasonably and reliably estimated using this approach are added to the economic returns to establish the total measured net benefit of the research. The limitation with social and environmental costs and benefits is the degree to which a reliable value can be determined, and how that value is applied in practice. These benefits and costs are discussed further in appendix A.

The model is summarised in general form in chart 5.5, where the ‘with research’ effect is initially the increased growth rate combined with a higher establishment success rate and a reduction in plantation costs.

[illegible]

Developing a baseline value of agroforestry

In order to assess the impact of the research we need to establish a baseline – the area of trees planted, the purpose for their planting and the expected returns from the plantings. Given the infancy of the farm forestry industry and lack of comparative analysis in the research reports we must base our estimates on a range of projections and assumptions. The primary source for the assumptions has been discussion with researchers involved in the projects and the source material generated by the different projects (see tables for specific references).

Hectares planted and distributions

Gross volumes for harvest are a function of the number of hectares planted. *Vision 2020* anticipates a total of 3.3 million hectares of plantation forestry in Australia by the year 2020. To reach this target from the 1.5 million hectares planted at 2000 will require almost 91 000 hectares to be planted per annum until 2020. Agroforestry plantations will be a part of this total plantation area. Plantations of Australia (Wood *et al* 2001) suggests that at the regional level farm forestry represents between one and 13 per cent of total forestry and on average makes up around six per cent of the area. We assume that the future proportion of farm forestry will remain roughly the same at six per cent of total plantations. This implies an expansion of around 5 500 hectares per annum.

There is little information about the likely planting locations of agroforestry trees, or the type of trees that will be planted throughout Australia, except that most plantings are anticipated to be in the high rainfall zone. In order to assess the baseline we make several assumptions about the planting distribution and type of trees that will be planted, based on averages between species types and location types from existing information on tree (based on Wood *et al* 2001 and ABARE 1999). These assumptions are presented in table 5.5.

Trees are categorised as either hard or softwood and the plantings are distributed three ways:

- block plantings — planted for commercial reasons;
- alley plantings — planted for income diversification; and
- shade and shelterbelt plantings — windbreaks, conservation, revegetation or generally non-commercial plantings.

Table 5.5 Hectare distribution assumptions

Distribution (wood type)	Area of FF	Source ^a
	%	
Hardwood	54.5	Discussions with researchers
Softwood	45.5	Discussions with researchers
Distribution (plantation type)	FF plantings	Source
Block planting	50	<i>pers comms</i> Vercoe
Alley Plantings	20	<i>pers comms</i> Vercoe
Shade and Shelter Belt / Conservation	30	<i>pers comms</i> Vercoe

^a Where 'discussions with researchers' is the listed source, this means it is the average rate given by discussions with researchers who have led particular projects in either of the site or species suitability clusters.

Growth and success rates

The baseline MAI and establishment success rate parameters are listed in table 5.6. The average growth rate has been split between hard and softwood and is based on a range of mean annual increments achieved in low to medium growth locations in existing plantations. These values are used to estimate a proxy for the growth rates achievable prior to knowledge of the site and species selection research. The rate of success in the baseline is estimated to be 73 per cent being the average establishment success rate achieved between land care officers, other extension officers and farmers in existing plantings. These data are used to estimate the potential harvestable volume of wood without the research.

Table 5.6 Distribution and growth assumptions - baseline

Growth Rates	Unit	Value	Source
Soft wood Mean Annual Increment	m ³ / ha / yr	16	Average Low – Med MAI (Ryan 2001b)
Hard wood Mean Annual Increment	m ³ / ha / yr	19.64	Average Low-Med MAI (Ryan 2001b)
Success Rate	%	73	Average rate (CIE 1995)

Estimating the volume and value of wood production

The volume of harvestable wood is a function of establishment success rates, the MAI, the length of rotation and the intended product use of the wood, which determines the wood recovery rate. The baseline assumptions used to calculate the returns are summarised in table 5.7.

Each planting type — block, alley or shade/shelter — is assumed to have different intended markets. It is assumed that shade and shelter plantings are not to be harvested so the direct commercial return —return on wood harvest —will

be zero for these plantings. Block plantings are assumed to be harvested and sold as sawlogs, pulpwood and peeler or ply veneer logs. ABARE data is used to assess the average usage distribution of hard and soft wood harvests for these products. Similarly, all alley plantings are harvested with a significant proportion sold for pulp wood.

Residues from using logs for sawnwood are between 35 and 50 per cent (*pers comms* Vercoe). The proportion of any commercial log lost to residues is assumed to be sold as pulp wood. This assumption explains why a large proportion of commercial plantings is sold for pulpwood.

Table 5.7 Use of wood and value assumptions

	Value	Source
	%	
Use of wood (soft and hard wood)		
<i>Block plantings</i>		
Sawlog	49	ABARE 1999
Pulp	50	ABARE 1999
Peelers/ply/veneer	1	ABARE 1999
<i>Alley Planting</i>		
Sawlog	20	CIE assumption ^a
Pulp	80	CIE assumption
Shelter belt / Conservation	0	Non commercial plantings
Prices – Hard Wood		
	\$/m ³	
Sawlog	50	ANU market reports
Pulp	20	ANU market reports
Peeler / ply / veneer	100	ANU market reports
Prices – Softwood		
	\$/m ³	
Sawlog	50	ANU market reports
Pulp	20	ANU market reports
Peeler / ply / veneer	100	ANU market reports

^a The assumptions are based on average usage reported in ABARE 1999.

Table 5.7 also provides average prices by wood product type. The prices are the estimated stumpage prices based on the average price by use and selling location (Sydney, Melbourne, Hobart, Tasmania and Adelaide) in 1999. Evidence in the ANU market reports suggests that between 1997 and 2000 prices grew for all

forestry products by 1.5 per cent per annum (ANU 1998, 199a and 1999b). Discussions in the market reports suggest that future price rises might be achieved in the order of 0.4 per cent per annum. These price growth expectations have been built in to the estimates of the base case.

The model used to estimate the base case does not take into account flow on effects such as transport or downstream processing. The reason they have been excluded is that the increase in volumes as a result of the research are relatively small and it is not clear whether additional farm forestry expansion will simply crowd out plantations. In addition, the resources devoted to the transport and processing activities add value only to the extent that they were previously unemployed or engaged in lower value adding activities.

Rotations are expected to differ between species, wood type and location. The average values assumed for harvest are:

- the proportion of harvestable volumes destined for higher quality products are thinned to 60 per cent of the standing volume nine years from planting;
- pulp logs are all harvested 12 years after planting; and
- commercial volumes remaining after thinning are clear felled in the twenty fourth year after planting.

These assumptions are summarised in table 5.8. The timeframes are weighted average estimated timeframes from a range of high rainfall regions in Australia, and for a range of different species types.

Table 5.8 **Harvest and thinning time line**

	Year	Percent	Source
Thinning			
Soft wood – block	9	40	Average ABARE 1999
Hardwood – block	9	40	Average ABARE 1999
Clearfell			
Sawlogs	24	remaining 60	Average ABARE 1999
Peelers	24	remaining 60	Average ABARE 1999
Pulp logs	12	100	Average ABARE 1999

Costs of production

Table 5.9 presents the costs of tree establishment, fencing, annual maintenance costs and the opportunity cost of the land. Tree establishment costs have been derived from the Farmer's Log (Reid and Stephen 1999), a publication associated

with the Master Tree Growers Program. The cost per hectare established was estimated at \$640 per hectare based on 800 stems per hectare. In this analysis the assumption is 1 000 stems per hectare on average, so the grossed up cost of tree establishment is assumed at \$800 per hectare. Similarly, the cost of establishing fences to protect the trees from livestock has been estimated at \$1 000 per hectare, which we have assumed is only relevant for the first rotation. Tree maintenance is assumed to cost on average \$20 per hectare per year (Reid and Stephen 1999). This reflects the share of sawlogs, which require much higher maintenance. Finally, the opportunity cost of land is a measure of what might have been generated if trees were not planted, and is estimated at \$65 per hectare per year for the cumulative number of hectares planted.

Table 5.9 **Assumed costs planting and associated costs**

Cost	Cost per unit	Total units	When cost is incurred	Source
Tree establishment	\$800 /ha	Hectares of trees established	Year of planting	The Farmer's Log
Fencing Costs	\$1,000 /ha	Hectare of first rotation planting	Year of first rotation only	The Farmer's Log
Tree maintenance	\$20 /ha	Cumulative hectares of trees	Annually from planting to harvest	The Farmer's Log
Opportunity cost of agroforestry	\$65 /ha	Cumulative hectares planted on arable land	Annually	Rowan Reid

Estimates of non wood benefits

Table 5.10 presents the anticipated non wood benefits from agroforestry. These benefits are generated in addition to the direct commercial return from wood sales. In the 'with research' scenario these benefits will not change from the baseline because there are no new hectares. In the case of additional hectares being planted in low rain or highly saline plantings the benefits have environmental origins in terms of a lower watertable or carbon sequestration however they generate economic benefits. Accordingly, they have been classified as indirect economic benefits. There may be environmental costs in high rainfall areas caused by trees changing stream water salinity, however these affects are uncertain have not been modelled A discussion of how these benefits have been calculated is given in appendix A.

Table 5.10 **Quantifiable benefits from plantations**

Benefit	Value	Attributable to	Period in which benefit accrues	Source
Amenity	\$8	Cumulative standing hectares (CSH)	Per annum	see appendix A
Shade / Shelter	\$17	CSH	Per annum	
Carbon Credits	\$300	Additional hectares	From 2008	
Fodder	\$3	CSH	Per annum	
Watertable	\$9	CSH	Per annum	
Soil erosion	\$8.3	CSH	Per annum	

It is worth emphasising that these benefits only arise with an expansion of the areas of farm forestry. The first ‘with research’ scenario only considers productivity shocks.

Estimating the impact of the research

Parameter changes with the research

The ‘with research’ scenario is simply the baseline scenario with the higher growth rates, higher establishment success rate and the lower costs of establishing trees where these R&D outputs have been adopted. Specifically:

- the first productivity shock of 30 per cent will increase MAI per hectare planted to 20.8 m³ for soft wood and 25.5 m³ for hard wood from 16 m³ pa and 19.6 m³ pa respectively;
- the second productivity shock will increase the MAI per hectare to 24 m³ for soft wood and 25.1 m³ for hard woods;
- non fencing establishment costs will fall from \$800 to \$560 per hectare due to reduced growth preparation, fertiliser application and watering;
- the volume of wood recoverable from a higher establishment success rate will increase to 90 per cent from 73 per cent; and
- the adoption rate for these parameter changes rises from 6.5 per cent in 1999 to 65 per cent by 2007.

Scenarios for expansion in area planted

The ‘with research’ scenario does not change the number of hectares planted, which means that the incremental returns generated from the research are all attributable to the sale of wood. The research might however provide some additional incentive for people in low rainfall or highly saline areas to consider

agroforestry as a reasonable option. Similarly there may be additional interest generated in agroforestry that means people in the higher rainfall zone consider planting more hectares. To achieve these additional plantings farmers would need to be convinced that an economic incentive exists to undertake the plantings.

A small ‘agroforestry investment’ model was developed to ask the question of whether farmers might consider planting in low rainfall or highly saline areas given that species have been identified for planting in these areas. The two questions underlying the model are — would a farmer have an economic incentive to plant 100 hectares on highly saline land or 100 hectares in a low rainfall zone? The costs of planting are assumed at the post R&D level, and the benefits calculated include all the indirect benefits described in the baseline on the main assumption that the use would be in shelterbelts — for reasons that are not necessarily commercial. The decision rule for an incentive existing was that the present value of costs in planting the 100 hectares are less than the potential benefits available from those 100 hectares of farm trees.

The result of this exercise was that an incentive exists to plant only when:

- carbon credits are present; or
- if the wood was sold at the average pulpwood price.

Importantly the indirect benefits such as shade and shelter, lower watertable and fodder values alone do not make these potential plantings economically viable.

Given that an incentive may exist for these plantings, particularly with carbon credits and potential wood sales, we have evaluated some scenarios to assess the value of the R&D if it generates an expansion in the area planted. These scenarios estimate the range of benefits from the site and species research, which gives some indication of the potential non-commercial benefits possible from the research projects that focussed on lower rainfall and saline plantings.

Price shocks

We have also modelled a price shock. The price shock will give an indication of what would happen to the net benefits of the research if the wood sold was of a higher quality in the ‘with research’ scenario. This is important to test because better trees should lead to higher quality output, which in turn should deliver marginally better returns.

Shock to high rainfall plantings

An additional scenario has been run to test what would happen if there were an additional one per cent increase in plantings in high rainfall zones due to the potential for high returns. The addition of these hectares will generate some indirect economic, environmental and social benefits above the baseline.

Quantifying the scenario shocks

The additional hectare assumptions for the low rainfall and high saline areas have been developed from existing knowledge of available land in these two areas. The *Trees Water and Salt* publication (Stirzaker et al, 2001) suggests there are 30 million hectares in low rainfall zone and if nothing is done to mitigate salinity by 2051 there will also be 15.7 million hectares in highly saline regions.

The scenarios for additional hectares are based on:

- an additional one per cent of total forestry planted in the higher rainfall zone, equivalent to an annual planting of 908 hectares;
- one per cent of the low rainfall area planted to trees, equivalent to an annual planting of 6 000 hectares until 2051; and
- one per cent of the potentially saline area by 2051 being planted to trees, equivalent to an annual planting of 3 269 hectares.

These assumptions are summarised in table 5.11

Table 5.11 Scenarios tested

Scenario	Additional hectares pa	Price shock
Scenario 1 – additional high rain	908	
Scenario 2 – low rain	6 000	0
Scenario 3 – saline	3 269	0
Scenario 4 – price shock	0	+ 10%

Results

The net present value of the research, given adoption rises to 65 per cent and the productivity gains, establishment success rate and reduced costs are achievable causes an increase in net benefits of \$106.4 million at a five per cent discount rate. The NBIR suggests that the project generates benefits 39 times greater than the research costs, and have generated an IRR of 26 per cent. The range of results at the zero, five and 10 per cent discount rates is presented in table 5.12.

Table 5.12 Incremental returns from research

Discount rates	PV R&D costs	With research additional NPV benefit	NBIR
	\$m	\$m	
0 %	0.4	737.2	184.2
5 %	2.7	106.4	39.4
10 %	1.9	19.8	10.4
IRR %	25.7		

Source: CIE calculations.

All of the benefits in this model have been generated from additional harvestable volumes caused by the productivity shocks. There are no additional indirect benefits as the area planted has not expanded. These results suggest that the research is an unqualified success, however caution is advised because the results rely on assumptions about the size of the productivity shocks and the adoption rate that may be best case outcomes. These parameters are varied in the sensitivity analysis to produce a ‘most likely’ estimate.

Sensitivity analysis

In the analysis four key parameters significantly affect the estimated results. The computer program @RISK was used to test the sensitivity of the results to changes in:

- the adoption rate;
- the growth rate (MAI) shocks;
- the potential establishment cost reductions; and
- the establishment success rate.

It should be noted that the results are not very sensitive to the baseline assumptions of MAI and establishment success rates , however they are highly sensitive to changes in these rates.

The range of values used to test the sensitivity of the results to these parameters is given in 5.13.

Table 5.13 Values used to test the sensitivity of the model

Parameter Changes	Minimum	Maximum	Mean
	%	%	%
Success Rate	80	90	85
Productivity Shock – 1	10	30	20
Productivity Shock – 2	10	50	30
Cost Reduction	10	30	20
Adoption rate	30	65	50

The result presented in 5.14 show the ‘most likely’ result and the 95 per cent upper and lower confidence intervals from the simulation. Specifically we are 95 per cent confident that:

- the NPV of the research will be between \$47 million and \$106 million, but most likely around \$70 million;
- the NBIR will lie between 17 and 37 times the research cost, but will most likely be 26; and
- the IRR will lie between 20 and 27 per cent, but will most likely be around 23 per cent.

These results suggest that, based on the model developed, there will be a high payoff to RIRDC’s research costs from the site and species suitability research clusters.

Table 5.14 Sensitivity analysis results confidence interval results

Results	Units	Lower	Upper	Most likely
NPV	\$m	46.8	106.4	70.7
NBIR		17.3	39.4	26.2
IRR	%	20.2	25.7	23.6

Benefit estimates with an expansion in area

The additional net benefit from the increased area scenarios required changing the baseline because in low rainfall and saline soil areas growth rates and benefit distributions change dramatically. The same model structure was employed to estimate the returns possible from the various scenarios specified with adjustments to consider the lower baseline. The 5 per cent discount rate has been assumed for comparative purposes and the results, relative to the baseline scenario, are presented in table 5.15. As each case specifies either an increase in hectares or prices, the values all exceed those of the research ‘with’ scenario. In other words, if the R&D results in an expansion of farm forestry in either high

rainfall, low rainfall or highly saline zones it will raise the returns to the R&D. Note that the criterion for the investment was only that the NPV of the investment was positive. This is not sufficient to guarantee the investment will arise.

In summary, comparing these results to the maximum NPV of \$106 million, the:

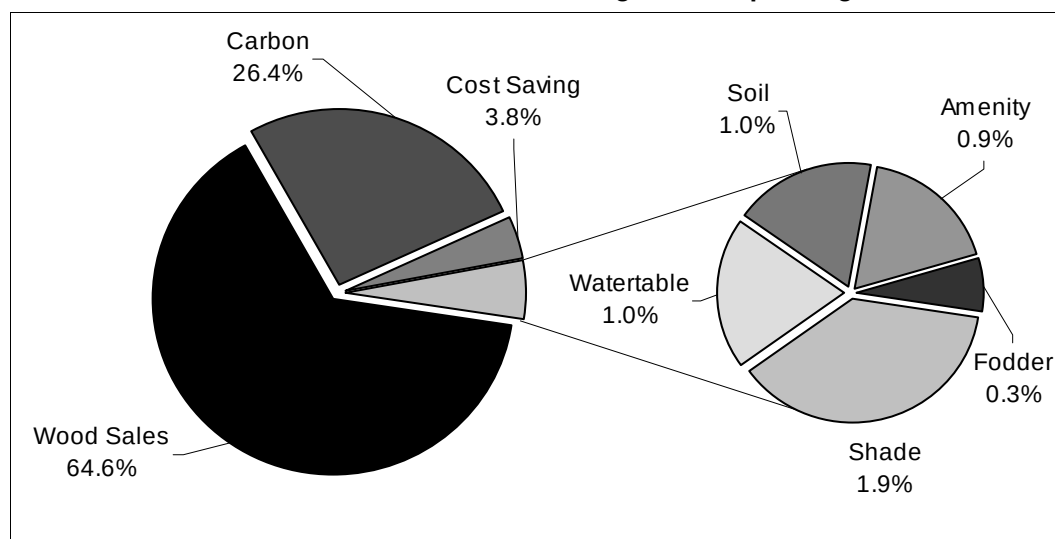
- additional high rainfall area increases the NPV by \$29 million for an additional implementation cost of \$21 million. The distribution of benefits is shown in chart 5.6. What the chart shows is that the additional hectares caused the share of the benefits to change from being 100 per cent in wood sales to 65 per cent in wood sales and 35 per cent spread across a range of other economic and environmental benefits;
- addition of hectares in low rain fall areas added \$131 million in NPV at a cost of \$40 million and has a higher NBIR, because the benefits derived from the new area exceed the additional implementation costs. The lower return per hectare from no additional wood sales brings the IRR down;
- addition saline area increases the NPV by \$55 million at a cost of \$29 million and increases the NBIR result, while the IRR is less than the ‘with research’ scenario because of the assumption this wood will not be harvested; and
- price shock that might be the result of increased quality in wood sold would add \$15 million to the NPV at no additional cost and significantly increases the NBIR but only slightly raise the IRR.

Table 5.15 Scenario results (5 per cent discount)

Scenario	PV additional implementation costs	Increase in NPV on base scenarios	BCR	Total NPV benefits	NBIR	IRR
	\$m	\$m		\$m		%
Scenario 1 –high rainfall	21	29	1.4	135	50	46
Scenario 2 – low rainfall	40	131	3.3	237	88	21
Scenario 3 – saline	29	55	1.9	161	60	20
Scenario 4 – price	0	15	na	121	45	26

n/a - not applicable

Chart 5.6 **Benefit distribution from additional high rainfall plantings**



Data source: CIE Calculations

The research and development into site and species suitability is expected to generate significant benefits for farmers involved in agroforestry based on the assumptions provided by researchers. The estimate of an NPV of \$106 million and NBIR of 39 is considered the best case. The results are highly sensitive to the adoption rate, and estimation that is more cautious puts the NPV at \$70 million giving a NBIR of 26 and IRR of 24 per cent. Based on these results the research has been worthwhile.

These estimates assume that the area of agroforestry does not expand as a result of the research, and that average wood quality is unchanged. If the research does increase the quality of wood then a price shock would augment the commercial returns and boost the NBIR to 49. An expansion in plantings in high rainfall and other zones will raise NBIR of the R&D investment, due to additional indirect economic and environmental benefits however, the returns on the additional implementation investment, while positive, may not be enough to encourage farmers to invest more in farm forestry. This is less the case in the low rainfall zone, but it should be noted that the estimated benefits rely heavily on carbon credits of \$300 a hectare a year for the sequestration period. Thus the future of farm forestry in this zone depends on developing wood markets, or the implementation of a carbon credit scheme. In all of the scenarios explored, the research has a high payoff relative to the R&D money invested.

A Estimation of indirect benefits

The project evaluated in this report will generate benefits and costs that extend beyond the bounds of direct economic impacts. This appendix outlines the framework that was used to classify and evaluate the wide range of benefits and costs associated with JVAP projects, some of which are difficult to value. Because the term ‘value’ means different things to different people, it is important to work from a common base when evaluating the returns from R&D that involves social and environmental outcomes and impacts.

In addition to setting out our approach to evaluating ‘triple bottom line’ impacts, we define key terms that may be unfamiliar to non-economists and provide background information about the non-market values used in the BCAs and the method used to derive them.

Triple bottom line framework

The triple bottom line — economic, social and environmental impacts — is not a new concept. But it has become more important as stakeholders increasingly demand an account of social and environmental impacts as well as of economic impacts. In some respects, benefit cost analysis (or economic reporting) is a form of triple bottom line reporting because it aims to measure economic, social and environmental impacts in monetary terms, thereby reducing many varied impacts to a common metric that can facilitate a comparison of benefits and costs.

Thus, economic reporting goes well beyond financial accounting because it reports not only returns to capital and labour but also the impact of R&D on consumers. And it has developed tools to report on environmental and social benefits wherever individual preferences can be considered representative of society’s preferences. Good benefit-cost analysis has been including estimates of these types of benefits for some time.

True triple bottom line accounting, however, challenges the standard economic paradigm that society’s value reflects the sum of the values of the individuals in that society. There may be consequences of R&D or a public investment that transcend individual preferences — impacting on ethics, intergenerational equity, moral duties, individual self esteem and empowerment — about which

‘economics’ can say little. It is clear that these factors do matter to people, as reflected by the development of safe minimum standards, which are often built on moral imperatives and respect for basic rights and intrinsic values.

Triple bottom line reporting aims to provide information on these impacts as well those more familiar to the economist. The problem is that there is no accepted philosophical underpinning to place values on these impacts. The framework used in this report deals with the problem by including impact indicators, but does not give them ‘values’ or add them up. Rather, the indicators are presented as a means of communicating to stakeholders the extent to which minimum standards have been met or ethical concerns addressed.

Application of the framework to JVAP

The process of compiling a triple bottom line report starts with identifying the planned outputs of the R&D program. Outputs are tangible products such as new gadgets, demonstration sites, technical reports and manuals. These outputs may lead to changes in the way things are done but in themselves they have no value. Outputs only generate benefits when they produce an identifiable outcome. The values of this outcome — or the impacts — are the benefits this approach aims to measure. The role of BCA is to:

- map the links between outputs and outcomes;
- quantify the magnitude of the outcomes (shocks) in physical terms;
- map the measured outcomes to their, often multiple, impacts; and
- estimate a monetary value for the impacts.

Adhering to this procedure minimises the possibility of double counting, which is a common problem when R&D outcomes are not mapped to measurable impacts. The division of impacts into the categories — economic, environmental and social — is not a straightforward task because many of the environmental and social outcomes produce economic effects. Thus there are some grey areas where the demarcation between the three types of impacts is not clear. The important point is not to double count the costs or benefits.

Chart A.1 sets out our interpretation of a triple bottom line reporting framework and provides examples of how different impacts from JVAP projects can be classified. Our approach is to identify all the impacts that can be assigned a monetary value and include them in the BCA. These impacts include:

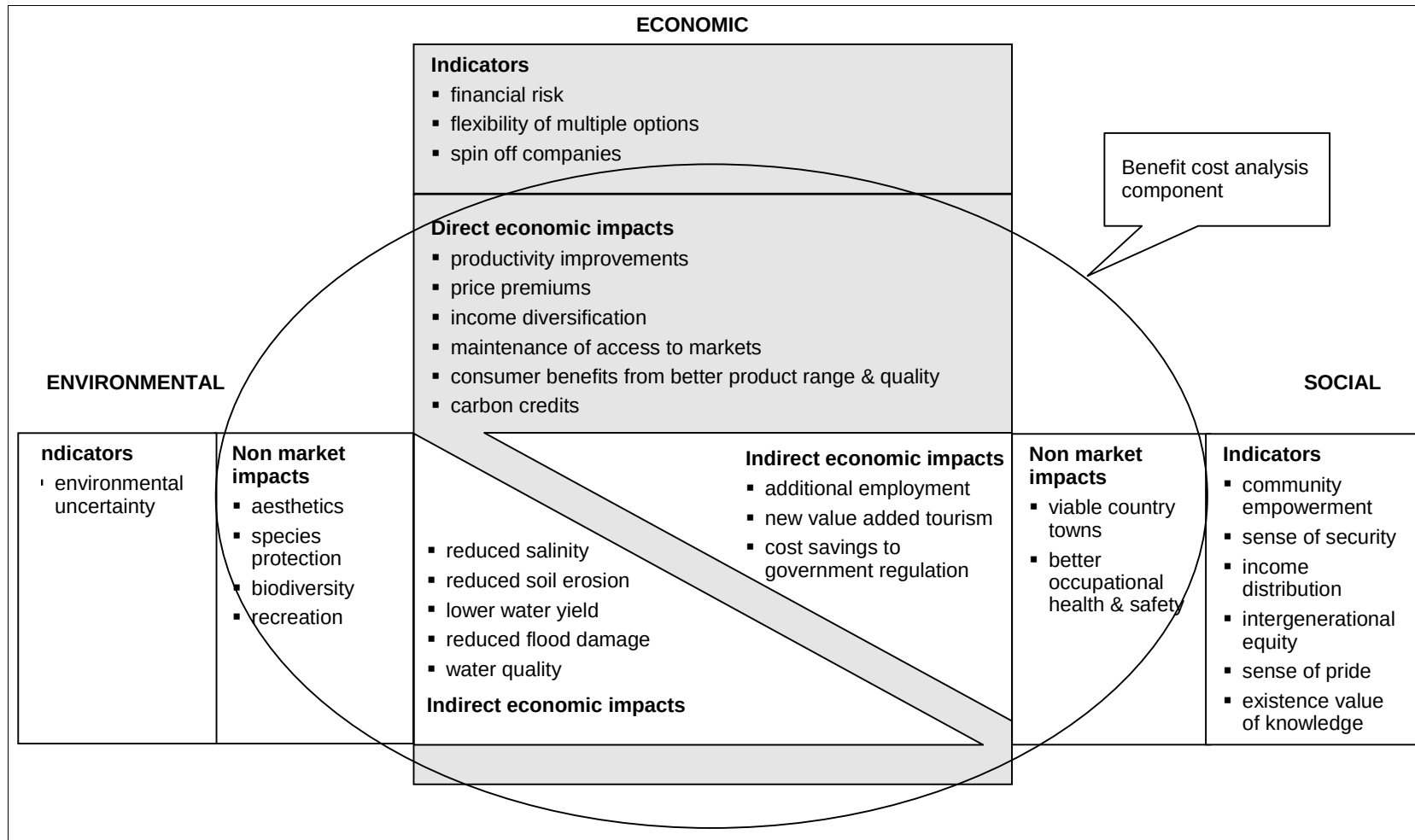
- direct market impacts (for example, increased timber yields);

- indirect market impacts (for example, reduced salinity damage to agricultural yields and infrastructure); and
- non-market impacts (for example, improved aesthetics, biodiversity and recreation).

Some of the indirect social and environmental impacts will influence economic outcomes and are therefore shown in chart A.1 to crossover into the economics box. Other types of social and environmental changes will have non-market impacts. The value of these impacts must be estimated using specialised survey techniques, so they are grouped in a separate category.

Factors such as intergenerational equity, ethics, individual's feelings, and protection of basic human rights belong to a group of impacts that are beyond the scope of economic theory to value. Consequently these factors sit outside the BCA and instead are assigned non-monetary quantitative or qualitative indicators.

Chart A.1 Economic, social and environmental outcomes: a guide for measuring benefits



Direct economic benefits

The commercial value of farm forestry differs from project to project depending on things such as the region in question and type of tree species. The JVAP R&D program enhances the commercial profitability of farm forestry by increasing wood yield (a function of tree growth rates and survival rates), lowering costs per unit of production and/or increasing the quality of wood products, which could lead to higher product prices.

Assumptions about these impacts, together with estimates of tree establishment costs and opportunity costs, are provided in the body of the report under each BCA.

Carbon sequestration

Carbon credits could provide an additional source of future income for farm foresters. The Kyoto Protocol on climate change makes provision for carbon sequestration activities to offset greenhouse gas emissions and to assist member countries to meet their emission reduction targets. Under the terms of the protocol, sequestration must be from trees established since 1990 on previously unforested land (afforestation) or on land that has not been forested from a period of years (reforestation).

Policy developments

While Australia has not ratified the protocol, there is a good chance that it will enter into force by 2003. The European Union is working towards ratification by June 2002 and Japan has confirmed its intentions to ratify. The conditions for entry into force mean that the protocol can enter into force without the United States participating, although ratification by some combination of key parties such as the European Union, Russian Federation, Japan and Canada would be required.

There is strong international pressure for Australia to ratify the Protocol. Even if ratification does not proceed, Australia will almost certainly introduce some form of policy measure to enforce emission reductions — and vegetation sinks are likely to be recognised as a valid means of offsetting emissions. Thus the uncertainty at present revolves around the extent of emissions abatement that will be required at a national level, the timing of these reductions and the type of policy mechanism(s) that will be introduced to achieve the reductions.

In a recent development, the New South Wales State Government is proposing an emissions trading scheme to cover emissions from the State's electricity sector — the first of its kind in Australia (AETF, 2002). The scheme is to be introduced on 1 January 2003. It will require electricity retailers to reduce per capita CO₂ emissions to a level 5 per cent below 1990 levels (or 7.27 tonnes per capita) by 2006-07. Firms will be able to meet their emissions target by purchasing carbon sequestration credits from anywhere in Australia.

Carbon credit price

Working on the assumption that the Kyoto Protocol comes into force and an international trading program is introduced, the ABARE (2002) projects that the global price for permits and credits – in present value terms - will be US\$102 per tonne of carbon by 2010. Assuming an exchange rate of US\$0.55 to the Australian dollar, this equates to A\$185 per tonne. Other estimates presented in by the Australian Greenhouse Office estimate carbon dioxide prices of A\$10 to A\$50. This translates to a price of carbon of A\$36 to A\$183 per tonne. Prices are forecast by ABARE to increase in real terms to US\$142 per tonne by 2015, at the top end of the range of estimates. Rising prices reflect a tightening of abatement targets.

These estimates are still subject to uncertainty and the price received by tree growers is likely to be less than the forecast ABARE figures because transaction costs (for example verification) must be subtracted off the credit price. Thus we have assumed an on-farm price ranging between A\$35 and A\$150 per tonne of carbon permanently sequestered.

Accounting rules

Under the protocol, sequestration that occurs during the commitment period (2008-12) is eligible for carbon credits. Sequestration before this date is not eligible for counting towards a country's emission reductions. However, tree growers may be able to forward sell carbon rights to the trees and therefore benefit from an income source prior to 2008.

The issue of sequestration permanency and how to account for carbon temporarily stored in harvested wood products is yet to be finalised. In this report we take the basic approach of assuming that emissions from wood products occur at the time a tree is harvested. In other words, carbon credits are only allocated to first rotation or new tree plantings. Once a tree is harvested, the emissions are offset by second rotation plantings — resulting in a stable pool of carbon and no new carbon credits. Trees planted for conservation purposes

(never harvested) are assumed to continue to accumulate carbon credits indefinitely.

Carbon sequestration rates

The rate of carbon storage by agroforestry activities will depend on tree growth rates which, in turn, is a function of species, site conditions, climate, silvicultural practices and the number of trees planted per unit area. Table A.1 contains indicative figures on the approximate amount of carbon that is able to be sequestered by various tree species and planting designs. The estimates put the annual carbon sequestration value mostly in the range of \$100 to \$500 per hectare of new trees planted in a block plantation.

Table A.1 Estimated carbon sequestration value of farm trees

	Rainfall zone	Average carbon sequestration rate	Annual credit value ^a
	mm per year	tonnes C/ha/yr.	\$ per hectare
Maritime pine block planting	400-600	3.4	119-510
Tasmanian bluegum block planting	>600	2.5	87.5-375
Oil mallee in alleys	250-400	3	105-450
Trees in alley plantings	400-600	2.2	77-330
Trees in windbreaks	400-600	4.3	150.5-645
Wide-spaced trees	250-400	0.43	15-64

^a At a carbon price of A\$35-\$150 tonne

Source: Australian Greenhouse Office 2000 and Shea et al (1998)

Indirect economic benefits

There are a number of indirect economic benefits from agroforestry which do not appear in the bottom line of a forestry budget but nevertheless contribute to the overall attractiveness of farm forestry to private growers and the community in general. Examples of indirect benefits are:

- crop and livestock shelter (on-farm benefits);
- salinity prevention and water quality improvement (on and off-farm benefits); and
- agricultural yield improvements from less waterlogging and soil erosion (on-farm).

These benefits can be estimated using a variety of methods. Improvements in agricultural yield due to the removal of a limiting factor can be valued by calculating the resultant increase in net agricultural profit. Other benefits can be

estimated using proxies such as the cost savings from less frequent repair and maintenance tasks.

Crop and livestock shelter

Trial work has shown that in some circumstances there are positive synergies between trees and crops/livestock, particularly when trees are planted in alley formation or shelter belts. The general principle is that despite some competition between trees and agricultural yields, the sum of profits from each product (wood, crop and livestock products) exceeds the sum of revenue from the production of these enterprises on their own.

The synergies come about because trees offer shade to livestock, shelter from heavy frosts and protect grain and some other crops from desiccation and windblasting. The RIRDC publication *Design Principles for Farm Forestry* indicates that the shelter benefits to agriculture are in the order of \$17 per hectare of farm forestry. Estimates made for the JVAP report (CIE 1995) were \$14 per hectare per year for broadacre farming in the wheat–sheep zone, and \$21 a year in the wet temperature (high rainfall zone), and \$17 a year in the dry subtropics (high rainfall zone).

Agroforestry also has the potential to meet a proportion of the farm's fodder requirements during the summer-autumn feed gap, resulting in a cost saving by reducing the need to buy in feed. Based on fodder costs and anticipated supplementary feed needs the fodder value is estimated to be between \$3 to \$10 per hectare of farm forestry.

Salinity prevention and water quality improvement

Increased adoption of farm forestry has the potential to reduce the incidence of dryland salinity — by reducing recharge to the water table — and improving the quality of surface water run off (for example less salt, nutrients, turbidity and sedimentation). A recent economic study by the NLWRA has estimated the cost of dryland salinity and water quality decline at a national level (table A.2). These cost estimates indicate, to an order of magnitude (to the nearest number of zeros), the potential benefits that could be realised if environmental degradation could be prevented.

The cost estimates for salinity are based on the Audit's assessment of current and future trends in the area of saline land. The current extent of salinity — defined as areas where salinity is causing yield losses — is estimated to be 3.1 million

hectares or 0.7 per cent of agricultural land. By 2020 this area is projected to increase to 4.4 million hectares. This projection is based on the assumption that existing agricultural practices continue and there is no change to the current area of agroforestry.

The value of current yield losses caused by salinity is estimated to be \$187 million per year (measured in terms of a reduction in profit at full equity). However, of more interest to policy makers is the future cost of additional land becoming saline, which is estimated to be \$558 million in net present value terms over the next 20 years. This figure is perhaps the most relevant for RIRDC because it is questionable whether the current extent of salinity can be reversed by agroforestry (Western Australia Salinity Taskforce 2001). This is one measure of the potential economic gain from prevention of future salinity damage.

Dryland salinity also damages infrastructure such as roads, buildings, railways and bridges. The Audit estimates that at the current extent of salinity, this annual damage cost is approximately \$89 million. The net present value of future increases in salinity damage over the next 20 years is estimated to be \$341 million.

Other forms of degradation examined by the Audit were the cost of increasing water salinity to downstream infrastructure (for example, corrosion in household and industrial plumbing and machinery) and the future cost of worsening levels of water turbidity and sedimentation. Turbidity increases the cost of water treatment and sedimentation adds to the cost of maintaining roads, railways, water reservoirs and navigation channels in rivers. The cost estimates in table A.2 are calculated for a 10 per cent increase in the levels of salinity, turbidity and sedimentation over the next 20 years. The combined net present value of future damage from deterioration in these water quality attributes is estimated to be just under \$2 billion. This figure excludes the cost of yield losses to irrigated agriculture from increasing stream salinity.

Table A.2 **Current and future costs of salinity, turbidity and sedimentation**

	Current cost	Cost of further degradation 2000–2020 ^a
	\$ million per year	\$ million NPV
Dryland salinity		
Agricultural yield loss	187	558
Institutional damage to infrastructure	89	341
Water quality deterioration		
Salinity	not estimated	1021
Turbidity	not estimated	814
Sedimentation	not estimated	123
Total cost		2857

^a Assumes 5 per cent discount rate

Source: NLWRA (2002)

Farm forestry as a control treatment

Deriving an estimate of the degradation control benefit of trees is problematic because there is no readily identifiable relationship between the area of agroforestry and the amount of environmental benefit. For example, it is not clear what area of agroforestry is required to deliver salinity benefits or the time lag between planting the trees and realising the benefits. Some hydrological models predict that 30 to 70 per cent of farmland may need to be converted to alley forestry to be effective in preventing the upward trend in future salinity (NLWRA, 2002).

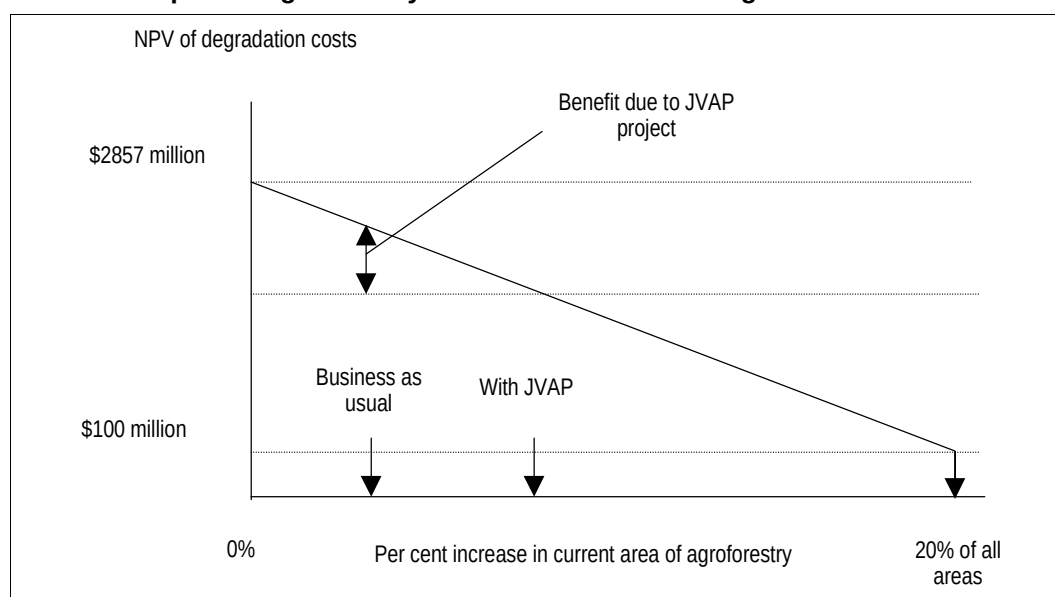
Our approach is to assume that the Audit estimate of \$2 857 million, being the future costs of ‘new’ degradation over the next 20 years, can be reduced to \$100 million with a high adoption scenario of converting 20 per cent of all broadacre farmland to farm forestry. A linear relationship is drawn between these two points as illustrated in chart A.2. This relationship is used to derive a per hectare estimate of the salinity and water quality benefits of establishing trees. Using the data in table A.3, the benefit over a 20-year period is \$120 per hectare (net present value), per additional hectare of trees — which is calculated as follows:

$$(2857-100)/(23-0.09) = \$120 \text{ per hectare.}$$

This is equivalent to an annual value of around \$10 per hectare. By comparison, a study by AACM (1995) — which forms the basis of data in RIRD’s *Design Principles* — estimates the following annual values:

- \$30 per hectare benefit due to reduced infrastructure damage;
- \$25 per hectare due to reduced water treatment costs;
- \$30 per hectare due to improved water quality; and
- \$2 per hectare due to improvements to the riparian zone.

Chart A.2 Impact of agroforestry on the future costs of degradation 2000–2020



Data source: CIE

Table A.3 Agroforestry adoption scenarios and impacts - key assumptions

	Agroforestry area at 2020	% increase on current area	% of broadacre farmland under agroforestry ^a	NPV of new degradation costs in period 2000–20
	million hectares	%	%	\$m
No change to current area	0.09	0	0.08	2857
Business as usual (5500 ha/yr. growth)	0.2	23	0.2	2844
High adoption	23	25456	20	100

^a Total area of broadacre farms in the wheat-sheep and high rainfall zones is 117 million hectares (ABARE 1997)

Source: CIE

Other indirect benefits

Increased adoption of agroforestry has the potential to deliver a range of other indirect benefits to farmers and the general community. These include:

- prevention of yield loss due soil erosion by wind and water;
- reduced water logging resulting in higher agricultural yields;
- lower nutrient runoff from farms and less eutrophication of waterways; and
- reduced flood frequency and severity of damage.

These factors were not considered by the NLWRA economic study. It is difficult to quantify the costs of some of these impacts without double counting. For example, many waterlogged areas coincide with saline areas and parts of the landscape with poor soil structure. So the cost of productivity losses due to waterlogging, salinity and soil structure decline are not additive. Given the difficulties of estimating damage costs and the lack of reliable information on the magnitude of these factors, we have limited our evaluation to salinity and water quality benefits as discussed above.

Non-market impacts

Agroforestry R&D potentially impacts on a range of environmental and social ‘assets’ which are characterised as non-market public goods and services. Examples include environmental services such as biodiversity, landscape aesthetics and recreation — and social assets such as viable rural townships. Despite the fact that these assets are not exchanged in markets, society may nevertheless hold a value for their provision and protection. In some circumstances it is possible to derive values by examining the role that environmental services play in the production of market commodities — for example the value of pollination services in producing agricultural crops.

However, in many instances there are no related markets from which to derive values. In such cases it is necessary to use non-market valuation surveys to estimate the community’s willingness to pay for improvements in the social or environmental attribute of interest. A recent study undertaken for the NLWRA (2002) used a choice modelling technique to estimate community values for a range of environmental and social outcomes. The choice modelling survey asked Australian households to make choices between a series of different 20 year resource use outcomes that were described in terms of four ‘generic’ attributes:

- species protection, measured as the number of native species protected from becoming endangered;

- landscape aesthetics, measured as the area of farmland whose visual amenity is improved through conservation works;
- waterway health, measured as the length of waterways restored for fishing and swimming; and
- rural township viability, measured as the annual net migration of people out of small country towns.

Different outcomes were presented to respondents by varying the level of these attributes. A money attribute was also included, specified in terms of an annual environmental levy which households would be required to pay. This too was varied across the different alternatives (from zero to \$200). The questionnaire forced respondents to make trade-offs between each of the attributes and elicited their willingness to give up some income for a unit improvement in one of the non-monetary attributes (see box A.1 for more details).

Box A.1 The Choice Modelling technique

In a Choice Modelling application, respondents are presented with a series of questions, each containing a set of options known as a choice set. Typically, five to eight choice sets are included in a questionnaire. In each choice set, respondents are asked to choose their preferred option from a range of alternatives. The options can be viewed as separate management policies, the outcomes of which are described in terms of a standard set of attributes. The levels assigned to the attributes differentiate the options from one another. An experimental design is used to ensure that the range of alternative options presented to respondents in the choice sets is adequate.

Each choice set includes a 'business as usual' option that describes the outcomes associated with a 'no change' policy. It serves as a base against which respondents' willingness to make trade-offs in securing change can be measured. The other options are deviations from the no change policy. The choices made by respondents enable the estimation of the relationship between respondents' choices, the levels of the attributes describing the choice outcomes, and the socioeconomic characteristics of the respondents. This 'model' of choice allows the analyst to estimate the extent to which individuals are prepared to trade-off one attribute against another. Provided one of the attributes is measured in dollar terms (for example, a tax, levy, or entry fee), it is possible to estimate the amount of money people are prepared to pay for improving a non-monetary attribute by one unit. This value is known as the implicit price of the attribute.

In the application undertaken by the NLWRA (2002), 10,800 households were surveyed across Australia. The survey yielded a response rate of 17 per cent which allowed an evaluation of how preferences vary across country and city households and how people value attributes in different contexts (regional versus national).

Using the results of the choice model, separate values — or implicit prices — can be estimated for each attribute (table A.4). The first row of estimates provide a measure of the average amount respondent households are willing to pay *each year* over the next 20 years for a unit change in the level of each attribute. In the case of township viability, a negative value was estimated indicating that households perceive the loss of people from rural towns as a cost.

The second row of data in table A.4 is aggregate population values. These are calculated by extrapolating the household value estimates to 45 per cent of the national household population. Values are only scaled to 45 per cent of the population because less than 100 per cent of households responded to the survey so extrapolating to the full population is speculative.

The third row of estimates are calculated by consolidating annual willingness to pay estimates over a 20 year period and converting the figure to a net present value. Thus, in the case of endangered species, the Australian community is

willing to pay approximately \$2.2 million each year to protect an additional species by 2020 and the present value of this payment is \$29 million.

Table A.4 **Non market value estimates for 20 year outcomes**

	Species protection	Landscape aesthetics	Waterway health	Rural towns viability
	\$ per species protected	\$ per 10,000 hectares restored	\$ per 10 kilometres restored	\$ per 10 persons leaving
Implicit price estimates				
annual household values	0.68	0.07	0.08	-0.09
annual population values ^a	2 198 775	226 334	258 679	-291 014
NPV value for 20 year period ^b	28 770 000	2 106 000	2 962 000	-2 106 000

^a Household values aggregated to 45 per cent of the national household population (7 185 540 households).

^b Assumes a 5 per cent discount rate.

Source: NLWRA (2002)

Incorporation of non-market value estimates into a BCA

If the non-market values are to be incorporated into a BCA, it is necessary to establish functional relationships between the area of agroforestry and the expected improvements in each attribute. Unfortunately this relationship is not clear-cut. As discussed below, agroforestry has both positive and negative effects on employment opportunities and hence on rural town viability. Given this uncertainty no net benefits can be assigned.

There is also a considerable debate over the impact on biodiversity. Short rotation monocultures are unlikely to do more for biodiversity than other agricultural crops. And even environmental plantings need to be adjacent to much larger reserve areas before they are likely to have a major impact on biodiversity (species protection). However, biodiversity motivated plantings and plantings in riparian zones that are not harvested have a high probability of contributing to protecting biodiversity, even if not the warm and fuzzy kind of biodiversity survey respondents may visualise.

As a result these kinds of plantings should be accorded some value. This value will grow in proportion to the area committed to these plantings as endangered species protection is fundamentally related to habitat area. As we do not know this relationship we take an admittedly crude approach and assume that every 100-hectare of trees (biodiversity motivated) and riparian plantings result in 0.1 per cent increase in endangered species survival. Even these conservative estimates imply a value of \$22 per hectare per year of additional diverse agroforestry. Riparian plantings also contribute considerably to waterway health.

The AACM estimates that the annual value of this contribution is \$2 per hectare (AACM, 1995).

Landscape aesthetics also contribute to the benefits. If a hectare of trees delivers a hectare of aesthetics then based on the willingness to pay for farmland restoration a rough estimate is that a hectare of trees delivers \$23 per hectare each year in aesthetics value. However, this is unlikely to apply to all plantings, with windbreaks and revegetation plantings likely to contribute to aesthetics while block-planting monocultures may not (and definitely not when harvested). The AACM (1995) estimate put aesthetics at \$8 per hectare of trees.

In summary

As there are benefits that need to be recognised we used these very crude assumptions as a starting point. We aim to be conservative, as it is clear that some minimum critical mass of trees is needed before some of the benefits will kick in. To estimate the benefits properly would require developing a series of scenarios and extensive ‘testing’ of these scenarios with ecologists etc. The non-market value estimates in table A.4 above provide an indication of the upper limit on benefits that could be realised from environmental and social improvements. The estimates discussed in this appendix are summarised in table A.5.

Table A.5 Some benchmark estimates of value

Type of benefit	Estimate \$/ha/year	Comments
Carbon sequestration	100–500	- Maximum value contingent on international mandatory emission reductions at Kyoto levels. - Valid only for expansion in area of trees not harvested or new first rotation plantings
Crop and livestock shade and shelter	17	Broadacre in high rainfall sub-tropics.
	21	Broadacre in high rainfall wet-temperature.
	14	Broadacre in wheat-sheep zone.
Fodder	3–10	
Salinity and water quality	10	Derived from NLWRA (2002) data as an average across all areas.
	up to 85	Assumes very large and high salinity affected areas in AACM (1995).
Riparian zone	2	AACM (1995) estimate.
Biodiversity	22	Derived from choice modelling survey (NLWRA 2002). Assumes 100 hectares of trees result in 0.1 per cent increase in survival of endangered species.
Aesthetics	8	AACM (1995).
	23	Based on willingness to pay for restored farmland (NLWRA 2002)

Source: CIE

Social benefits

The effect of the research on the social bottom line is the most difficult to quantify. There are some indicators that can be derived, such as the impact on employment, and possibly on the pressures for out migration from rural towns. Some willingness to pay estimates for such outcomes are available and can be used to back out some general community willingness to pay values. However most social indicators are by their nature not amenable to 'valuation'. Social outcomes are part of the multidimensionality of the benefits that public investment is trying to achieve. A survey conducted by AgKnowledge and AgInsight is looking at some of these types of social outcome indicators.

The discussion below looks at some of the potential impacts with an aim to assess whether the impact is positive or negative. The conclusion is that the impact on employment and population in rural areas is uncertain. However, the work is likely to bring gains in terms of security of the farmer, human capital and social capital.

Employment and population

The effect of agroforestry generally on employment and population is dependent on the type of agroforestry undertaken and the size of nearby regional centres.

When trees are planted as shelterbelt and are grown *along side* alternative production then such agroforestry adds to industry – supplying new jobs and introducing new money to local communities. However, when trees are planted in blocks, and are grown *instead of* alternative production, then such agroforestry may not create a net positive in terms of employment.

Tree production is not as labour intensive as some alternatives, and farmers may choose to use ‘mobile gangs of timber workers rather than employing locals’ (RIRDC, 2001). Subsequently, such production may have a negative effect on local employment and population.

Another important factor in determining whether agroforestry will have a positive or negative effect on the population is the size of the nearby regional centres. Small centres are most especially vulnerable to a decrease in labour demand and are unlikely to establish value-adding industries such as processing plants.

However, medium to large towns are more likely to be able to accommodate new value-adding industries and, due to their broader demographic base, are less likely to be affected by changes in labour demand.

To the degree that agroforestry has a positive or negative impact on rural communities – this impact will be multiplied as the JVAP research will result in an increase in the amount of agroforestry.

Security of farmer

The security of farmers is a complex social outcome, and the degree that a strong agroforestry sector contributes to such security is impossible to quantify. The survey conducted by Agknowledge for RIRDC on the Master Tree Growers program found that the potentially higher profitability of plantations, as well as

higher land values and greater diversification of production all have a positive influence on security. However, this is offset to some degree by the long time lags between planting and harvest, higher rates paid due to higher land prices and the difficulty in switching between timber crops and alternative crops.

To the degree that there is a net positive or negative effect from agroforestry on the security of the farmer – this impact will be multiplied, as the JVAP research will result in an increase in the amount of agroforestry.

Human capital

All research activities increase human capital, both directly with regards to people associated with the research and indirectly in the effect on those ‘near’ the research. Students of researchers go on to use this information effectively in promoting the industry and this indirect benefit — while not readily quantifiable — is an important inclusion.

The growth of the stock of human capital with regards to cabinet timber agroforestry is a prime example of this indirect effect. For example, students of Dr David Lamb — who undertook the Mt Mee project ‘Growth of High Value trees on farms’ — have gone on to hold important positions such as manager of the CRRP.

Social capital

Social capital includes such things as trust and the effectiveness of relationships and networks.

B Guidelines for triple bottom line reporting

Objective

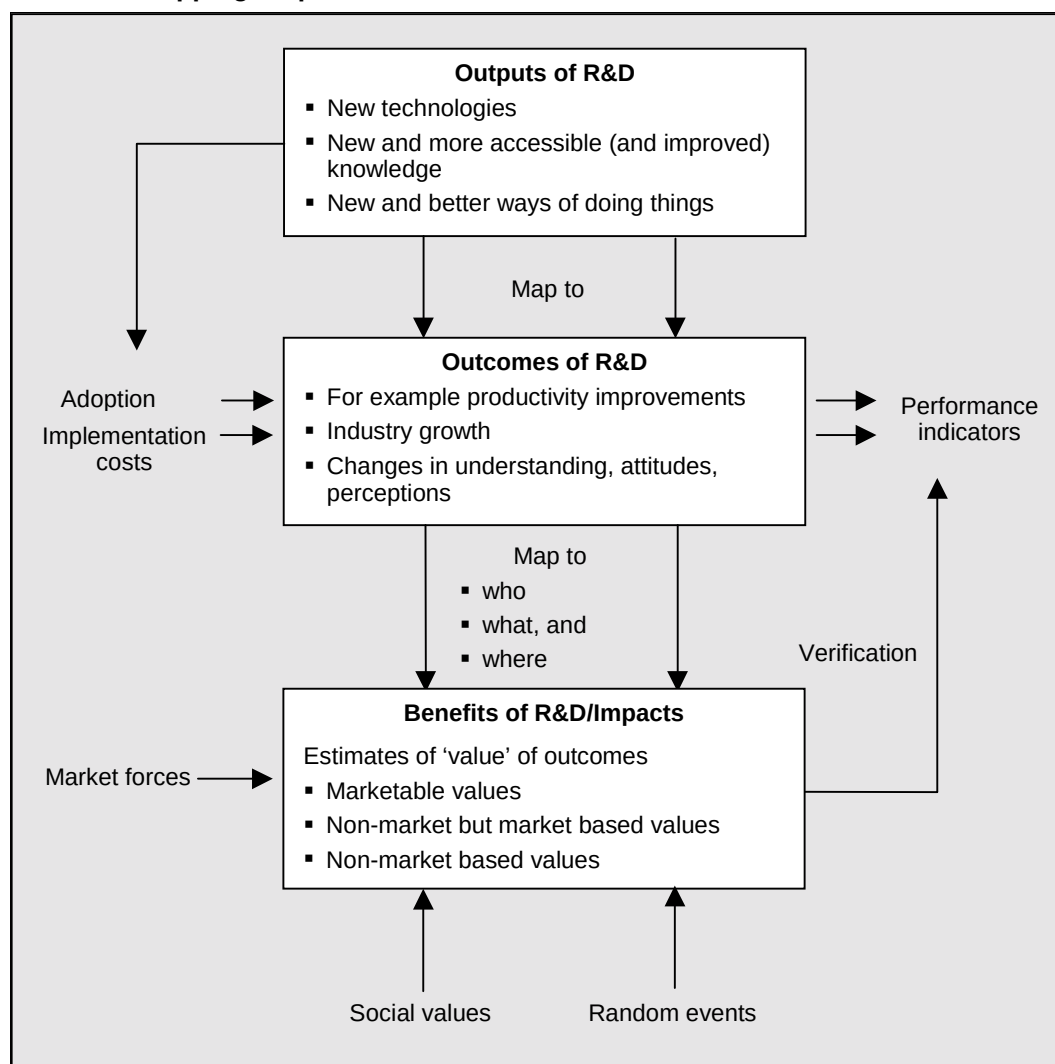
This overview presents a draft framework for undertaking triple bottom line reporting on the outcomes and impacts of R&D. This work is being undertaken for the RIRDC as part of its annual review of programs — in 2002 the Joint Venture Agroforestry subprogram. Comments on the framework have been sought from practitioners and users of triple bottom line reporting and benefit-cost analysis. While the response rate to date has been low, the comments received have been very useful in revising the framework. It is hoped that this revised version will go another round and make a significant contribution to triple bottom line reporting.

Approaches to triple bottom line reporting

The recent review of the reporting by the Research and Development Corporations (RDCs) demonstrated that a plethora of indicators have been utilised for triple bottom line reporting purposes (Agtrans, 2001). Many of these indicators are qualitative in nature and difficult to compare. The response to these difficulties has been the adoption of an anecdotal approach to demonstrating the environmental and social benefits of the R&D. A recent report by AFFA (2001) demonstrates this approach, which is a response to community demands for triple bottom line reporting.

Other government R&D organisations such as the National Health and Medical Research Council (NHMRC) and CSIRO are exploring options for new performance indicators that better reflect the return to the Australian economy. This return comes in many forms from employment and income growth to more effective social services and better environmental outcomes. Evidence of superior performance of companies that engage in 'ethical' investments, and new legislation requiring investment service companies to report against the triple bottom line have raised interest in the private sector. The aim of developing the framework presented in this paper is to provide a starting point for discussion on what triple bottom line means, how it should be interpreted and what indicators are sensible to report.

Chart B.1 Mapping outputs to outcomes to benefits



What we mean by a framework to evaluate the impact of R&D

The value of R&D outcomes to Australia can be defined in dollar terms, in quantitative measures of explicit outcomes, or in more general terms. For example, the benefits of improvements in preventative health care can be described in terms of:

- the dollars saved on medical treatment costs and dollars of wage income that would have been forgone through ill health — dollar valuation of impacts;
- lower prevalence and death rates and suffering from disease — outcome indicators; and

- more general descriptions of improved health and welfare, including measures of subjective values such as changes in satisfaction with the health outcomes.

Economists using BCA have tended to focus on the first type of measure — dollar values — that are derived from the quantitative indicators of health outcomes. The methods used in BCA put dollar values — a measure of impact — on non-dollar but quantified outcomes. But there is another dimension to health and well-being, such as lower individual and community risk and levels of confidence, that is not picked up by these measures. Nor may it be appropriate to do so.

The aim of this note is to put together an overall framework for evaluating the impact of R&D. This impact has economic, social and environmental dimensions. Not all elements in each dimension can or should be quantified. The aim of this guide is to identify which elements can be quantified, how double counting can be avoided, and to provide some guide as to techniques for quantifying the impacts of R&D, and estimating outcome indicators.

Benefit-cost as a framework

The benefit cost framework simply refers to identification of all benefits and all costs, broadly defined, over time. As summaries in chart 1 require that we map from the outputs of R&D to identifiable outcomes — usually in some explicitly quantified way, whether objective or subjective. Performance indicators need to be developed at this outcome level, and the other inputs required to deliver the outcomes identified. But outcomes need not map one to one with values and this is where the challenge of verifying performance indicators comes in. To verify indicators we need to map from outcomes to measured impacts. While not always possible, the goal of evaluation is to develop a verifiable mapping from the outputs to outcomes to impacts that can be measured – in dollar or other terms. Where the mappings are unknown, information collected should aim to assist in developing and testing relationships. Some will be robust and can be used to inform future decisions to what outcomes are desirable.

Economic impacts can usually be quantified in dollar terms. Where social norms exist non-market valuation techniques can be used to quantify the ‘average’ individual willingness to pay for explicit outcomes. But there are dimensions to social and environmental outcomes that cannot be quantified in dollar values. Values cannot be explicitly assigned where no markets exist, where individuals vary widely in their preferences, and where social values diverge from the sum of individual values. For example with choice modelling, where people reveal

their preferences through the choices they make, the results will only be statistically significant if there is a roughly a normal distribution of preferences with a low standard deviation. In this exercise average individual values are thought to reflect social values. So choice modelling cannot provide sensible results in either of the cases described above, as a market value must be included in the choice sets.

Trade-offs can be assessed in terms of dollar values where they can be assigned. Multi-criteria assessment is needed to assess the non-dollar values of R&D.

Why do we need triple bottom line reporting?

Until recently the focus on triple bottom line reporting was accountability for public expenditure. Evaluation often focused on whether the goals set out in the program were achieved. The adoption of a BCA framework takes evaluation beyond this – to address, in addition to effectiveness issue, the question of whether the goals were the right choice in the first place. The investment of public money, whether in R&D or in other investments, makes it is important that benefits beyond the commercial benefits (return to capital) be assessed. Public investment in R&D is justified where private investment is less than economically and socially desirable. The market will tend to under invest where:

- producers are highly fragmented — public support may be required to assist industries to invest in R&D of common benefit where there are substantial economies of scale in conducting R&D;
- the technology and knowledge developed is easily transferable so the investor shares the returns with other producers;
- there are substantial externalities — that is the benefits accrue to others in the industry, other industries, the public, or to future generations; and
- the investment enhances the value or reduces the cost of publicly provided goods.
- There is not yet the existing information to underpin a potential new industry.

Externalities can take many forms but recently the focus has been on environmental externalities. Improvements in environmental outcomes, for example reducing salt loads in rivers, have a range of benefits from improved agricultural yields to enhanced biodiversity protection in wetlands. The farmers making the investment in salt mitigation capture little of this benefit as salinity impacts frequently occur at locations remote to the source of the problem.

The reasons for under investment by the market come down to the investors being unable to capture some of the economic, and most of the environmental and social benefits. Given that the public makes the investment, accountability requires that the full range of impacts of a public investment are reported. And in making investment decisions the public wants to be able to assess the total impact of an investment, and apply their weights or values in making investment choices.

So what is in the triple bottom line?

The triple bottom line — economic, social and environmental — is not a new concept. But it has become more important as stakeholders increasingly demand an account of social and environmental impacts as well as of economic impacts. Like the term ‘sustainability’ ‘triple bottom line’ can mean very different things to different people.

Economic reporting goes part of the way

Economic reporting goes well beyond accounting in reporting not only returns to capital and workers but also the impact on consumers. It has developed tools to report on environmental and social benefits wherever individual preferences can be considered representative of society’s preferences. Good benefit-cost analysis has been including estimates of these types of benefits for some time.

But the economic approach cannot reflect all individual and societal values

True triple bottom line reporting challenges the standard economic paradigm that society’s value reflects the sum of the values of the individuals in that society. There may be consequences of R&D or a public investment that transcend individual preferences — impacting on ethics, intergenerational equity and moral duties — about which ‘economics’ can say little. Triple bottom line reporting should provide information on these impacts as well those more familiar to the economist. For example, social outcomes are often associated with the process of R&D, such as through empowerment of the community in the decision process. These benefits are important and should be reflected in a triple bottom line account. This means that sociologists and economists need to work together to evaluate the impact of R&D. Putting explicit dollar values on impacts does help in resource allocation decisions, but decision making will always be based on a multiple set of criteria. The aim of triple bottom line accounting is to present the information together, providing a clear and testable mapping from the R&D to the benefits or impacts.

A framework for triple bottom line reporting

The framework is summarised in chart B.1. The first step identifies the outputs of the R&D investment. Note that process outputs includes things such as participation in the decision making. Outputs are mapped into outcomes (step 2) that can be classified as economic, social and environmental. These outcomes largely depend on adoption — firm and individual take-up of the outputs. The third step in the framework is mapping outcomes into impacts or net benefits and, where appropriate, to quantify the value in dollar terms.

The three categories of outcomes do not map directly into the same three categories of triple bottom line impacts and this leads to a lot of confusion. For example, economic outcomes often have social as well as economic impacts for example, by creating employment opportunities. And environmental outcomes often have economic benefits, such as improvements in water quality leading to lower water treatment costs.

There are lots of feed back loops as the bottom line impacts on adoption and on the outcomes, and outcomes influence the outputs. The simplification is useful because it forces us to explore the assumptions we make about the value of the investment, and to identify how that value might be achieved.

Estimating value

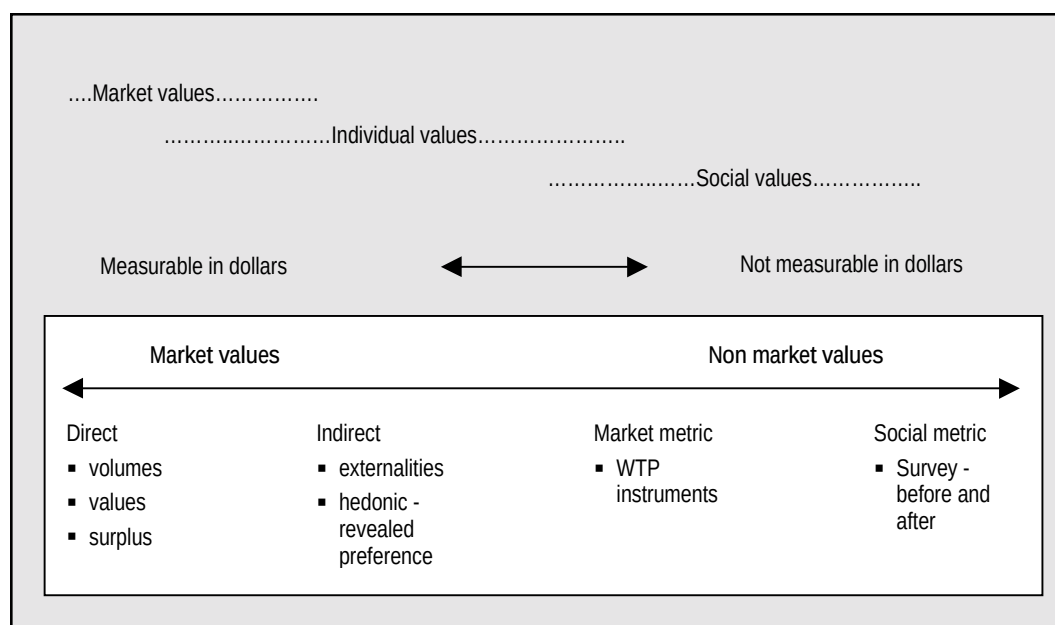
The bottom line is the value that arises from the triple bottom line outcomes. This value is derived from the market values, individual values and societies' values placed on the benefits that flow from the outcomes. The values are not always straight forward, nor are they always easy or appropriate to quantify in dollar terms, but for reporting some quantification is required.

In estimating values the context for the values needs to be established. Only values made in the same context are truly comparable. With market values the context is established by observed market prices and quantities and the observed relationships that can be captured in economic models. Economic techniques to establish willingness to pay (WTP) by individuals uses these individual stated preferences to estimate average community values. If survey responses are formed under a market context, with a credible market based payment vehicle, then they can be added to market based values. Care should always be taken to ensure that the context is well understood, and the level of confidence in the estimate made explicit.

There are other measures that have no basis in market values and these cannot be added to market based values. Some social outcomes have market based values but some cannot be measured in this way and other measurements are needed. Chart B.2 summarises the range of values needed. But the projects also deliver social outcomes. In this report, we focus on the market based values that can be used to estimate the benefits from economic and some environmental outcomes. The report by AgInsight / Agknowledge looks at some of these benefit measures from social outcomes.

Where a common metric is used, such as dollar estimates, the trade-offs can be seen directly. However, where the metric differs, such as with a measured increase in confidence from survey data, the measures need to be presented together and multi-criteria established for decision making.

Chart B.2 Measuring benefits – from market based dollars to survey based assessments



Adoption

Adoption provides the link between the outputs and the outcomes. One of the best performance indicators is the adoption level where people are free to choose whether they adopt or not. People will adopt where:

- they understand the output and the expected outcome and can assess the value of this outcome;

- the value of the outcome to them is positive, where the value may arise through market values (for example, higher profits) or individual values (for example a sense of pride); and
- they have the capacity to adoption, where capacity is the skills, finances, legal right and absence of any other impediment to their adoption.

Adoption means that all three criteria are satisfied. However, benefits accruing to the individual may or may not reflect the benefits to the broader community or Australia in general.

Performance indicators

Performance indicators are most important at the outcome level, which is where the links to the R&D should be clearest. But the interpretation of performance indicators needs to be informed by the values (market, individual and societal values) of the outcomes. The context will influence the value to be gained from outcomes. For example, falling world prices due to increasing volumes of production will reduce the benefits from any productivity gain that leads to the expansion in output. Thus the outcome may appear to be great — a productivity improvement of say 20 per cent — but the impact in terms of returns to the farmer could be much smaller.

The rest of this paper comments on the mappings from the triple bottom line outcomes to measurable impacts of R&D. The focus is on measurable impacts in terms of market values. But it is recognised that there is also a need for guidelines in terms of impacts that are not measurable in terms of market values, but still reflect individual and society values. Some suggestions are made as to possible indicators at this level.

Classifying triple bottom line outcomes and impacts

Economic outcomes

These are defined as anything that changes the demand and supply of goods and services (products) in the market and hence the consumer and producer surplus in that or any other market. The three key shocks that result in changes in prices and volume of production are;

- lower unit costs of production — from labour saving, capital saving and other resource saving technological progress. For example, higher yielding seeds

varieties and faster machine speeds both increase output per unit of input. Machines can replace labour, and better systems can replace machines, resulting in lower inputs per unit of output. The outcome of lower unit costs of production depends on the market but is generally an expansion in production and a decline in price;

- improved quality products (goods and services) — from greater assurity of supply, constancy and / or timeliness of quality, as much as from enhanced physical qualities, resulting in a shift in demand and higher prices received for products as well as the greater value (surplus) for consumers; and
- new products — new supply and demand indicated by new volumes and the prices received.

Most of these outcomes lead to measurable impacts; in terms of increases in consumer and producer surplus. There will also be some products, such as health care, that will provide benefits well beyond any measure of consumer surplus, that could be captured in indications such as changes in average life spans, or quality of life indicators.

Environmental outcomes

Environmental outcomes result from any changes in the stock or condition of natural resources as a result of investment. There are two key outcomes:

- reduced pollution (air, water, land, noise, etc.) — from reduction in the use of natural resources and from less harmful use due to changes in production processes and systems. The outcomes are usually measured in physical units such as changes in NO_x parts per million, salt loads; and
- improved environmental health — from reduced pollution, but also from protection and restoration. The outcomes can be measured in a variety of ways such as areas protected, species removed from endangered lists and so on. These outcomes will have both market and non-market impacts.

As markets expand (such as for water) through allocation of property rights some outcomes that are currently environmental in nature will become economic in nature. Natural resources are an input into production, so these outcomes will have economic impacts as well as environmental impacts. They deliver benefits through non-market uses of the environment such as recreational and aesthetic uses. And they will deliver non-use benefits for example by improving intergenerational equity. These use and non-use benefits are often difficult to separate. Contingent valuation and choice modelling make use of surveys to back out willingness to pay estimates for environmental outcomes.

Social outcomes

Social outcomes are the most difficult group to define, and in many ways capture outcomes that are either non-market and non-environmental in nature. We have identified four broad categories.

- More effective institutions — this category encompasses better government decision making and more cost-effective public programs and policies. But it could also include non-government institutions, for example Landcare groups. This outcome category can deliver benefits in all three triple bottom line areas, and is one of the most important for delivering non-market benefits such as equity.
- Enhanced human capital — there is some overlap in this category with economic outcomes as this can be a direct input into all three of the economic outcome categories, indeed new services may be wholly about enhanced human capital. It is considered a separate outcome as it has longer term impacts on economic outcomes and important social impacts in terms of enhancing lifestyle opportunities.
- Human health and safety — more effective treatments and prevention of disease, injury and harm are good social outcomes. They deliver both economic and social benefits, including ‘basic rights’.
- Empowerment – the enhanced control of individuals and / or a society over the choices it makes. This may or may not result in higher incomes or other impacts.

Reduced risk

There is an additional or supplementary outcome that spans all three categories of outputs and this is reduced risk. R&D may actually increase risk, but when it does reduce uncertainty this can be considered a separate outcome. While adoption is clearly influenced reduced uncertainty also lowers the transaction costs of doing business. It also has social benefits in terms of greater confidence. Greater certainty can raise investment and boost economic growth. It can enhance institutional effectiveness by firming policy decisions. And it makes an important contribution to people’s sense of well being.

At the impact level many other factors are likely to influence what we observe and hence what we measure. Sorting out the influences of the specific outcomes and other factors often requires models of behaviour — of markets and people — to work backwards to place values on outcomes and hence on the value of the investment.

Triple bottom line impacts — what are we measuring?

Quantification is useful to be able to compare the potential impacts of proposed R&D investments and to understand the contribution of past investments. The BCA framework is used to identify who benefits as well as the magnitude of benefits. Done well it will eliminate double counting, and only estimate the additional benefits due to the R&D. And, as long as outcomes can be mapped to measurable impacts — whether economic, social or environmental — and these can be quantified in a meaningful way, BCA provides a way of summarising these benefits.

Accounting measures of return on capital (profits), return on labour (wages) and return on resources (rent) capture only the market value of production. Gross Domestic Product (GDP), measures the return to these factors used in production in a country in a one year period. Gross National Product (GNP) measures the return to factors of production owned by a country regardless of where they are used. GNP is a better measure of a country's income than GDP, but it is a flawed measure of welfare. Welfare measures can include the value of:

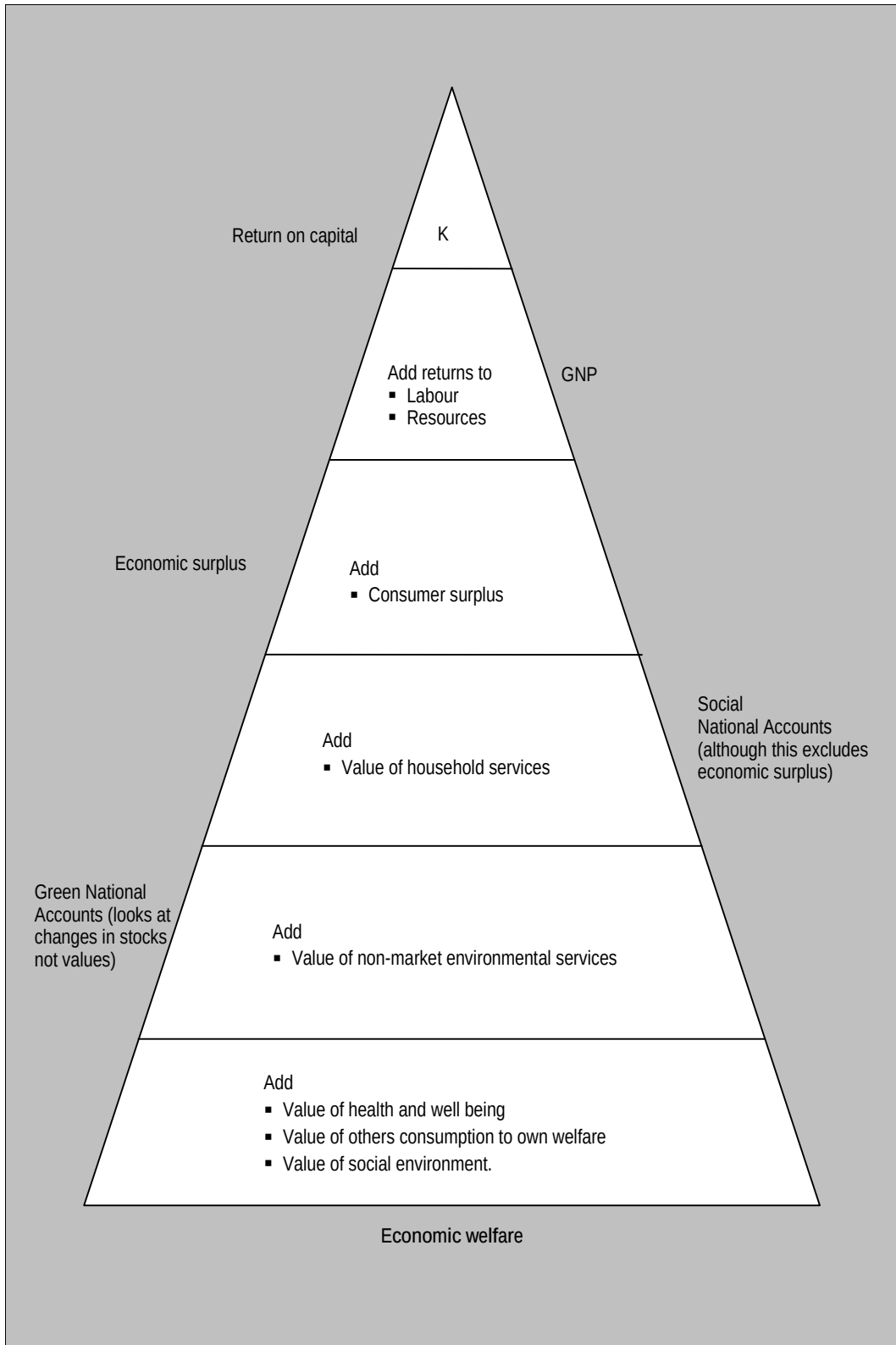
- consumer surplus — the gain above market price that final consumers would have been prepared to pay — their value from the product is this surplus added to the price paid. Unlike consumer surplus, producer surplus is captured in economic profit estimates, hence is measured in the National Accounts;
- non-market goods and services produced by households — GDP measures will often impute a value for household production of goods for own consumption where this is significant and the Social National Accounts attempts to measure the value of household and volunteer services;
- non-market goods and services provided by the environment — these have to be estimated using various techniques that either use revealed preference based on market interactions or stated preference techniques which are framed in terms of having to sacrifice household income (a market metric); and
- non-market goods and services provided by the broader environment — again that have to be estimated using various techniques grounded in an income metric.

Despite all the estimation techniques being grounded in a common metric — GNP as a measure of income — the sum of all these values will greatly exceed GNP as payments do not actually have to be made. Chart B.3 provides one way to think about the comparative base that any measured change of value should be compared to. This chart helps explain why BCA results are often

misinterpreted, as people compare the internal rate of return based (usually) on the first three levels with the rate of return on capital, which is only the top triangle, and even then the return will not necessarily accrue to the firm making the investment.

It is important that the quantification be presented using an appropriate metric. It does not appear that the general community understands the standard economic measures of surplus, let alone the meaning of willingness to pay (stated preference) or revealed preference measures. Estimates of internal rates of return on R&D investments are sometimes criticised because they are often well above market rates of interest. This demonstrates a misunderstanding of what is being measured by economic surplus — the benefits that flow onto labour in higher employment and in wages and to consumers in lower prices and better quality as well as the higher return to capital. It is also common to see measures of the value of life, for example, that are based on surveys of willingness to pay not to die or revealed preference from wage differentials, be compared to GDP.

Chart B.3 **Measuring economic impact**



The failure of economics to measure aggregate welfare

These measures are all essentially ‘economic’ in nature with the possible exception of the last layer in the triangle. Economists tend to define welfare largely in terms of consumption. Utility or welfare specifications can include the utility of others (such as children or a community of interest) but it tends to relate this to their consumption opportunities. How important consumption by others is (now and future) depends on the degree of altruism of the individual whose welfare is being defined. The uncertainty of future consumption can also be built into an individual’s welfare function, but the benefit derived from a reduction in uncertainty depends on the level of risk aversion of the individual.

While at an individual level economics can offer a way to build in some of the intrinsic benefits it has not been successful in doing this well at an aggregate level. It just needs one individual to place an infinite value on, say, intergenerational equity for the standard approach to fail. And there are other dimensions to welfare that do not relate, even eventually, to consumption. For example, poverty is a multidimensional concept of which the power of the individual to influence their environment is one element. These types of impacts fall into the non-market end of the spectrum and almost by definition do not have sensible aggregate dollar value estimates.

The approach used in this report to estimating the value of triple bottom line impacts

The approach is a BCA approach that relies on standard economic evaluation techniques to assess the value of economic outcomes (as set out in the *Guidelines to economic evaluation of R&D*). Also included is using stated and reveal preference techniques to put representative values on environmental and social impacts where there is a clear empirical case for a representative value. This means that not all the benefits from social and environmental outcomes are not included in the BCA estimates.

The framework

Chart B.4 outlines the framework. The main box contains the valuation component. It contains impacts that can potentially be valued, using market based valuation. The box to the right side represents outcomes that are important but do not have market based values. It is worth noting that as social norms change outcomes in this box may move into the main box as values converge. For example, 20 years ago the value of protecting biodiversity may have elicited very

different answers. But changing social norms about protecting the environment now mean that representative values have some meaning. The box at the top is the indicator box. It cannot be added to the other two boxes. What is important here is that there is a good mapping from the indicators in the top box to an impact in the main box. Unless this mapping can be established these indicators are not generally meaningful.

Benefit cost analysis relies on being able to map R&D outputs into measurable outcomes

Mapping R&D outputs into outcomes is the biggest challenge for BCA. Once outcomes—which include adoption and the resulting changes—are measured, the valuation exercise is relatively straightforward. All assumptions can be made explicit and sensitivity analysis based on ranges and distributions of parameters conducted.

Performance and other indicators

There are 3 types of indicators:

- Outcome indicators are needed to be able to estimate the impacts. The greatest challenge is often measuring outcomes and being able to attribute these to the R&D outputs. Once this step is achieved, the next step is to map to impact. In cases where outcomes cannot be mapped to impacts due to lack of information, measures of outcomes should be reported. If reporting stops at the outcome level care should be taken in interpreting this as a value as clear accepted links to bottom line impacts and values is needed for interpretation.
- Indicators of interest to particular stakeholder groups may be important to report although to include them in the BCA component would be double counting. Examples would include employment created in rural areas and the number of spin-off companies generated. It should be noted that of themselves these may not actually contribute much to the bottom line if jobs were lost elsewhere or if public money supported new companies at the expense of other businesses.
- Indicators of outcomes that do not have a market metric that individuals and society values should be reported. These indicators need to be assigned at the design stage of projects or investments as there are a plethora of measures to choose from. The critical component is to have a before and after measure to assess the change in these subjective values. It can be very difficult to map these values back to the R&D, but the attempt should still be made in order to identify the internal factors that have impacts.

Performance indicators that focus on outputs rely on a proven mapping from outputs to outcomes to be meaningful. The value of undertaking BCA takes the process one step further than performance indicators:

- It challenges the mapping from outputs to outcomes and hence the process is of value to researchers and others involved in project design and portfolio management. This should improve the understanding of what outcomes can be expected from an investment.
- It establishes the market related value of different outcomes and aids in making decisions where there are trade-offs between these expected outcomes.

Social indicators

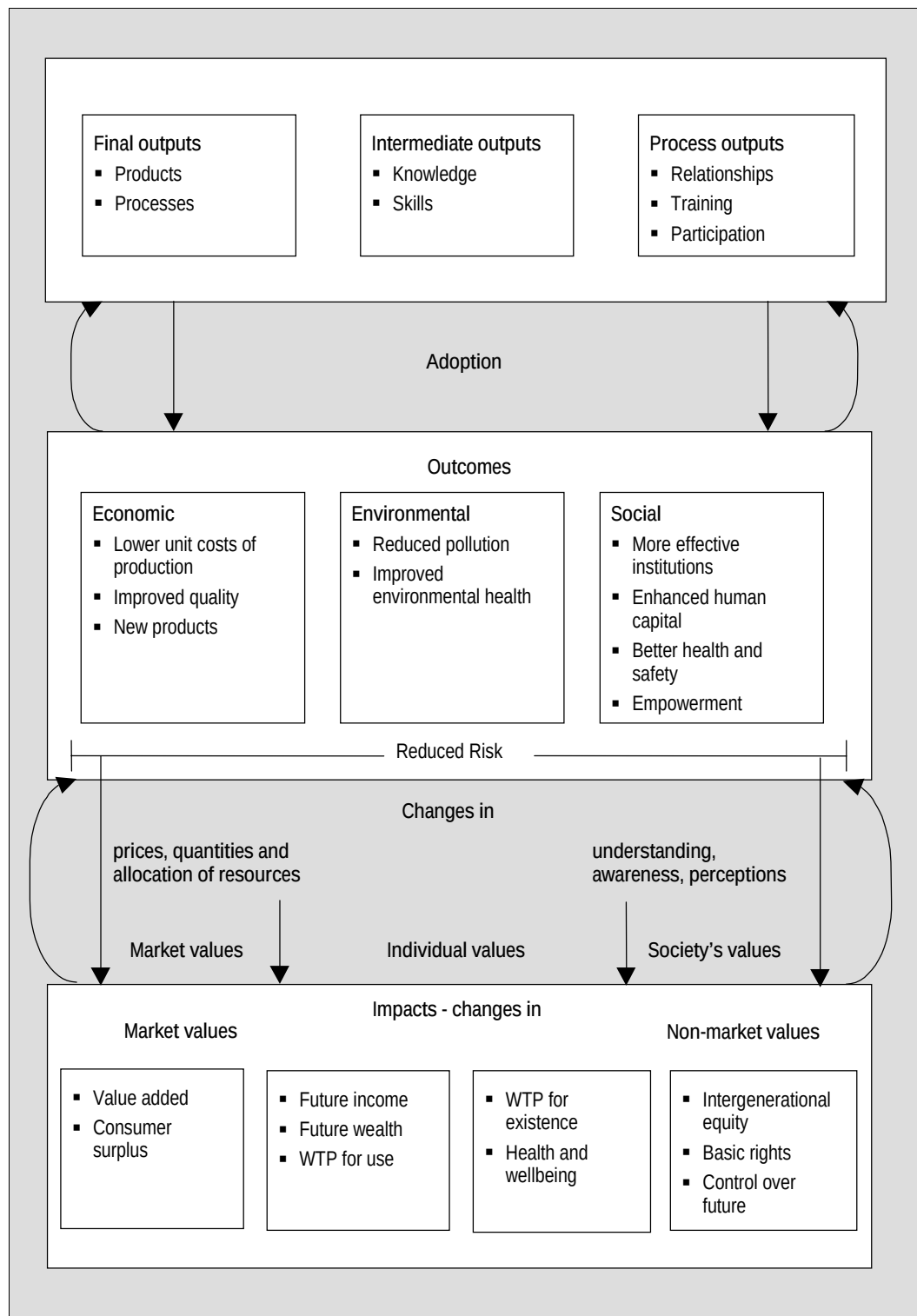
Social indicators need to be collected using survey techniques. Ideally, before and after surveys are conducted to assess the changes that have occurred due to the dissemination of the R&D. Although other factors will often influence outcomes this approach has greater potential to track the changes that might be attributable to the research.

AgKnowledge / AgInsight were contracted to undertake a survey of participants of the MTG program. Unfortunately, they did not have the opportunity to conduct a survey before the course so the questions required respondents to reflect on the changes they have made due to the course information. The focus of the survey was on perceptions and attitudes. Some on-ground changes are reflected in comments made but these are hard to quantify.

The social indicators measured in the surveys reflect considerable satisfaction with the MTG program. Some indicators are:

- an improvement in confidence in the agroforestry industry and farming — 90 per cent of people came away from the course positive about their future in farming; and
- confidence in their decision making as a result of the MTG course — over 50 per cent definitely felt confident, and over 30 per cent felt confident to a large extent.

Chart B.4 Mapping R&D outputs to a triple bottom line



References

- AACM International PTY Limited 2002, *Kyoto Protocol — the first commitment period and beyond*. In Australian Commodities, March Quarter, 2002.
- , Centre for International Economics and Forestry Technical Services 1996, *Commercial Farm Forestry in Australia: Development of a Strategy Framework*, RIRDC Publication, Canberra.
- 1995, *Cost Sharing of On-Ground Works*, discussion paper prepared for the Murray Darling Basin Commission, Canberra.
- ABARE (Australian Bureau of Agricultural Research Economics) 2002, *Australian Commodities Outlook – March 2002*, ABARE, Canberra.
- 2000, *Australian Commodity Statistics 2000*, Canberra.
- 1999, *Forest plantations on cleared agricultural land in Australia: a regional economic analysis*, Canberra.
- 1997, *Australian Farm Surveys Report 1997*. Canberra.
- ABS (Australian Bureau of Statistics) 2002, *Agriculture, 1999-2000*, Cat. No. 7113.0, ABS, Canberra.
- 2001, *Australia's environment: Issues and trends*, ABS Catalogue Number 4613.0, Canberra.
- 1999, *Environment protection expenditure: Australia. 1995-96 and 1996-97*, ABS Catalogue Number 4603.0, Canberra.
- AETF (Australasian Emissions Trading Forum) 2002, *AETF Review*, February-March issue, 2002.
- AFFA (Agriculture, Fisheries and Forestry Australia) 2001, *Innovating rural Australia. Research and development corporation outcomes*, Canberra.
- AgKnowledge / AgInsight, 2002, *The intangible contribution of the Master TreeGrower Program*, Joint Venture in Agroforestry Program and Master Treegrower Program, June 2002.
- Agtrans 2001, *Report on the Performance of Rural Research & Development Corporations and Options for Future Performance Measures of the Rural Research & Development Corporations, Volume 1: Draft Report*, report to RIRDC.
- AGO (Australian Greenhouse Office) 2000, *Greenhouse sinks and the Kyoto Protocol – an issues paper*. Canberra.

- Alexandra, J 1994, 'Sustaining Agriculture', *Habitat Australia*, August 1994, pp 26-31.
- ANU (Australian National University) 2002, *Market Report 19: What's happening to consumption of sawnwood in Australia?*, March 2002, <http://sres.anu.edu.au/associated/marketreport/index.html>2002, Accessed 24 April 2002.
- 2001, *Market Report 15: Stumpage trends in South Australia*, March 2001, <http://sres.anu.edu.au/associated/marketreport/index.html>2002, Accessed 24 April 2002.
- Forestry 1998, *Market Report 3: Log and Agricultural Product Prices Beyond 2000*, March 1998, <http://sres.anu.edu.au/associated/>
- 1999a, *Market Report 8: Woodchip markets and prices*, June 1999, <http://sres.anu.edu.au/associated/marketreport/index.html>2002, Accessed 24 April 2002.
- 1999b, *Market Report 9: Trends in sawnwood market*, September 1999, <http://sres.anu.edu.au/associated/marketreport/index.html>2002, Accessed 24 April 2002.
- Arnold, R. 2001, 'Review of CAL 4A: The Australian Farm Forestry Site Selection Manual', letter from Roger Arnold to RIRDC, 6 November 2001.
- Booth, T. 1999, 'Developing farm forestry systems mainly for low-medium rainfall areas', presentation from CAL 4A, ref R99/54.
- , et al 2002, *Potential Productivity Assessment: sub project of CSF 56A*, unpublished RIRDC report, Canberra.
- Borough, C. 1999, *Review of Paper – Commercial Prospects for Tree Species in Low Rainfall Zones – Agtrans Research*, prepared for RIRDC, February 1999.
- Borschmann, G. and Lamb, D. 1999 'Rainforest cabinet timber trees trialled', *Greening Australia – Yearbook*, Greening Australia, Brisbane.
- Buffier, B. and the Allen Consulting Group 2002, *Environmental and commercial outcomes through agroforestry. Policy and investment options*, a report for the RIRDC, LWA, FWPRDC and MDBC, a Joint Venture Agroforestry Program, RIRDC publication no. 02/057, RIRDC project no. BDB-2A.
- Bulman, P. and Dalton, G. 1994, *Species Selection Data Base: RIRDC PIF 1A – Final Report*, publication details not known.
- Burns, K., Walker, D. and Hansard, A. 1999, *Forest Plantations on Cleared Agricultural Land in Australia: A Regional Economic Analysis*, ABARE Research Report 99.11, Canberra.

- Canberra Times 1999, 'Forest shoots for the canopy', article in *The Canberra Times*, 12 August 1999.
- Carr, D. 2001, letter from David Carr, Greening Australia, to Charlotte Keller, RIRDC, regarding CAL 4A, 18 October 2001.
- CIE (Centre for International Economics) 1998, *Benefit-Cost analysis of RIRDC's Emerging Industries Program*, RIRDC Publication No. 98/104, Canberra.
- 1995, *Commercial Farm Forestry in Australia, Development of a Strategy Framework*, prepared for RIRDC, 1996.
- Coram, J 1998, *National classification of catchments for land and river salinity control*, RIRDC publication number 98/78, Canberra.
- Crammond, P 1999, *An Investigation of Aleppo Pine for Low Rainfall Farm Forestry*, RIRDC Publication No 99/16, Canberra.
- CSIRO 2002, *Species Catalogue*, unpublished RIRDC report from project CSF 56A.
- Davis, S. 2000a, 'DAV-129A' email from Sharon Davies, RIRDC, to Justin Wong, researcher, including project review notes (external reviewer not noted), 18 April 2000, RIRDC file R97/53.
- 2000b, 'RE: RIRDC Project CSF 57A: Conifers for the dry country', letter from Sharon Davis, RIRDC, to David Spencer, CSIRO, 4 July 2000, ref 99/56.
- 1999, 'RE: RIRDC Project No. DAV 129A: Forecasting tree growth and yield and financial returns of key agroforestry species across southern Australia', letter from Sharon Davis, RIRDC, to Tom Baker, Centre for Forest Tree Technology, 7 October 1999, ref 97/53.
- Freischmidt, G., Terrill, S., Pereira, A., Reilly, M. and Collins, P. 2001, *Oriented Strandboard: Farm forestry information support project 13b*, unpublished RIRDC report from project CSF 56A.
- Harper, R. 2000, *Progress Report to RIRDC: Cal 4A*, ref 99/56.
- et al 2001a, *The Australian Farm Forestry Site Selection Manual*, unpublished RIRDC report from CAL 4A, Canberra.
- Hicks, C. and Clark, N. 2001, *Pulpwood quality of 13 eucalypt species with potential for farm forestry*, RIRDC publication No 01/164.
- Hingston, F. (ed), *Evaluating the effect of soils and climate on productivity of Eucalyptus Globulus plantations on contrasting site in south west of Western Australia*, RIRDC Publication for project CSF 41A, Canberra.

- James, R. 2001, *Defining the Product: Log Grades Used in Australia*, RIRDC Publication No. 01/161, Canberra.
- Jovanovic, T. and Booth, T. 2002, *Improved species climatic profiles*, Unpublished RIRDC report from project CSF 56A.
- Lamb, D. and Borschmann, G. 1998, *Agroforestry with High Value Trees*, RIRDC, LWRRDC and FWPRDC Joint Venture Agroforestry Program, project no. UQ-18A, RIRDC publication no. 98/142, Canberra.
- Lloyd, S. 2001, *Revegetation Information and Training Needs of Western Australia's Extension Intermediaries: A qualitative and quantitative market research assignment*, prepared for NHT (National Heritage Trust) Department of Agriculture, February 2001.
- Lowry, B.J 2000, *Trees for wood and animal production in northern Australia*, RIRDC, LWRRDC and FWPRDC Joint Venture Agroforestry Program, project no CSC-58A, Canberra.
- 1997a, 'Dual purpose trees for agroforestry', *Rural Research* 175, Winter 1997.
- and Seebach, J. 1997b, *The Potential for Tropical Agroforestry in Wood and Animal Feed Production*, RIRDC, LWRRDC and FWPRDC Joint Venture Agroforestry Program, RIRDC publication no. 97/73, Canberra.
- MDBC (Murray Darling Basin Commission) 1999, *Murray Darling Basin Salinity Audit*, Canberra.
- NDSP (National Dryland Salinity Program) 2002, Costs of salinity
<http://www.ndsp.gov.au/>. Site accessed 9 August 2002.
- NLWRA (National Land and Water Resources Audit) 2002, *Australians and natural resource management 2002 – social and economic dimensions of natural resource management based on natural resource accounting and a social profile of Australia*. Canberra.
- 2000, *Australian dryland salinity assessment 2000. Extent, impacts, processes, monitoring and management options*, Canberra.
- O'Connell, D. 2001, 'Review of The Australian Farm Forestry Site Selection Manual (Harper et al.)', letter from Deborah O'Connell, reviewer, to Sharon Davis, RIRDC, 29 January 2001.
- Race, D. and Robins, L. 1998, *Farm Forestry in Australia: A Research Update (Volume 1)*, RIRDC Publication No. 98/103, Canberra.
- Reid, R. and Stephen, P. 2002, *The Master Treegrower Program 1996-2001: Development, Delivery and Impact of a National Outreach and Education Program*, RIRDC, Canberra.

- Reid, R. 2001, 'Review of CAL –4A: The Australian Farm Forestry Site Selection Manual', an email to Sharon Davis, RIRDC, 23 July 2001.
- 1999a, 'Integrating farm forestry into your property: a framework for the development of appropriate farm forestry and agroforestry designs', *Trees and Natural Resources*, June 1999, pp 24-27.
- and Stephen, P (eds) 1999, *The Farmer's Log 1999*, RIRDC Publication No. 99/81, Melbourne.
- Research and Development Project Agreement 1999a, between RIRDC and CSIRO Forestry Products, *CSF 56A: Seed and information support for farm forestry*.
- 1999b, between RIRDC and CSIRO Forestry Products, *CSF-57A: Conifers for the Dry Country*.
- 1997, between RIRDC and the Centre for Forest Tree Technology, *DAV 129A: Forecasting tree growth and yield, and financial returns of key agroforestry species across southern Australia*.
- 1996, between RIRDC and Forestry South Australia, *PIF 1A: Species Selection Database*.
- 1993, between RIRDC and CSIRO Forestry Products, *CSF 44A: Collection of Tree Performance Data*.
- 1990, between RIRDC and CSIRO Forestry and Forest Products, *CSF 41A: Evaluating the Effect of Soils and Climate on Productivity of Eucalyptus Globulus Plantations on Contrasting Sites in the Southwest of Western Australia*.
- REX (Revegetation Expert) 1995, RIRDC database from project CAL 1A, floppy disk format, Canberra.
- RIRDC (Rural Industrial Research Development Corporation) 2001, *Farm Forestry in Australian Rural Communities*, short report no. 103, summary of a full report *Socioeconomic impacts of farm forestry* by Matthew Tonts, Colin Campbell and Alan Black, publication no. 01/045 DAW-70A, Canberra.
- Sewell, A.J. 1997, *Australian Timbers, Volume 1: Commercial Timber Species of Eastern Subtropical Australia*, Department of Natural Resources, Queensland.
- Shea, S., Butcher, G., Ritson, P., Bartle, J., and Biggs, P., 1998, *The potential for tree crops and vegetation rehabilitation to sequester carbon in Western Australia*. Paper presented at the Carbon Sequestration Conference, Melbourne, October 1998
- Spencer, D. 2001, *Conifers in the Dry Country*, RIRDC Publication No. 01/46, Canberra.

- Stirzaker, R., Vertessy, R. and Sarre, A. (eds) 2002, *Trees, water and salt: An Australian guide to using trees for healthy catchments and productive farms*, RIRDC Publication No. 01/086, Canberra.
- Vercoe, T. and Clarke, B. 1996, *Trees for South – Eastern Australia*, RIRDC publication no. 96/5, Canberra.
- Virtual Consulting Group 2000, *National Investment in Rural Landscapes: An investment scenario for NFF and ACF*. Prepared by Virtual Consulting Group in associated with Griffin NRM Pty Ltd. April 2000
- WA Salinity Task Force, 2001, *Salinity: a new balance*, report of the Salinity Taskforce established to review salinity management in Western Australia, September 2001.
- Warden, P., Pereira, A. and Reilly, M. 2002, *Cement Board: Farm forestry information support project 13b*, Unpublished RIRDC report from project CSF 56A.
- Washusen, R. and Reid, R. 1997, *Agroforestry and Farm Forestry: Productive trees for shelter and land protection in North East Victoria*, place of publication unknown.
- Webb, M.J. 2001b, 'Site assessment for farm forestry in Australia ad its relationship to scale, productivity and sustainability', unpublished transcript from *Journal of Ecological Management*.
- and Reddell, P. 2000, *Demonstration of the potential effects of nursery nutrients – Tropical Cabinet Timber Trees*, RIRDC, LWRRDC and FWPRDC Joint Venture Agroforestry Program, project no. CSL-6A, RIRDC publication no. 00/119, Canberra.
- Wilson, S.M. and Tran, Y.D. 1995, 'Trees on farms', in ABARE Farm Surveys Report, Canberra, pp. 83-5.
- Wong, J., Baker, T., Duncan, M., McGuire, D. and Bulman, P. 2000, *Forecasting Growth of Key Agroforestry Species in South-Eastern Australia*, RIRDC Publication No. 00/68, Canberra.
- Wood, M.S et al 2001, *Plantations of Australia*, a report from the National Plantation Inventory and the National Farm Forestry Inventory, National Forestry Inventory, Bureau of Rural Sciences, Canberra.
- Zorzetto, A and Chudleigh, P. 1999, *Commercial Prospects for Low Rainfall Agroforestry*, RIRDC Publication No. 99/152, Canberra.

Personal communications

- Annandale, M., Queensland Forest Research Institute, 22 April 2002.
- Booth, T. 2002, Personal Communications, 17 May 2002.
- Harper, R 2002, Personal Communication, 26 April 2002.

Harrison, S., University of Queensland, Brisbane, 22 April 2002.

Lamb, D., University of Queensland, Brisbane, 22 May 2002.

Lowry, B., Researcher (retired), CSIRO, Brisbane, 22 May 2002.

Reid, R. 2002, Personal Communication, 15 May 2002.

Reid, R., Melbourne University, personal communication, 24 April 2002.

Sexton, G., Community Rainforest Re-forestation Program, 7 May 2002.

Vercoe, T. 2002, Personal Communication, 30 April 2002.

Warner, A., Private Forests Tasmania, 8 May 2002.

Wong, J 2002, Personal Communication, 29 April 2002.