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An Economic Analysis and Cost Sharing Assessment for Dryland Salinity Management

A Case Study of the Lower Eyre Peninsula in South Australia

A Report to
Primary Industries and Resources, South Australia

Prepared by
Stefan Hajkowicz and Mike Young

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REPORT SUMMARY

- This report has two components. Firstly, it discusses issues relating to cost sharing for dryland salinity management. Secondly, it presents an economic analysis and cost sharing assessment of six dryland salinity management options for the Lower Eyre Peninsula (LEP) in South Australia.
- The management options are based on a recent study of the Wanilla Catchment (within the LEP) by Stauffacher *et al.* (2000). These options involve different revegetation and land-use scenarios in the catchment over a 20 year period. The major trade-off posed by each scenario is the amount of cropping land revegetated against the additional land prevented from becoming salt affected.
- Options are explored first for the Wanilla Catchment (where there are few off-site impacts on infrastructure and urban water users) and then for the entire lower Eyre Peninsula.

Cost sharing

- Cost sharing mechanisms are often proposed when there are significant public benefits for a project and when the private costs of the project are much greater than its private benefits. Cost sharing provides a means for multiple stakeholders to receive benefits that would otherwise be unattainable.
- The key challenge in setting up a cost sharing arrangement is to find a logical basis for the distribution of costs amongst the stakeholders. This need not necessarily imply that each stakeholder pays an equal amount of the cost. Some stakeholders will stand to make greater gains than others. The extent and nature of individual rights, duties of care and community obligations need to be considered.
- The primary economic tool for assessing the costs and benefits for each stakeholder is benefit cost analysis (BCA). It provides a framework to assess whether a proposed action is in the interests of project investors. In the case of dryland salinity, the Nation as a whole, the State of South Australia, the local community and individual landholders may be interested in investing in a project. A BCA returns a net present value (NPV) for the project being evaluated. The NPV can be thought of as the total

project benefits minus the total project costs. If the NPV is negative the project costs exceed the benefits and the project is not desirable from an economic perspective.

- The cost sharing process proposed in this report applies BCA to determine the NPV for the landholder ($NPV_{landholder}$) and the NPV for society ($NPV_{society}$) of a dryland salinity management project. Initially, the process includes only market goods and services in the BCA. Non-market (intangible) goods and services include items such as biodiversity and landscape aesthetics are not included in the initial analysis. Once the NPV of net market benefits have been calculated, the question of whether or not there are sufficient non-market benefits to justify the project can be asked.
- When the value for $NPV_{landholder}$ is less than zero, the landholder will need to find additional investors for the project to be worthwhile. For example, agroforestry on a landholder's private land will produce costs and benefits for the landholder. Where the costs exceed the benefits, it will be necessary for the shortfall to be covered if the landholder is to undertake the agroforestry project.
- Government, through programs such as the Natural Heritage Trust, must decide whether the cost sharing or investment is in the interests of society. It can do this by also undertaking BCA on the proposed project giving consideration only to market goods and services. Typically the value for $NPV_{society}$ will also be negative. The key policy question for government is whether the non market benefits (eg biodiversity, landscape aesthetics) exceed the shortfall. If they do then cost sharing may be in the interest of society.
- The landholder's duty of care is an important issue in the cost sharing framework. This represents the minimum environmental performance standards which society demands of land management activities. In general, government should not enter into cost sharing arrangements which enable a landholder to avoid duty of care obligations. This suggests that cost sharing is only justifiable for actions that go above and beyond the duty of care. Duty of care is an evolving concept that changes with time and experience.
- This represents an approach to cost sharing which can be used to assess whether projects with negative net private, but significant net public, benefits should be funded by government.

Lower Eyre Peninsula

- Two case study regions were used in this study. The first of these is the Wanilla Catchment located on the LEP in South Australia. The second case study region is the LEP basin which covers the Wanilla Catchment. Both case study regions are shown in figure 3 (page 20). Two case study regions were used to enable extrapolation of the Wanilla model to a larger region. This enabled consideration of broader policy implications of the detailed biophysical modelling undertaken for the Wanilla Catchment by Stauffacher *et al.* (2000). The management options are listed in the table below.

Table A. Dryland salinity management scenarios for the Wanilla Catchment (Stauffacher *et al.* 2000).

Scenario	Upper Catchment Land Use	Lower Catchment Land Use	Reduction in current recharge (%)
Status-quo	Retain existing land-use	Retain existing land-use	0%
A	Retain existing trees Replace current farmland with: 100% trees	Retain existing trees Replace current farmland with: 50% crops 50% shallow-rooted lucerne	49%
B	Retain existing trees Replace current farmland with: 50% trees 25% crops 25% shallow-rooted lucerne	Retain existing trees Replace current farmland with: 50% crops 50% shallow-rooted lucerne	33%
C	Retain existing trees Replace current farmland with: 100% trees	Retain existing trees Replace current farmland with: 50% crops 50% deep-rooted lucerne	59%
D	Retain existing trees Replace current farmland with: 50% trees 25% crops 25% deep-rooted lucerne	Retain existing trees Replace current farmland with: 50% crops 50% deep-rooted lucerne	47%
E	Retain existing trees Replace current farmland with: 100% trees	Retain existing trees Replace current farmland with: 50% trees 25% crops 25% shallow-rooted lucerne	74%

F	Retain existing trees Replace current farmland with: 50% trees 25% crops 25% shallow-rooted lucerne	Retain existing trees Replace current farmland with: 50% trees 25% crops 25% shallow-rooted lucerne	42%

- An economic model was constructed for this study using spreadsheets and geographic information systems (GIS). The major components in the design of the model involved:

  1. Developing a relationship between recharge reduction and salt affected area in 2020. This enabled an assessment of how the salt area changed over time and how much land was lost or gained for agricultural production. The technique developed built upon work by Stauffacher *et al.* (2000).
  2. Identifying gross margins for pasture and crop production. These were used to calculate the returns from crop and pasture land-uses in each year. The main source were gross margin booklets produced by the Primary Industries and Resources department of South Australia. Additional information was obtained from previous benefit cost studies in the Tod River Catchment which is also on the LEP.
  3. A technique for determining yield decline in land areas surrounding a salt patch was developed. This provided a more realistic model than the 'all-or nothing' approach. The model assumes that relative crop yields are reduced by 50% in an additional 10% of land surrounding a salt patch.
  4. Impacts of saline water and road maintenance were determined based on previous studies conducted in the Murray Darling Basin (GHD 1999, Wilson 1999).
  5. A discount rate of 8% was used in all economic analyses. This is in keeping with previous BCA studies of a similar nature.
  6. Sensitivity analysis was conducted to assess the robustness of each key assumption.

Conclusions

- The results of the models indicated extremely large negative NPVs for each dryland salinity management option. Based on the results obtained the dryland salinity management options proposed by Stauffacher *et al.* (2000) are not economically feasible. The most significant results for the case studies are shown in tables 7, 8 and 9 on pages 37 and 39.
- For the most favourable option to break even, the value of the non-market benefits (eg biodiversity, drinking water quality) of dryland salinity control would need to be around a minimum of $173m for the LEP basin and $10m for the Wanilla Catchment. If these benefits accrue only to people living in the LEP region, each household (of which there are roughly 6,600) would have to contribute roughly $26,600 or $2,500 per year over 20 years. Costs of this magnitude would need to be carefully considered against other options for avoiding the negative impacts of dryland salinity.
- For the LEP, results suggest that broad-scale revegetation for dryland salinity management is not economically feasible given returns expected from the current options. There may, however, be site specific situations where targeted remedial works will deliver benefits which exceed costs. Similarly, dryland salinity management options will become more attractive if more profitable land-uses designed to reduce recharge are identified.
- These results have some implications for other parts of Australia but may differ if a major population centre such as Adelaide was incorporated into the study region. A large population such as Adelaide's would mean that infrastructure costs of salinity problems would rise dramatically. This would have the effect of increasing the NPV values for the management options and their economic feasibility.

ACKNOWLEDGEMENTS

This study has been greatly enriched by the generous support and assistance of many people. During March 2000 a series of productive meetings were held with land managers on the Lower Eyre Peninsula to help us better understand the research question. In particular we would like to thank David Davenport, Geoff Edwards, Mark Sindicic, Lindsay Fulloon, Rachel May, Ben Hyde, Simon Bey and Alan Piper for their assistance at these meetings. They all freely lent highly valuable knowledge and insights into the issue of dryland salinity management. We would also like to thank Andrew Bradford, Mirko Stauffacher, Glen Walker and Iain Jolly of CSIRO Land Water for helping us interpret the biophysical studies of dryland salinity and for making available valuable datasets. We would like to thank Mike Read for working with us on this project and his insights into economic aspects of dryland salinity management. Lastly we would like to thank Dave Pannell for reviewing the final draft (along with several others mentioned above) and providing detailed and helpful comments which added much value to the final report.

Whilst we are most grateful for the assistance of these people in compiling this report decisions relating to its content were made by the authors and therefore the responsibility for any errors or oversights rest solely with the authors.

CONTENTS

INTRODUCTION

As awareness of the dryland salinity problem is growing, so too is the pressure on government to take remedial action. However, as yet few studies have been undertaken to determine the cost burden placed on society or to evaluate the economic desirability of remedial works. This report looks at these issues on the Lower Eyre Peninsula. It commences with a discussion on cost sharing. This discussion deals with the fundamental principles, which guide a cost sharing arrangement, and proposes a framework which can be used for assessing cost sharing arrangements.

Following the discussion of cost sharing arrangements, the report presents a case study of economic issues relating to dryland salinity management on the Lower Eyre Peninsula in South Australia. The case study draws upon biophysical modelling undertaken by Stauffacher *et al.* (2000). The biophysical model identifies six management options for controlling dryland salinity in the Wanilla Catchment. These options involve different revegetation and land-use scenarios in the catchment over a 20 year period. The major trade-off posed by each scenario is the opportunity cost of land used for revegetation against the benefits from preventing additional land from becoming salt affected.

Through the use of a benefit-cost analysis (BCA) framework the economic desirability of catchment management options are appraised from landholder and social perspectives. This provides information on the level of cost sharing required by governments to make the management scenarios worthwhile for both landholders and society.

Some significant policy implications arise from this report. These relate to the economic desirability of widespread catchment revegetation schemes in order to address problems of dryland salinity. Whilst the findings of this report cannot be applied in other regions without significant qualification, they do have some relevance to broader issues of dryland salinity management.

The report is broken up into two sections. Section A describes cost sharing and proposes a cost sharing framework. Section B presents case studies on dryland salinity management on the Lower Eyre Peninsula. The case studies are based on the cost sharing framework proposed in section A. At the conclusion of section B the policy implications of this study are discussed. The final sections identify limitations of the model and highlight requirements for further research and investigation into the management of dryland salinity.

SECTION A: COST SHARING

Many of the on-ground works required to correct problems caused by dryland salinity are not financially attractive to individual landholders. This is because they will typically have mostly social benefits (eg biodiversity, improved water quality, reduced extent of salt affected land) but largely private costs (eg costs of revegetation). A solution is for government, on behalf of society, to invest in on-ground works so that the social benefits are realised. However, the benefits from on-ground works can often be greater for landholders (on whose land the works are undertaken) than other individuals in society. The question then becomes how much investment (if any) is it appropriate for government to make in on-ground works so that society benefits.

This section of the report discusses the issue of cost sharing for on-ground salinity management works. It commences with a discussion on the purpose of cost sharing. This is followed by a section which deals with the issue of 'duty of care' in relation to cost sharing arrangements. Defining the duty of care is presented as a prerequisite for effective cost sharing arrangements. Related to the duty of care are the beneficiary pays principle and the polluter pays principle. These are described as alternative perspectives on the duty of care. Following this, the technique of benefit cost analysis is briefly described. This is the major economic tool used in cost sharing arrangements. It can be used to analyse the desirability for on-ground works from multiple stakeholder perspectives. The section on cost sharing concludes by proposing a process which could be applied on the Lower Eyre Peninsula.

Purpose of Cost Sharing

When two or more stakeholders stand to gain from a proposed action some form of cost sharing may be appropriate to ensure an equitable distribution of costs. Arguably, but depending upon the nature of social contracts, both stand to benefit so, for an efficient outcome when property right markets are imperfect, both should pay. The primary requirement for cost sharing is that the benefits should exceed the costs for each stakeholder group. If this requirement is not met, it would be irrational and against the best interests of the 'net loss' stakeholders to enter into a cost sharing arrangement.

Cost sharing is often advocated when a project or proposed action of some type is excessively costly if funded by one stakeholder alone. If such a project can be demonstrated to hold benefits for multiple stakeholders then cost sharing is a means of obtaining benefits from the project which still exceed the costs.

Cost sharing is essentially a process of bargaining and negotiation. There is no ’correct’ solution to a cost sharing problem and no analytical tool that can simply deliver an answer. The fundamental principle driving cost sharing arrangements is that each landholder will only be involved if they perceive their benefits to be greater than their costs. The amount offered must make the perceived net benefits positive.

Duty of Care

Society imposes environmental and social performance requirements on many industries. Examples of such requirements include maximum tolerable levels of pollution, thresholds for environmental health risks and habitat preservation. Meeting basic environmental and social performance requirements is seen as a fundamental requirement of the landholder or private enterprise. In other words, the enterprise has a *duty of care* to meet certain levels of performance. Failing to meet these levels of performance can potentially lead to litigation against the offending enterprise.

Generally, government should not expend public funds through cost sharing arrangements which relieve landholders of their duty of care. When assessing whether or not a proposed action is feasible the firm involved needs to factor any costs of meeting duty of care into its decision making. If the costs of meeting baseline duty of care requirements for an enterprise (eg cropping in a certain location) exceed that which can be met by the firm (eg landholder) the enterprise should not be undertaken. In general, it is unreasonable to expect society to cover the costs of meeting a duty of care. The duty of care represents the minimum performance standards demanded by society of an enterprise.

In practice the use of duty of care to guide cost sharing arrangements is unclear. Typically there exists much uncertainty regarding what represents a duty of care and what represents performance above and beyond society’s expectations. Does a landholder have a duty of care to preserve valuable natural habitat on their land? Does a landholder have a duty of care to limit groundwater accessions that cause dryland salinity? Both these actions will have a cost to the landholder and provide benefits to society. But is it reasonable for society to expect the landholder to meet these costs in full as part of their operation?

Deciding what represents a duty of care and what represents levels of environmental performance significantly in excess of that duty is a complex question. However, it must be addressed before cost-effective and consistent cost sharing arrangements can be developed. Once established cost sharing can be considered for on-ground works or other projects which increase performance beyond those minimum levels.

Currently, the performance requirements that collectively define each landholder’s duty of care for agricultural production are hard to identify. Developing such requirements is complex because they are likely to differ significantly in different agricultural regions and for different agricultural enterprises. The development of performance requirements also requires negotiations between government and industry groups to determine what is appropriate. Such negotiations can take considerable time because they have significant implications for the economic viability of enterprises under consideration and the performance of industry. Currently such requirements, where they exist, are defined in legislation, local government plans and regulations and, also in catchment plans. In the future, environmental management systems may also help to define duty of care.

Another major difficulty of identifying the duty of care for cost sharing is the likelihood of historical failures to understand long-term impacts. The classic case is tree clearing which in Australia's earlier agricultural history was encouraged. Duty of care defines the limits to current practice not historical practice. In most circumstances, current land managers have no duty of care for the correction of past mistakes which they themselves may not have made or may have made under the advice and support of government agencies.

Perspectives on Who Pays

Much of the literature on cost sharing identifies principles which guide the governments in setting the duty of care (eg MDBC 1996, Fargher and Moyle 1997, Kennelly 1989). Examples of these principles are the polluter-pays principle, beneficiary-pays principle, the beneficiary reimburses, and user-pays principle. In this report, it is argued that lines between the various 'who pays' principles actually define duty of care. The polluter-pays principle is at one end of the spectrum. If adopted the polluter pays principle would minimise the cost burden placed on government. Landholders would have a duty of care to correct any dryland salinity problems occurring on nearby properties. A failure to do so could lead to litigation and/or the application of disincentives.

At the other end of the spectrum is the beneficiary compensates principle. This principle implies that the land-holder has no obligation to improve the status-quo. Any change which improves the welfare of people other than the landholder must be paid for. One step back from here is the beneficiary pays principle where beneficiaries are called upon to pay for the “cost” of work done but not the “value” to them of the work done.

The issue as to whether government places high or low expectation on landholders to manage and correct salinity problems is an ethical and practical dilemma. As duty of care requirements are tightened agricultural enterprises become less profitable. However, relaxing the duty of care requirements will typically increase burdens on public monies.

The question of cost sharing cannot be resolved by simply adopting one of the 'who pays' principles. In reality, there is more likely to be a spectrum of positions along a duty of care continuum. This spectrum ranges from low duty of care to high duty of care. A low duty of care will relieve the landholder of pressures but place a higher expenditure requirement on public funds. Conversely, a high duty of care will place increased pressures on landholders whilst reducing the pressure on public funds. This trade-off is essentially an ethical dilemma usually resolved through negotiation and informed debate. The most common position taken is that of arguing that landholders should not pay costs greater than the benefits they expect to attain. Governments, as representatives of society, should, at least, pay for the cost of providing public benefits.

Figure 1 shows how costs to government and landholders vary along the duty of care spectrum. Ideally society would establish a point along this spectrum for each land management issue.

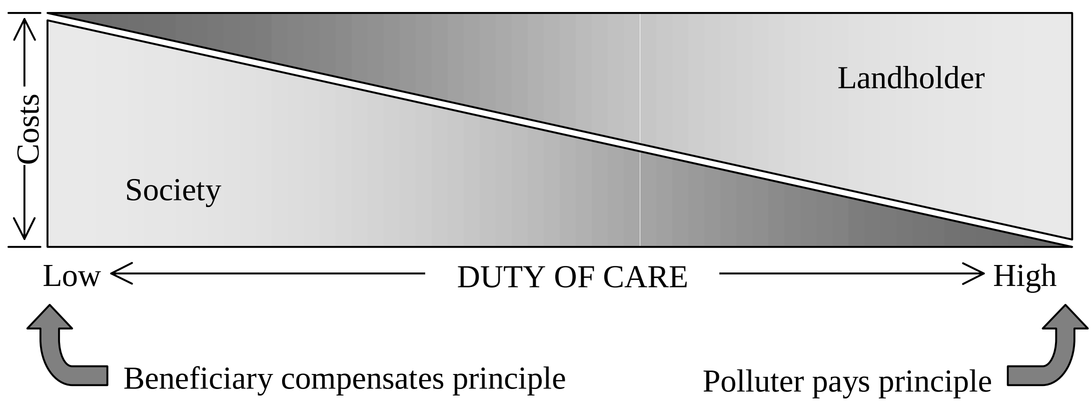


Figure 1. The duty of care spectrum used for cost sharing arrangements. The various 'who pays' principles represent viewpoints along the spectrum. A lower duty of care places a greater cost burden on society and a higher duty of care places a greater cost burden on landholders.

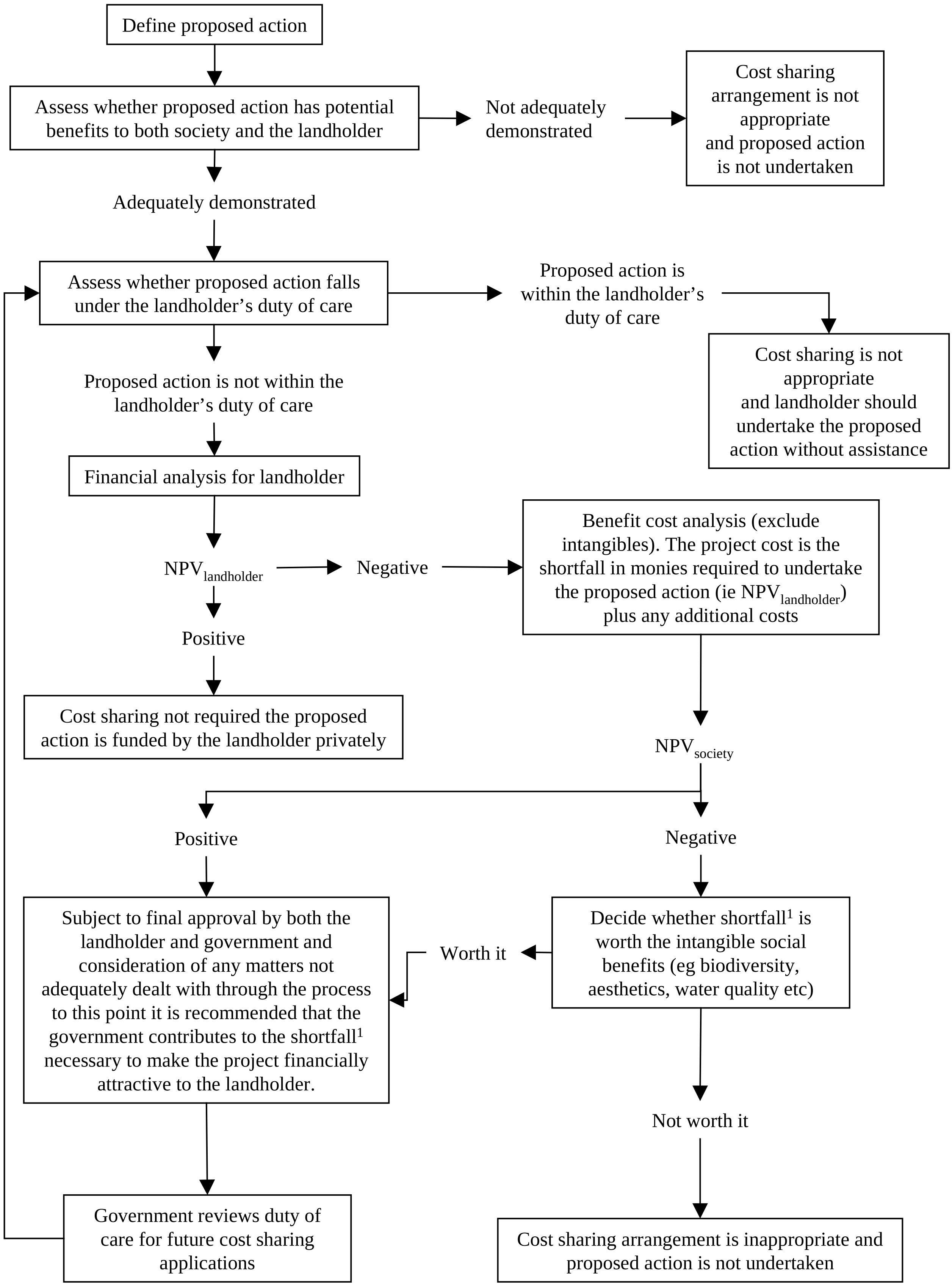
Proposed Cost Sharing Process

Processes for cost sharing become increasingly complex as the number of stakeholders increases. An acceptable simplification applied here is to assume the existence of only two stakeholders, the landholder and society (represented through government). This simplification works for the majority of government cost sharing decisions faced in programs such as the Natural Heritage Trust. The general question that must be addressed in cost sharing is: *Is it in the interests of society, as represented through a government department, to cover additional costs required to have landholders implement changed practices or on-ground works which lead to improved environmental quality above and beyond that which is required of them through their duty of care*?

The proposed cost sharing process is shown in figure 2. It is based on the application of financial analysis and BCA to assess the benefits and costs incurred by both the landholder and society. These techniques both involve the calculation of the net present value (NPV). For the purposes of this document the process of determining the NPV can be considered the same for both BCA and financial analysis. The NPV can be either positive or negative. It equals the total discounted value of project benefits minus the total discounted value of project costs. If a negative NPV is obtained the project costs exceed the benefits and it is economically not worthwhile. In this report the term NPV shortfall is used to make reference to the size of the NPV below zero, in other terms the value of the NPV multiplied by minus one (ie NPV shortfall = NPV * -1). This way it is possible to refer to a large or small NPV shortfall without confusion (it avoids having to refer to a large negative NPV).

The cost sharing process commences with a definition of the proposed activities. This should clarify their objectives, methods and expected results. A decision then needs to be made by both the landholder and government as to whether they will receive a clear benefit as a result of the proposed action. If either stakeholder considers that they will not benefit from the proposed activity then cost sharing is inappropriate. In this case the stakeholder which does perceive gain must consider the merits of the project without assistance from the other stakeholder.

The next major step is to consider whether the proposed activity falls under the landholder's duty of care. If it does cost sharing is inappropriate. On the other hand, if the proposed action is considered to be above and beyond the landholder's duty of care the NPV is determined for the landholder using financial analysis and the government using



1. The shortfall is the amount the landholder needs for the proposed action to become attractive. It equals the $NPV_{landholder} \times -1$.

Figure 2. A cost sharing process for dryland salinity management.

BCA. In both these analyses non-market (intangible) goods and services are not included. Due to difficulties associated with monetisation of non-market goods and services their inclusion can serve to blur and confuse a cost sharing arrangement rather than improve its clarity.

The NPV determined from the landholder through a financial analysis provides the next decision point as to whether cost sharing is necessary or not. If the NPV for the landholder is positive this means that they should be doing the project regardless of whether or not there is government assistance. This satisfies the principle that government should only enter into cost sharing agreements where necessary.

Assuming that cost sharing is not necessary when a financial analysis returns a positive NPV for the landholder has some important implications. Firstly, it means that society receives a 'free good'. By this stage in the proposed process government has already decided that society stands to gain some benefit from the proposed activities. Allowing the landholder to undertake the activity alone (even if it is in their own interests to do so) will result in society receiving some benefits but not covering any of the costs. Secondly, a positive NPV for the landholder may not necessarily lead to the proposed action being undertaken. This could be because the financial analysis was incomplete or inaccurate, there is a high level of risk or the landholder simply cannot obtain the necessary funds (even though their expenditure will lead to greater gains). Thirdly, it is noted that it would be rare to get to this point in the cost sharing procedure and obtain a positive NPV. Typically the need for cost sharing arises because the landholder does not perceive the proposed action to be sufficiently in their private interests. This means that we would typically expect a negative NPV to be returned from the financial analysis.

When the financial analysis does return a negative NPV it is necessary to conduct a social BCA. In this BCA the cost of the proposed activity is the shortfall in funds required by the landholder to undertake the proposed action plus any additional social costs. Social costs and benefits include any impacts that are in any way harmful or beneficial to society. This includes the benefits and costs accruing to landholders. In the BCA only market (tangible) goods and services are included.

If the NPV for society derived from the BCA is positive then the government, subject to consideration of any matters not adequately dealt with in the process to this point (eg availability of public funds for cost sharing), should pay the shortfall and undertake the proposed action. If the NPV is negative the government needs to consider whether the shortfall is worth the non-market (intangible) benefits. That is, the government decides whether the $NPV_{landholder}$ shortfall minus the $NPV_{society}$ shortfall is worth the intangible benefits. In the case where government does consider the shortfall to be worth the intangible benefits then, pending considerations of other matters, it should pay the shortfall and have the project funded.

SECTION B: LOWER EYRE PENINSULA CASE STUDY

This section of the report presents an economic analysis and cost sharing assessment of six options for dryland salinity management on the Lower Eyre Peninsula (LEP) in South Australia. The management options are derived from a recent biophysical study of the Wanilla Catchment, located within the LEP, by Stauffacher *et al.* (2000). Stauffacher *et al's* study sought to identify strategies for managing dryland salinity in the Wanilla Catchment which could be applied in other catchments with similar characteristics. Their study proposed six dryland salinity management options which involved revegetation strategies for different regions within the Wanilla Catchment. The report can be used to determine the area of salt affected land under each option by the year 2020.

The six salinity management options represent trade-offs between (i) the amount of potentially productive land sacrificed for revegetation and (ii) the amount of land prevented from becoming saline. This report considers the economic viability of each option compared against the 'do-nothing' scenario of maintaining current land management practices in the catchment. It also discusses the implications of the results found for the Wanilla Catchment in larger areas. This discussion is based on an extrapolation of the Economic-Biophysical Models for Wanilla to the larger LEP drainage basin.

Information was generated for this report using geographic information system (GIS) and spreadsheet models. The GIS was used to determine the current areal allocation of land-uses in the Wanilla Catchment and LEP basin. It was also used to identify the amount and location of infrastructure and vegetation. These data were then fed into a large spreadsheet model which determined the NPV and benefit-cost ratio (BCR) for each dryland salinity management option. Calculations were based on a 20 year period from 2000 to 2020. The main driving factors in the models were (i) the area of lost production for agroforestry (ie revegetation), (ii) the area of salt affected land lost or regained and (iii) the returns from agroforestry. In the case of the LEP basin infrastructure impacts on roads and saline water impacts on households were included. These impacts are not considered significant in the Wanilla Catchment.

The following section of the report describes the characteristics of the Wanilla Catchment and LEP basin. After this, six dryland salinity management options proposed for the Wanilla Catchment are described. The next two sections describe how the economic model was built and implemented. Following this, the results are presented and discussed. The final section details the limitations of the economic model and identifies directions for further research and investigation into the management of dryland salinity.

Case Study Description

Two case study regions were used in this investigation. The first of these is the Wanilla Catchment located on the LEP in South Australia. The second case study region is the LEP basin which covers the Wanilla Catchment. Both case study regions are shown in figure 3. Two case study regions were used to enable extrapolation of the Wanilla model to a larger region. This enabled consideration of broader policy implications of the detailed biophysical modelling undertaken for the Wanilla Catchment.

Both case study regions occur within the Eyre Peninsula region, the biophysical characteristics of which are described by Jeffrey and Hughes (1994). The Eyre Peninsula region has a Mediterranean climate with cool wet winters and hot dry summers. The mean annual rainfall in the south of the Eyre Peninsula region, where the Wanilla Catchment and LEP basin are located, is around 550mm/yr. In the Wanilla Catchment, the mean annual rainfall is 520 mm/yr (Stauffacher *et al.* 2000). During winter months mean maximum temperatures are usually around 16-17°C and in the summer they are around 24-25°C in most coastal regions.

The LEP basin covers three statistical local areas as used by the Australian Bureau of Statistics (ABS). These include the Lower Eyre Peninsula, Tumby Bay and Port Lincoln statistical regions. Table 1 lists the number of households, population and total value of agricultural production for each statistical region. The number of households was determined by summing the number of dwellings owned, occupied and rented in ABS data for 1996. In 1991 the major town centres were Port Lincoln (11,500 people), Tumby Bay (1,150 people), Cummins (750 people) and Coffin Bay (350 people).

In tables 2 and 3, agricultural statistics have been totalled for livestock and crops. It can be seen that the dominant form of livestock production is sheep and the dominant forms of crop production are wheat and barley.

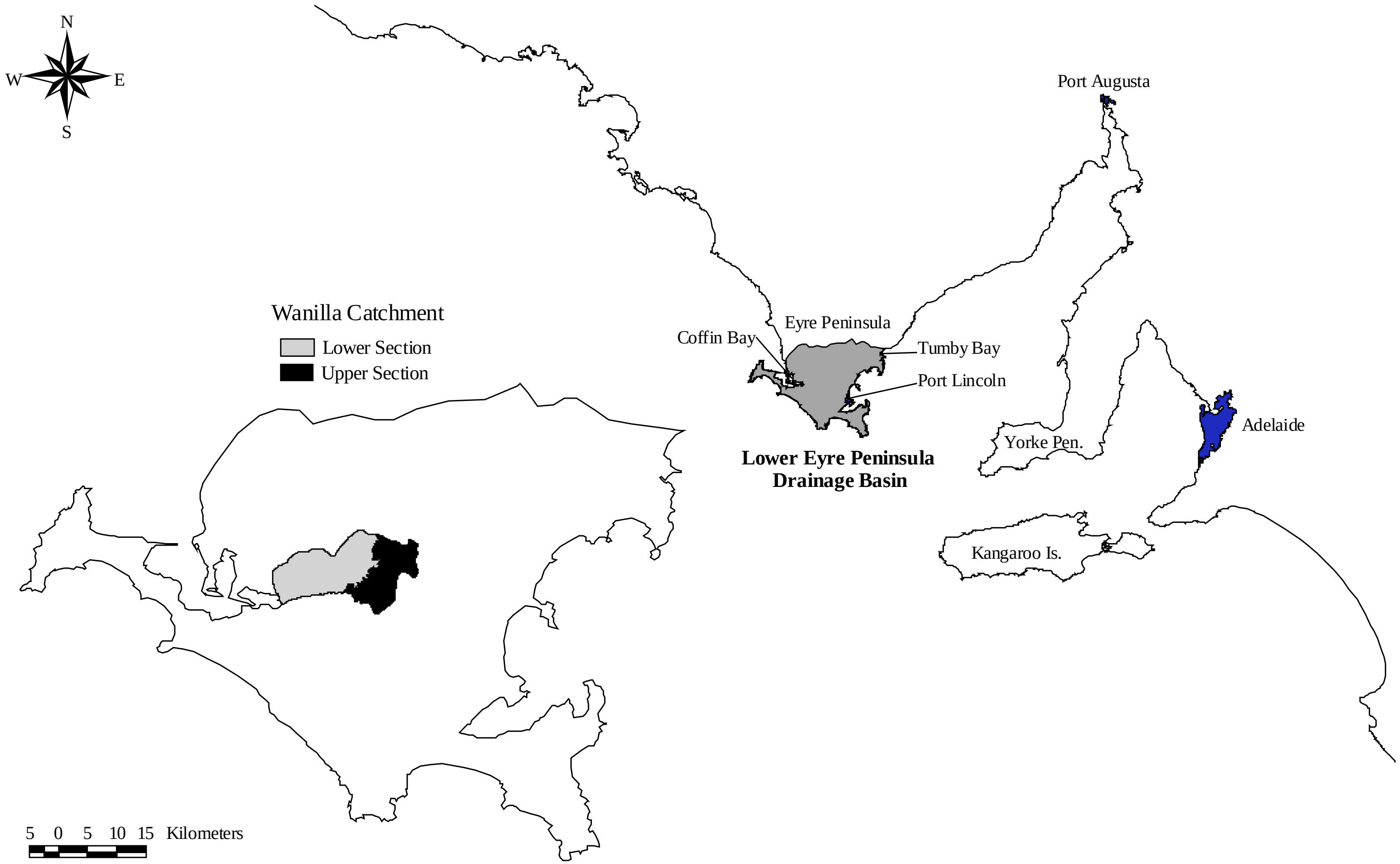


Figure 3. Location of the Wanilla Catchment and Lower Eyre Peninsula Drainage basin.

Table 1. Number of people and households for the three statistical local areas covering the Lower Eyre Peninsula based on the Australian Bureau of Statistics Integrated Regional Database.

Item	Lower Eyre Peninsula	Port Lincoln	Tumby Bay	Totals
Households	1,240	4,433	880	6,553
Population	3,860	12,181	2,553	18,594

Table 2. Gross value of livestock production ('$000) for the three statistical local areas covering the Lower Eyre Peninsula based on the Australian Bureau of Statistics Integrated Regional Database.

Item	Lower Eyre Peninsula	Port Lincoln	Tumby Bay	Total
Wool - value	8,274	245	5,268	13,787
Sheep and lambs slaughtered - value	2,888	47	2,321	5,256
Cattle and calves slaughtered - value	898	45	238	1,182
Pig slaughterings - value	422	-	302	724
Honey - value	104	55	-	159
Goats slaughtered - value	8	-	150	158
Beeswax - value	11	3	-	14
Milk - value	2	-	-	2
Total	12,607	395	8,279	21,281

Table 3. Gross value of crop production ($'000) for the three statistical local areas covering the Lower Eyre Peninsula in 1997 based on the Australian Bureau of Statistics Integrated Regional Database.

Item	Lower Eyre Peninsula	Port Lincoln	Tumby Bay	Totals
Wheat	21,164	101	29,745	51,010
Barley	15,068	119	14,858	30,045
Lupins	3,165	60	3,272	6,497
Canola	1,623	-	1,097	2,720
Triticale	563	10	702	1,275
Oats	466	26	436	927
Faba beans	588	-	313	901
Pastures (excl lucerne) cut for hay	177	2	73	252
Chick peas	106	-	41	148
Cut flowers	80	-	27	107
Vetches for seed	30	-	50	80
Lucerne cut for hay	4	-	56	59
Grapes	28	14	-	42
Almonds	10	-	-	10
Safflower	3	-	-	3
Totals	43,074	331	50,670	94,076

Wanilla Catchment

The Wanilla Catchment covers an area of approximately 16,800 ha (168 square kilometres). Problems of dryland salinity emerged in this region due to clearing of native vegetation during the 1950s (Richardson *et al.* 1994). The area currently affected by dryland salinity is roughly 8% (990 ha). This is expected to grow to an area of 15.3% by 2020 if current land management practices are continued (Stauffacher *et al.* 2000).

Land-uses within the Wanilla Catchment are allocated such that 15% (2,600 ha) is used for the production of cereal crops and 58% (9,800 ha) is devoted to pasture, leaving a remaining area of 4,400 ha (27%) which is mostly occupied by remnant vegetation. These land-use areas were determined from an interim land-use map produced by the Bureau of Rural Sciences in February 2000 as part of the National Land and Water Resources Audit.

The land-use map is a 1km Australia-wide grid which shows the dominant land-use within each grid cell. It was combined with a vegetation map for the Wanilla Catchment used by Stauffacher *et al.* (2000). Areas in the BRS land-use map classified as residual and not covered by vegetation were assigned to pasture. This led to the establishment of a 1km grid covering the Wanilla Catchment which coded each grid cell as either pastures, cereal crops or residual (mostly existing vegetation). This grid is shown in figure 4. The salinity management options for Wanilla are based on revegetation in the upper and lower sections of the catchment.

Lower Eyre Peninsula Basin

Dryland salinity over the whole LEP basin has not been subject to the detailed investigations which have occurred in the Wanilla Catchment. Therefore, some fairly brave assumptions are necessary. This study has assumed that the amount of land affected by dryland salinity in the LEP basin is proportional to that in the Wanilla Catchment (ie it is also 8%). It also assumes that the management options will lead to the same percentages of land being lost to salinity.

Land-uses in the LEP basin were determined from the BRS land-use map as used in the Wanilla Catchment. As with the Wanilla Catchment, each pixel was coded as either cereal crops, pasture or residual. The land-uses were assigned such that cereal crops cover 73,000 ha (23%), pastures cover 175,000 ha (54%) and the residual area is 734,000 ha (22%). Figure 4 contains a map showing the land-uses on the LEP basin. In order to model the revegetation scenarios used in the Wanilla Catchment, it was necessary to identify an upper and lower catchment. This was done by halving the area totals for the LEP basin. This approach assumes that the upper and lower catchments both cover 50% of the LEP basin and there is an equal break-up of land-uses in each. Other definitions are possible.

Revegetation for Recharge Control

A catchment can be divided up into areas of recharge and discharge. A recharge area is the region of the catchment within which water is absorbed into the soil and subsequently enters the watertable. A recharge area will typically have a higher elevation than other parts of the catchment. The discharge area has lower elevation and a higher watertable. It is the region of the catchment from which water is discharged into rivers and streams.

Dryland salinity can be tackled by addressing watertable problems recharge or discharge areas of the catchment.

The major cause of dryland salinity is the increase of recharge due to the clearance of deep rooted perennial native vegetation in order to make the land available for agriculture. Through the process of evapotranspiration native vegetation can have a significant effect in taking water from the soil and releasing it into the atmosphere. Removal of native vegetation means that the process of evapotranspiration is reduced and increased amounts of water will be entering the groundwater table.

As increased amounts of water enter the groundwater system the watertable will rise. The rise in the watertable mobilises salts, that occur naturally in the soil, taking them beneath the plant root zone and to the soil surface. This leads to the problem of dryland salinity. Crop yields in areas that are subject to the problem can be significantly reduced or crops may be unable to exist entirely. Severely affected areas are sometimes referred to as salt scalds or salt patches. Salinisation also means that water leaving the catchment is more saline. This can cause problems for downstream agricultural, domestic and commercial water users.

Re-establishing deep rooted perennial vegetation in recharge areas is widely regarded as the most reliable long term solution to the problem of dryland salinity. It tackles the cause of the problem rather than dealing with the symptoms which are predominantly evident in discharge areas. Richardson *et al.* (1994) indicate that in the Wanilla Catchment deep rooted perennial vegetation is the 'best-bet' for reducing recharge and consequently the area of salt affected land. However, there are many other effective means for controlling dryland salinity.

Identifying areas of recharge in a catchment is one of the major challenges of dryland salinity control (Peck 1993). Recharge areas will generally be at a higher elevation than other parts of the catchment. They will also typically have no surface water run-off and good internal drainage. Some recharge areas will have shallow soils over fractured rocks and be poorly vegetated due to poor retention of water in the plant root zone (Peck 1993).

Generally recharge areas in a catchment will cover areas of productive or potentially productive agricultural land. This creates a significant trade-off in the management of dryland salinity. The main benefits of revegetation will be the increased area of land

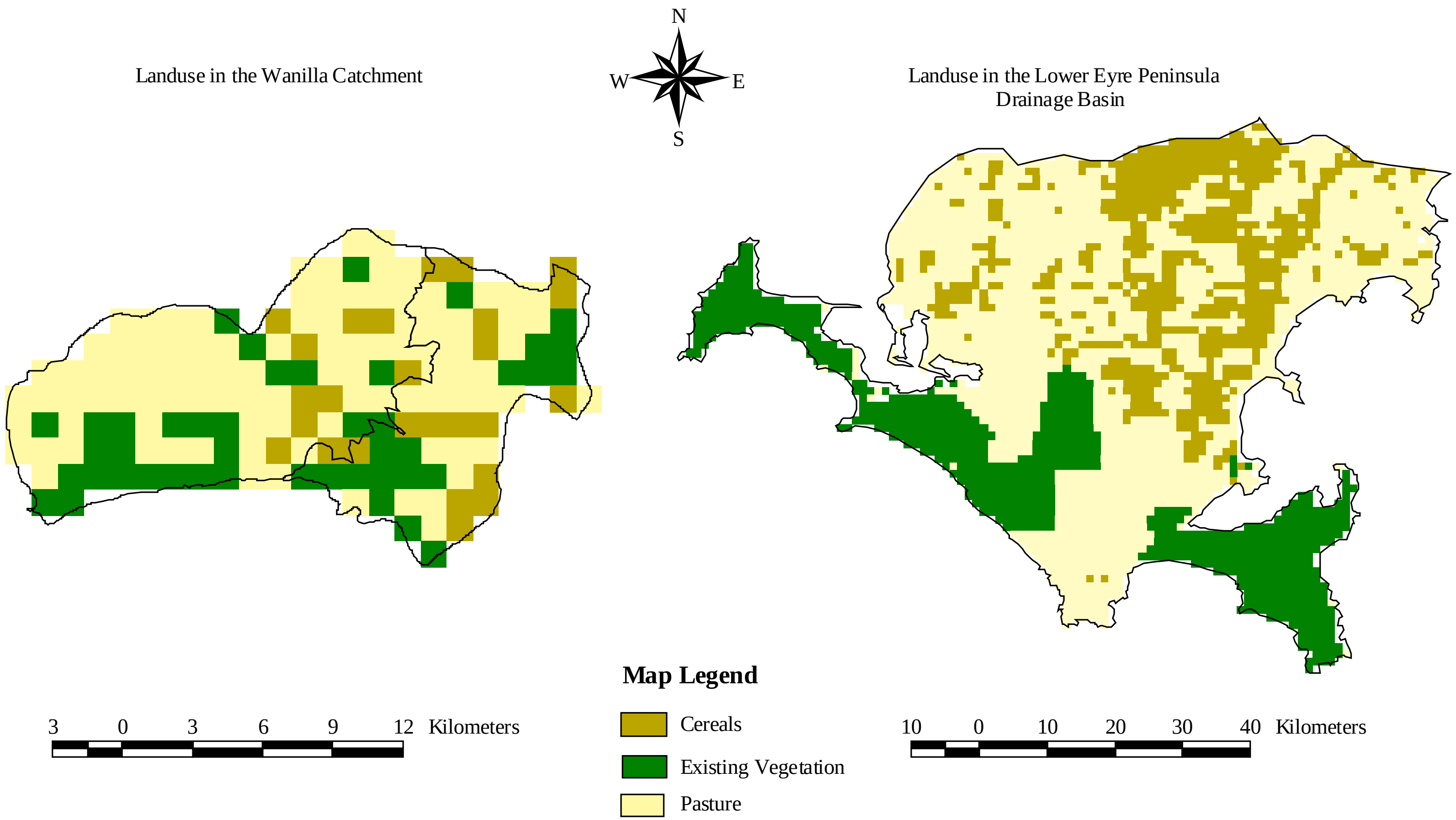


Figure 4. Land-uses on the Wanilla Catchment and Lower Eyre Peninsula Drainage basin. Derived from the Bureau of Rural Science's Interim Land-Use Map and overlay with vegetation data layers in a geographic information system.

prevented from becoming saline and the decreased salinity of water leaving a catchment. The costs will be the loss of agricultural land in recharge areas. These costs can be offset through the use of farm forestry (described in more detail later). Tree species used in farm forestry can reduce recharge rates whilst providing income, albeit in 10-30 years from the time of planting.

The major question faced in economic evaluation of revegetation for salinity control is whether the opportunity cost of losing current productive land-uses in recharge areas exceeds the benefits associated with decreased areas (and severity) of saline land in the future. It is necessary to apply complex and advanced biophysical models in order to generate information required to make this evaluation. Essentially, the biophysical models must indicate how the area affected by salt changes over time. Affects of this salt on production potential and infrastructure must then be modelled along with the likely impacts of alternative management options such as those likely to arise from dryland salinity.

Dryland Salinity Management Options

Stauffacher *et al.* (2000) identify six dryland salinity management scenarios for the Wanilla Catchment as listed in table 4. These management options involve changed land use scenarios in the upper and lower sections of the Wanilla Catchment. Each option leads to a given percentage reduction in current recharge rates. The percentage reduction in recharge is used to determine the salt affected area by 2020. A linear growth or decline in salt area is assumed to occur between now (2000) and 2020. Stauffacher *et al.* (2000) indicate that the management options can be used as a basis for other catchments with similar conditions to the Wanilla Catchment. In this study they are applied to the LEP basin which surrounds and covers the Wanilla Catchment.

Adopting any of the six management options leads to abandonment of the current catchment land-use and its replacement with an alternative scenario aimed at reducing recharge. Therefore, the opportunity cost of any option is equal to the profit that would have been derived from all current agricultural production in the catchment in each year over the 20 year period. It is an opportunity cost because the current agricultural production must be forgone to permit the new land-use pattern.

Each of the salinity management options leads to lower recharge rates than maintaining the status-quo. This means that each will produce the benefit of maintaining a larger area for agricultural production (less land is lost to salt) over the 20 year time period. However, recharge reduction is achieved through the establishment of vegetation on potentially or currently productive land. This incurs a cost. It is assumed that agroforestry is feasible for revegetation. This will provide some returns from land areas revegetated, but not until the trees can be harvested which typically takes a minimum of around 10 years. There is also the cost of establishing agroforestry which occurs in the first year. Essentially, each option involves a trade-off between the amount of area prevented from becoming salt affected and the amount of area lost to production for revegetation.

Within the Wanilla Catchment urban water salinity and infrastructure impacts are considered negligible. However, there are some significant infrastructure and saline water impacts in the larger LEP basin. These are considered additional cost items which affect the six management options and the status-quo option.

Table 4. Dryland salinity management scenarios for the Wanilla Catchment (Stauffacher *et al.* 2000).

Scenario	Upper Catchment Land Use	Lower Catchment Land Use	Reduction in current recharge (%)
Status-quo	Retain existing land-use	Retain existing land-use	0%
A	Retain existing trees Replace current farmland with: 100% trees	Retain existing trees Replace current farmland with: 50% crops 50% shallow-rooted lucerne	49%
B	Retain existing trees Replace current farmland with: 50% trees 25% crops 25% shallow-rooted lucerne	Retain existing trees Replace current farmland with: 50% crops 50% shallow-rooted lucerne	33%
C	Retain existing trees Replace current farmland with: 100% trees	Retain existing trees Replace current farmland with: 50% crops 50% deep-rooted lucerne	59%
D	Retain existing trees Replace current farmland with: 50% trees 25% crops 25% deep-rooted lucerne	Retain existing trees Replace current farmland with: 50% crops 50% deep-rooted lucerne	47%

E	Retain existing trees Replace current farmland with: 100% trees	Retain existing trees Replace current farmland with: 50% trees 25% crops 25% shallow-rooted lucerne	74%
F	Retain existing trees Replace current farmland with: 50% trees 25% crops 25% shallow-rooted lucerne	Retain existing trees Replace current farmland with: 50% trees 25% crops 25% shallow-rooted lucerne	42%

Benefits and Costs of the Dryalnd Salinity Management Options

The benefits associated with the dryland salinity management option include the returns from agricultural production and the reduced costs of infrastructure maintenance in each year. The returns from agricultural production are calculated from gross margins obtained from the different land uses. A gross margin is a 'dollars per hectare per year' figure which relates to a specific mode of agricultural production in a particular region or location. The gross margins used in this study are discussed below. Benefits resulting from reduced infrastructure maintenance were determined only for the LEP basin. The Wanilla Catchment did not have significant infrastructure impacts. The annual reduced cost of infrastructure maintenance is determined by:

- calculating the cost of infrastructure maintenance for each year under the status-quo option;
- calculating the cost of infrastructure maintenance for each year under each dryland salinity management option; and
- subtracting the infrastructure costs under the dryland salinity management option from the infrastructure costs under the status-quo option.

The costs of infrastructure maintenance will always be greater under the status-quo option because it has a larger area of salt affected land in each year than any of the management options. In the economic modelling discussed below, infrastructure costs are proportional to salt affected area.

The cost associated with each management option is the income forgone from not being able to continue current agricultural land uses in each year. This may be thought of as the opportunity cost of the salinity management option in terms of agricultural production potential forgone. Because this is the cost item used for each salinity management option it is not meaningful to determine an NPV or BCR for the status-quo. The status-quo has no opportunity cost of this type.

It is likely that additional benefits and costs exist. These have not been included due to the lack of available data or difficulties associated with measurement. For example, there are significant biodiversity impacts from dryland salinity in the Wanilla Catchment and throughout the LEP. Aquatic ecosystems and riparian vegetation are being damaged by highly saline water runoff. Due to a lack of knowledge surrounding these issues and due to problems of monetisation these costs and benefits have not been included in the analysis.

Economic Model Design

In constructing an economic model for this study, it was necessary to undertake several key tasks. Firstly, it was necessary to develop a relationship between recharge reduction and salt affected area in 2020. This enabled an assessment of how the salt area changed over time and how much land was lost or gained for agricultural production. Secondly, gross margins for pasture and crop production had to be determined. These were used to calculate the returns from crop and pasture land-uses in each year. Thirdly, it was necessary to determine a gross margin for agroforestry. The gross margin for agroforestry is used to determine the returns from revegetated areas. Fourthly, a technique for determining yield decline in land areas surrounding a salt patch was developed. This provided a more realistic model than the 'all-or nothing' approach. Fifthly, a technique to cost the impacts of saline water and road maintenance was required. Sixthly, it was necessary to segregate social and landholder benefits and costs. This enables an assessment of cost sharing requirements. Lastly, it was necessary to identify a discount rate to guide all economic analyses.

Relationship Between Recharge Reduction and Salt Area

The relationship between recharge reduction and salt affected area is based on the following statements in the report by Stauffacher *et al.* (2000): "*under a 50% reduction in recharge, the area* [in the Wanilla Catchment] *increases by the year 2020 to 11.7%*" and "*a 90% reduction is required to allow the possibility of recovering some already saline areas*". Given that 8% of the catchment is currently affected it is possible to develop a function which allows 'area affected in 2020' to be determined from 'recharge reduction'.

This function is shown in figure 5. It is a disjointed linear function separated at a 50% recharge reduction which corresponds to an 11.7% area affected in 2020. If necessary it may be acceptable to assume that the percentage recharge reduction equals the additional percentage area revegetated in recharge zones. However, this assumption was not needed in this study. The recharge reduction was already given by Stauffacher *et al.* (2000).

Given that the current area of dryland salinity in the Wanilla Catchment is 8% (and is assumed to be the same in the LEP) it is possible to determine the area of salt in each year up to and including 2020. This is done by assuming the increase in salt area over the 20 year period is linear. Land-Use in each year will be constrained by the size of the salt affected area.

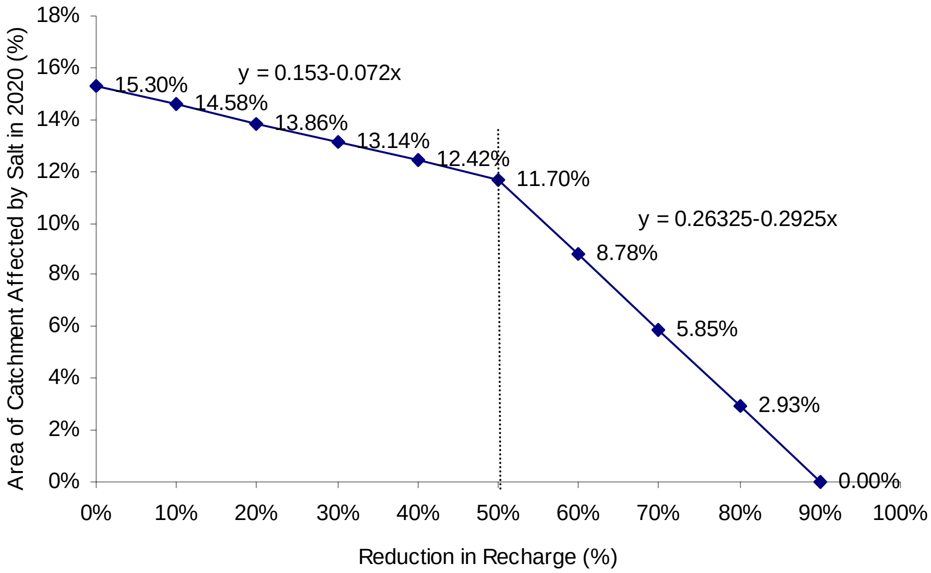


Figure 5. Assumed functional relationship between recharge reduction and the area of the Wanilla Catchment affected by salt in 2020.

Gross Margins for Pastures and Crops

The gross margin used for pastures were based on livestock gross margins issued by PIRSA. Sheep are by far the most significant form of livestock on the LEP. The gross margin booklets for the 400mm plus rainfall zone in South Australia indicate that (i) a stocking rate of seven sheep per hectare is attainable; (ii) with a gross price of $24 per sheep; and (iii) variable costs of production at $14 per sheep. This produces a gross margin of $70 per hectare. This is considered to be the value of pastoral land uses.

The gross margin for crops was based on the 1999/2000 "Crop Harvest Report" issued by PIRSA. An average was taken of the values for wheat and barley. This provides a yield of 3.05t/ha, gross returns of $164/t and variable costs of $178/ha. Using these values the gross margin for crops is $322/ha.

Gross Margin for Agroforestry

Several forms of agroforestry are potentially suited to the LEP region. These include a Eucalypt woodlot, Radiata pine forest, Wide-spaced eucalypt agroforest, Wide-spaced pine agroforest and Eucalypt firewood woodlot. Of these the Eucalypt firewood woodlot provides returns within the shortest time period. Eucalypt firewood woodlots provide returns around 10 years after planting. They are used to represent agroforesty in this study because they provide returns twice (once every ten years) within the 20 year planning period.

Values for timber yields and prices were derived from benefit cost analysis conducted for natural resource management projects in the Tod River Catchment (AACM 1998). These studies were based on an end product sold as firewood on-stump. They identify yield at maturity as 110 t/ha and revenue at $20/t. The establishment costs for a Eucalypt firewood woodlot are $880/ha with a minimum period before return of 10 years (Farm Forestry Note 1998).

Given these values it was possible to obtain a gross margin for agroforestry by calculating an annual annuity over a 20 year growing and harvesting period. Additional maintenance costs over this period mostly related to landholder labour. As this is not usually costed in other gross margins these costs were also set to zero in this study. Over the 20 year period, the establishment costs are only incurred once and harvesting is possible twice (at year 10 and year 20). This approach provides a gross margin of $68.87/ha/yr using the 8% discount rate adopted throughout the study. This is the gross margin used for agroforestry.

Determining Yield Decline Near Salt Affected Areas

Much of the biophysical modelling work on dryland salinity produces results which suggest that land is 'all or nothing' affected by dryland salinity. In reality, there is likely to be a gradual shift in the severity of dryland salinity from an area where there is no yield loss to an area where there is a high or complete yield loss. For the economic model used in this study, a decline in yield loss was assumed to occur in areas surrounding a salt patch. It was assumed that an additional 10% of land surrounding the salt affected area would have a relative yield of 50% as shown in figure 6. The relative yield is used to adjust the crop yields or sheep stocking rates in the gross margins described above.

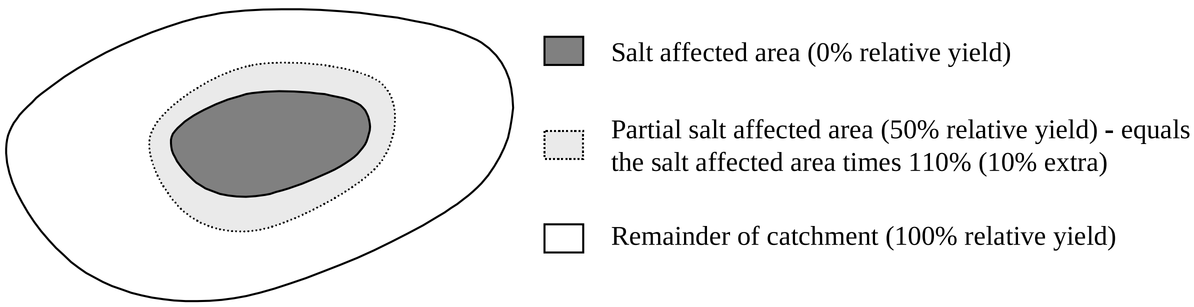


Figure 6. Method for modelling yield decline in areas surrounding a salt affected area.

In the case of agroforestry, this meant that the gross margin would be negative. Assuming that an enterprise is abandoned when the gross margin falls below zero (this need not necessarily always be the case) a gross margin of zero was assigned to agroforestry occurring in partial yield areas surrounding salt patches. Pasture and crop gross margins do not fall below zero but are significantly reduced.

Costing the Impacts of Saline Water

The cost impacts of salt in domestic water supplies were only considered in the LEP basin. The Wanilla Catchment has overland waterflow which does not have a significant impact on drinking water supplies. Most of the runoff from the Wanilla Catchment enters the ocean.

Wilson (1999) lists several functions for costing the impacts of saline water supplies to urban households. These functions were originally developed by GHD (1999) in a study aimed at costing the impacts of dryland salinity in the Murray Darling Basin. The cost functions use measurements of hardness and total dissolved solids (TDS), or just TDS where hardness is unavailable, to determine the extra costs of saline water to households. Table 5 lists these functions. As hardness measures were unavailable the functions using just TDS were used in this study.

Table 5. Functions for costing the impacts of saline water supplies (GHD 1999).

Cost ($/household/yr)	Function
Plumbing costs	Cost = 0.020 × TDS + 24 (where TDS < 262 mg/l) or
	Cost = 0.081 × TDS + 8 (where TDS > 262 mg/l)
Hot water heater cylinder costs	Cost = 0.051 × TDS + 73
Hot water heater relief valve costs	Cost = 0.0068 × TDS + 29.8
Hot water heater electrical element cost	Cost = 0.4 × (0.107 × TDS + 8.8)
Domestic filter costs	Cost = 0.25 × (0.035 × TDS + 5)
Rainwater tank costs	Cost = 0.25 × 0.018 × TDS
Domestic water softener costs	Cost = 0.048 × TDS

TDS = Total Dissolved Solids measured in mg/L

It was assumed that the increase in TDS over the 20 year period would be proportional to the increase in salt affected area. For example, if the salt affected area grew by 5% it was assumed that a TDS of 1000 mg/l in the year 2000 would be 1050 mg/l in the year 2020. Given this assumption, management scenarios which led to an increased salt area also led to increased costs from saline water supply.

The number of households in the LEP basin was determined from ABS statistics for the Port Lincoln, Tumby Bay and the Lower Eyre Peninsula statistical regions. For each of these regions, the ABS holds values for the number of dwellings that are fully owned, rented or being purchased (1996 data was used). By summing the number of dwellings in each of these categories and then summing for the three statistical local areas, the number of households in the LEP basin was determined to be 6,553. This enabled a total dollars per year figure to be estimated for each year over the twenty year period.

In order to apply the saline water costing functions it was necessary to identify current TDS levels within the LEP basin and the number of households being affected by those TDS levels. This was done using a recent study by Jolly *et al.* (2000). Amongst other objectives Jolly et al's study sought to assess stream/river salinity trends in South Australia. The study provided a set of TDS measurements currently affecting the LEP. The water supply sources for which TDS measures (for current conditions) are available include the Uley South Basin, Uley Wanilla Basin, Polda Basin and Lincoln Basin. Jolly et al's study also indicates the portion of the Eyre Peninsula receiving supply from these basins. Table 6 lists the supply basins, their current TDS levels, the portion of their supply to the LEP and the number of households using their supply. The number of households using the water supply was simply determined as a proportion of the total number of households on the LEP, which using the method described above is 6,553.

Table 6. Households affected by different water quality levels (measured using TDS in mg/L) in the LEP basin (based on Jolly *et al.* 2000).

Basin	Portion of Supply (%)[1]	Number of Households Affected[2]	TDS in mg/L
Uley South	50%	3277	500
Uley Wanilla	10%	655	500
Polda	5%	328	1000
Lincoln	10%	655	800
Remainder[3]	25%	1638	700

1. This is the portion of supply to the Eyre Peninsula. It is assumed to be the same for the Lower Eyre Peninsula drainage basin region used in this study.

2. A portion of the total number of households on the LEP basin which is roughly 6,553.

3. This is the remaining water supply not allocated to the Uley South, Uley Wanilla, Polda or Lincoln basins. It is assigned a TDS which is the average of these basins.

Because the supply percentages for each of the basins summed only to 75% it was necessary to identify a TDS for the remaining 25% of supply (and 25% of households). This was done by creating a 'remainder' category which had the average TDS for all other basins.

Road Maintenance Costing Technique

Wilson (1999) identifies cost impacts on affected roads occurring within dryland salinity affected areas as being $2,500/km/yr for main sealed roads, $1,500/km/yr for other sealed roads, and $800/km/yr for gravel roads. According to Wilson (1999) these estimates have not been widely applied and their accuracy is untested. However, there are few alternative approaches. For this study, the road data was not neatly classified as indicated above. Therefore the three cost impact measures were averaged and applied to all roads occurring in salt affected areas. This provided a cost impact measure of $1,600/km/yr.

The roads in salt affected areas were determined by using the GIS. A road database from SA Transport (supplied in 1999) was overlain with the LEP basin boundary. The total distance of roads in kilometres was then determined. The kilometres of road affected was then assumed to be proportional to the area of salt affected land. This value was multiplied by the $1,600/km/yr figure to obtain a cost impact on roads for each year in the 20 year period.

Segregating Landholder and Social Impacts

In order to facilitate cost sharing assessments it is necessary to determine whether the costs and benefits accrue to landholders or society in accordance with the cost sharing framework proposed earlier. In the case of the Wanilla Catchment the task was straight-forward. Here all tangible costs and benefits included in the BCA were assumed to accrue solely to landholders. This is because the only costs were land areas being lost from production and the only benefits were land being prevented from becoming salinised so that it could be used for agricultural production. No infrastructure impacts were identified in the Wanilla Catchment.

In the LEP basin, infrastructure impacts on roads and saline water impacts were included in the BCA. These impacts were assumed to represent benefits to society (not landholders). This means that in the LEP basin two sets of NPV and BCR values were calculated. One was for landholders and the other was for society.

Choosing a Discount Rate

Despite many research efforts there is still no definitive answer or foolproof method for identifying an appropriate discount rate to be used in economic analysis. The discount rate is a factor used to compare costs and benefits that occur in different time periods. It is usually expressed as a percentage. It is based on the notion that something of value is worth more to us now than it will be worth if we receive it in, say, 10 years time. The discount rate has strong implications for sustainable development and if it is high it can disadvantage future generations. As different people and social groups are likely to have different perspectives on what a discount rate should be, there is no single correct answer.

The discount rate used in this study is 8%. This is the same as that used in recent benefit cost analyses for natural resource management projects (AACM 1998) in the Tod River Catchment located within the LEP basin. Later in the study, this discount rate is systematically varied to determine its impact on the final results.

Results

Results obtained from the model indicate the NPV and BCR for each scenario obtained from a landholder and social perspective. They are presented in the following sub-sections for the Wanilla Catchment and LEP basin. An internal rate of return (IRR) which is often given in benefit costs analyses was not given because the cash flow was negative in each year.

Wanilla Catchment

As infrastructure costs were not included in the economic model for the Wanilla Catchment, the social BCA and landholder financial analysis are identical. For any of the scenarios to be suitable for cost sharing the intangible (non market) benefits to society must exceed the NPV shortfall. The NPV shortfall is the approximate amount which needs to be made available to landholders across the whole catchment in order to make the proposed scenario in their financial interest. Table 7 contains the NPV and BCR values for each catchment management scenario. The tables also list the area lost to salt under each scenario. In simplified terms, the policy question is whether the NPV shortfall is worth the intangible benefits associated with the area prevented from becoming salinised by 2020.

Where a management scenario performs worse on both NPV and on salt affected area in 2020 than another management scenario, it is considered dominated by that scenario. Unless other information becomes available which makes a dominated scenario more attractive it should not be considered in decision making. On this basis options A, B and F are dominated by other options and should not be considered in decision making for the Wanilla Catchment.

Table 7. Economic performance of the six dryland salinity management scenarios for the Wanilla Catchment over a twenty year period (2000-2020).

Scenario	NPV ($000)	BCR Ratio	Catchment Area Lost to Salt (%)	Catchment Area lost to salt (ha)	Dominated By Scenario*
Status-quo	*NA*	*NA*	15.30%	2,570	*NA*
A	-$12,468	0.570	11.77%	1,978	C
B	-$10,095	0.652	12.92%	2,171	D
C	-$12,270	0.576	9.07%	1,523	-
D	-$10,010	0.654	11.92%	2,002	-
E	-$16,578	0.428	4.68%	786	-
F	-$14,521	0.499	12.28%	2,062	A, C, D

* Where a management scenario performs worse on both NPV and on salt affected area in 2020 than another management scenario, it is considered dominated by that scenario. Unless additional information becomes available it should not be considered in decision making.

For all non-dominated scenarios it can be seen that the smallest NPV shortfall of roughly $10m is for option D which leads to 11.9% of the catchment being affected by salt in 2020. Option E will save the largest area of the catchment from becoming salinised with only 4.7% affected in 2020, although it also has the largest NPV shortfall of $16.6m. The NPV shortfall on option C is also very large at $12.3m. These results indicate that benefits from non-market goods/services and avoidance of infrastructure impacts resulting from dryland salinity in the Wanilla Catchment must have an extremely high value (of at least $10m over 20 years) to make any of the proposed management scenarios worthwhile for society.

LEP Basin

In the LEP basin infrastructure costs of saline water impacts and road damage were considered. This creates two sets of NPV and BCR values for each scenario. One set applies to the landholders across the entire basin and the other set applies to society. The benefit cost analysis includes the same benefits and costs for both landholders and society, except for society it also includes infrastructure damage costs. In order to make an alternative worthwhile for landholders, it would be necessary for society to cover the entire $NPV_{landholder}$ shortfall. The value of the intangible benefits associated with a scenario must be greater than the $NPV_{society}$ shortfall. Because of the inclusion of infrastructure costs the $NPV_{landholder}$ shortfall will always be greater than the $NPV_{society}$ shortfall.

Table 8 contains an economic assessment of the management scenarios from the landholder perspective (does not include infrastructure). Table 9 contains an economic assessment of the management scenarios from the perspective of society (includes infrastructure). The NPV shortfalls in table 8 represent roughly what the landholders across the entire LEP basin would need to be compensated in order to adopt the changed land-use patterns required by the management scenarios. The NPV shortfalls in table 9 represent what the non-market and any other benefits not included in the model must be worth to society over the 20 year period for a scenario to be worth funding. The main policy question for government is whether the intangible benefits exceed the NPV shortfalls when infrastructure is included.

From both the landholder and social perspectives options A, B and F are dominated. This means that consideration should only be given to options C, D and E. As would be expected these are the same options that were non-dominated in the Wanilla Catchment.

The option which would require the least amount of compensation for landholders across the LEP basin is option D with an NPV shortfall of $175m. However, it also leads to the largest area of salt affected land (11.9%) of the three non-dominated options. Option E requires the largest amount of landholder compensation at $307m but also has the lowest area of salt affected land (4.68%) of all six options.

Table 8. Economic performance of the six dryland salinity management scenarios from the perspective of landholders (infrastructure not included) for the Lower Eyre Peninsula basin over the twenty year period (2000-2020).

Scenario	NPV ($000)	BCR Ratio	Catchment Area Lost to Salt (%)	Catchment Area lost to salt (ha)	Dominated By Scenario*
0	*NA*	*NA*	15.30%	49,174	NA
A	-$243,915	0.543	11.77%	37,835	C
B	-$176,142	0.670	12.92%	41,538	D
C	-$240,429	0.549	9.07%	29,143	-
D	-$174,538	0.673	11.92%	38,298	-
E	-$306,528	0.425	4.68%	15,042	-
F	-$244,564	0.542	12.28%	39,455	A, C, D

* Where a management scenario performs worse on both NPV and on salt affected area in 2020 than another management scenario it is considered dominated by that scenario. Unless additional information becomes available it should not be considered in decision making.

Table 9. Economic performance of the six dryland salinity management scenarios from the perspective of society (infrastructure) for the Lower Eyre Peninsula basin over the twenty year period (2000-2020).

Scenario	NPV ($000)	BCR Ratio	Catchment Area Lost to Salt (%)	Catchment Area lost to salt (ha)	Dominated By Scenario*
0	*NA*	*NA*	15.30%	49,174	*NA*
A	-$242,332	0.546	11.77%	37,835	C
B	-$175,076	0.672	12.92%	41,538	D
C	-$237,633	0.555	9.07%	29,143	-
D	-$173,020	0.676	11.92%	38,298	-
E	-$301,764	0.434	4.68%	15,042	-
F	-$243,208	0.544	12.28%	39,455	A, C, D

* Where a management scenario performs worse on both NPV and on salt affected area in 2020 than another management scenario it is considered dominated by that scenario. Unless additional information becomes available it should not be considered in decision making.

As is to be expected the NPV shortfalls decrease when the social perspective, which includes infrastructure, is taken. This indicates that when infrastructure costs are included the management scenarios become more favourable. However, there is not much difference between the NPV values obtained with infrastructure and the NPV values obtained without infrastructure. This indicates that infrastructure does not have a major impact on the economic desirability of the dryland salinity management options. Even with infrastructure all management scenarios have NPVs well below zero and benefit cost ratios well below one. Of the non-dominated options, option D requires the lowest value (at least $173m) to be placed on non-market benefits in order to be worthwhile for society. In order for option E, the most costly option for government, to be worthwhile for society its non-market benefits need to be valued at least $302m.

Relative Income Streams

Figures 7,8 and 9 show the un-discounted stream of income before fixed costs of production over the 20 year period for the Wanilla Catchment, LEP Basin (without infrastructure) and LEP Basin (with infrastructure). These graphs compare the status-quo with each of the six dryland salinity management options. The graphs for the Wanilla Catchment and the two LEP Basin scenarios are similar. It can be seen that under each management option, except for option E, the benefits decrease over time. Over time the income received increases slightly for option E because it actually reclaims currently salt affected land. All other management options loose land to salt over the 20 year period.

The status-quo provides greater income in each year for all three graphs. The opportunity cost of each management option in any given year is the income associated with the status-quo minus the income associated with the management option. Extending the lines of the graphs beyond the 20 year period would identify a point where the status-quo curve intersects the curve associated with one of the management options. It would not be until this point in time that any of the management options would economically out-perform the status quo. However, it is unlikely that such a point would ever be reached. The catchment (or basin) is likely to reach equilibrium before this happens. At equilibrium the salt area ceases to increase significantly in each year.

Because the income from the status-quo exceeds the income from all the management options in each year, the effect of the discount rate may appear counter-intuitive. By increasing the discount rate the performance of each management option is improved (ie they obtain higher NPVs). Conversely, decreasing the discount rate will lead to worsened performance of the management options (ie lower NPVs). This can be seen in the sensitivity analysis presented in the next section (also see appendix A).

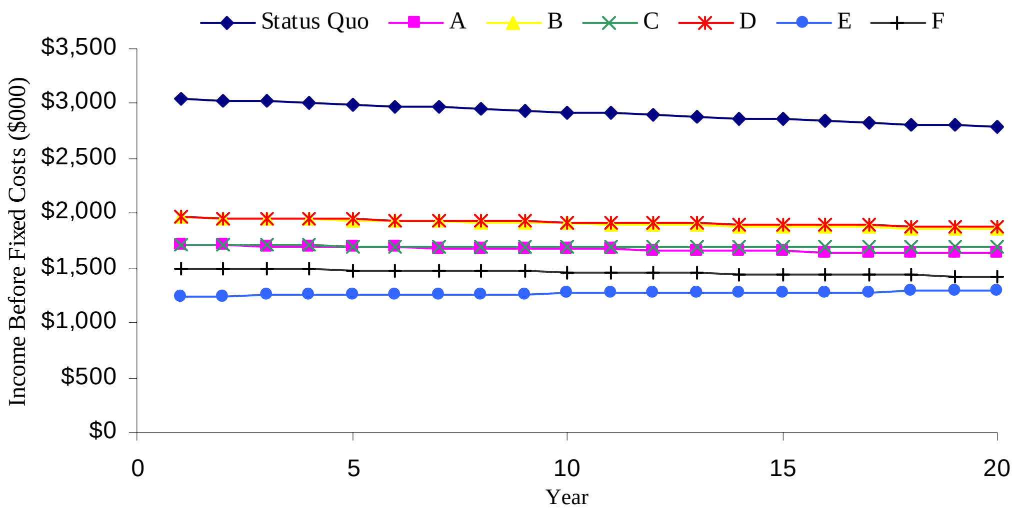


Figure 7. Relative income stream (un-discounted) from agricultural production in the Wanilla Catchment.

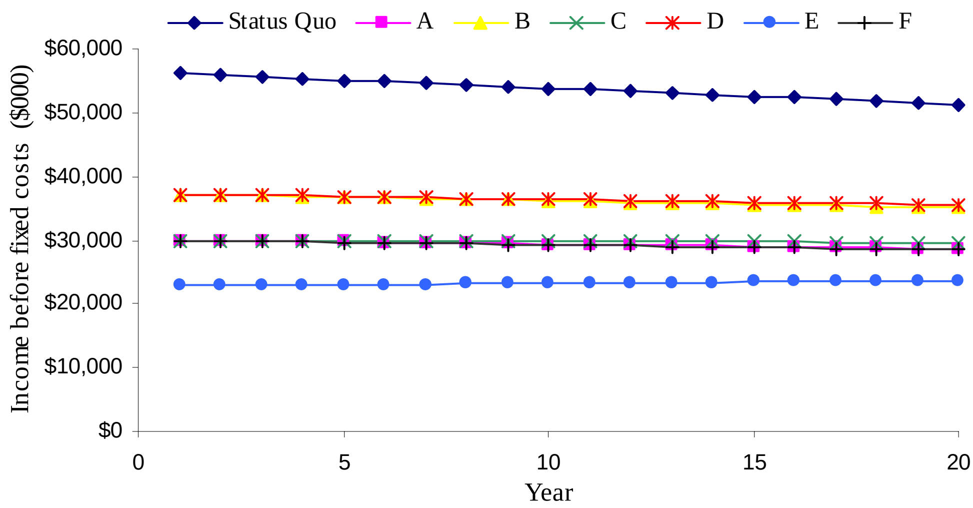


Figure 8. Relative income stream (un-discounted) from agricultural production in the LEP Basin, infrastructure damage avoidance benefits not included.

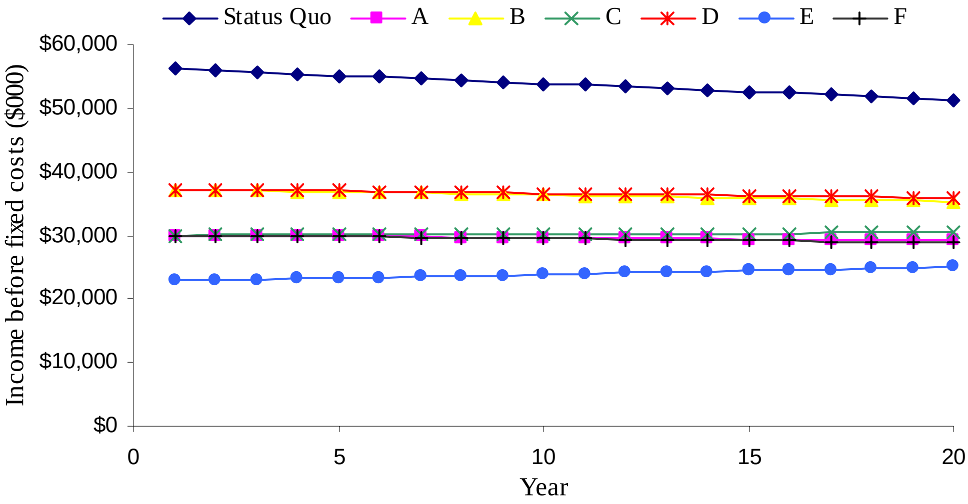


Figure 9. Relative income stream (un-discounted) from agricultural production in the LEP Basin with infrastructure damage avoidance benefits included.

Sensitivity Analysis

The sensitivity of the above results to variations in key assumptions was explored by systematic random variation of key variables. The variables altered include:

- the discount rate (%);
- the additional area of land surrounding the salt affected area which is subject to yield decline (%);
- the relative yield in the area of yield decline (%);
- the yield obtained from timber in agroforestry (t/ha); and
- the price of timber in agroforestry ($/t).

These variables were chosen because there was most uncertainty surrounding their true values. The sensitivity analysis chose 100 randomly selected values within ±50% of the original value. Each variable was systematically varied whilst the others were held at their original value. This process generated 100 values for NPV and BCR for each of the variables. The output is shown for the Wanilla Catchment in Appendix A. This appendix contains a series of graphs which show the variation in NPV as a response to variation in the above listed variables. Although not shown in this report sensitivity analysis for the LEP basin landholder perspective and social perspective was undertaken in the same manner as for the Wanilla Catchment. It was found that the LEP models were sensitive in almost exactly the same way as the Wanilla Catchment model.

From the graphs, it can be seen that the results are sensitive to variations in the discount rate, timber yield and timber price. The results are insensitive to variations in the additional area of land subject to yield decline and the relative yield in the area of yield decline. This suggests that any further refinement of the model should concentrate on better defining the discount rate, timber yield and timber price. By comparison the area of yield decline and relative yield within that area of little importance.

It is worth emphasising that despite considerable variation of the discount rate, timber yield and timber price (±50%), the NPV shortfall is extremely large in every case. No single test produced a positive NPV and the maximum values for NPV were all well below zero. This suggests that the results may be interpreted as a large NPV shortfall for each scenario. For even the best performing scenario to be suitable for cost sharing (ie worthwhile for society) the value of the intangible benefits would need to be extremely large.

Model Limitations

As an abstraction or simplification of reality every economic model necessarily has limitations. The key question is the extent to which the model's departure from reality undermines the value of the results. In other words: *Is the underlying message of the model reliable?* The following limitations of the economic models applied in this study are not considered sufficiently important alter the central messages conveyed in the above discussion. The main limitations of the model are as follows:

1. Naive farming patterns. This economic model assumes that a farmer will continue to apply the same form of production on an area of land as it gradually becomes salt affected over the twenty year period. In reality a farmer is likely to switch enterprises as salt reduces the returns from what is currently being done. A typical enterprise switch on the LEP that will occur as land becomes increasingly salt affected is: wheat → barley → puccenelia.

2. Constant prices for crop, pasture and agroforestry production. This model has identified the current prices for wheat, barley, sheep and agroforestry products. These

have been assumed to remain constant over the 20 year time period. In reality these prices may undergo considerable shifts.

3. Road and saline water impact assessment techniques. The road and saline water impact assessment techniques were taken from other studies largely based on the Murray Darling Basin. Some accuracy may be lost when these studies are applied to the LEP.
4. Linear increase in the area of salt affected land. It is assumed that the area of salt affected land increases over time according to a linear function. In reality it may reach a threshold where the rate of increase goes down. This may occur as the catchment approaches equilibrium.
5. Discount rate. A discount rate of 8% was assumed. This is consistent with other economic analyses of this type. Whether or not this is correct cannot be said as there is no such thing as a 'correct' discount rate.
6. Water quality and salt area relationship. It was assumed that the area of increase in salt affected land was directly proportional to increases in total dissolved solids in water supply. Many other factors may influence this relationship.

Policy Implications

Based on the results obtained from the economic model presented in this report it is unlikely that the dryland salinity management options proposed by Stauffacher *et al.* (2000) will be considered economically feasible. The amount of public expenditure required to attain the non-market benefits (eg biodiversity, drinking water quality) of dryland salinity control would need to be around a minimum of $173m for the LEP basin and $10m for the Wanilla Catchment.

Given that the population of the LEP basin region is approximately 18,600 people and that benefits of salinity control to people living outside the region will be minimal these expenditures would represent an extremely large opportunity cost (eg hospitals, schools, roads) for the LEP community. It is unlikely that the non-market benefits will be sufficiently high to justify opportunity costs associated with any of the management options. If the benefits accrue only to people living in the LEP region, each household (of which there are 6,553) would have to contribute roughly $26,600 or $2,500 per year over 20 years. Costs of this magnitude would need to be compared against other options for avoiding the negative impacts of dryland salinity. For example, a variety of engineering structures could be used to avoid the detrimental impacts of saline water on urban households. It may even be appropriate to consider alternative water supply options.

Despite this seemingly bleak outlook, it would be inappropriate to conclude that any attempts to repair or prevent dryland salinity on the LEP are not worthwhile. It is likely that there will be specific cases, localised both spatially and temporally, where salinity control projects will deliver benefits which exceed project costs. Such projects are likely to be highly targeted to combat a specific problem and preserve a specific area or natural habitat. These projects are likely to emerge more often as the biophysical processes controlling dryland salinity on the LEP are better understood.

A conclusion that can be reached from the economic model is that catchment or basin-wide revegetation projects aimed at controlling dryland salinity are not likely to deliver benefits which exceed costs over a 20 year time period.

The findings of this study will have implications for other regions of Australia. They tend to support the need for 'living with salt' options found in parts of New South Wales. They also support economic analysis by Herbet (1999) which found that revegetation to control dryland salinity in Western Australia typically has low benefit cost ratios. Of nine salinity management strategies evaluated by Herbet (1999) only two received benefit-cost ratios above one (1.64 and 1.37) and the remaining seven had benefit-cost ratios ranging from 0.15 to 0.45.

However, the models may provide different results if they were applied in a region which impacted on a major city such as Adelaide. The increase in population would lead to a massive increase in the infrastructure impacts associated with dryland salinity. This could be sufficient to lower the NPV shortfalls associated with the six dryland salinity management options to feasible levels.

This study highlights a need for further research into economically feasible techniques for dryland salinity management. It would be desirable to undertake similar studies within regions that affect major cities with large populations. It would also be desirable to prioritise salinity control projects throughout South Australia which have targeted and specific benefits. It is works of this nature that are likely to be of most benefit in the control of dryland salinity.

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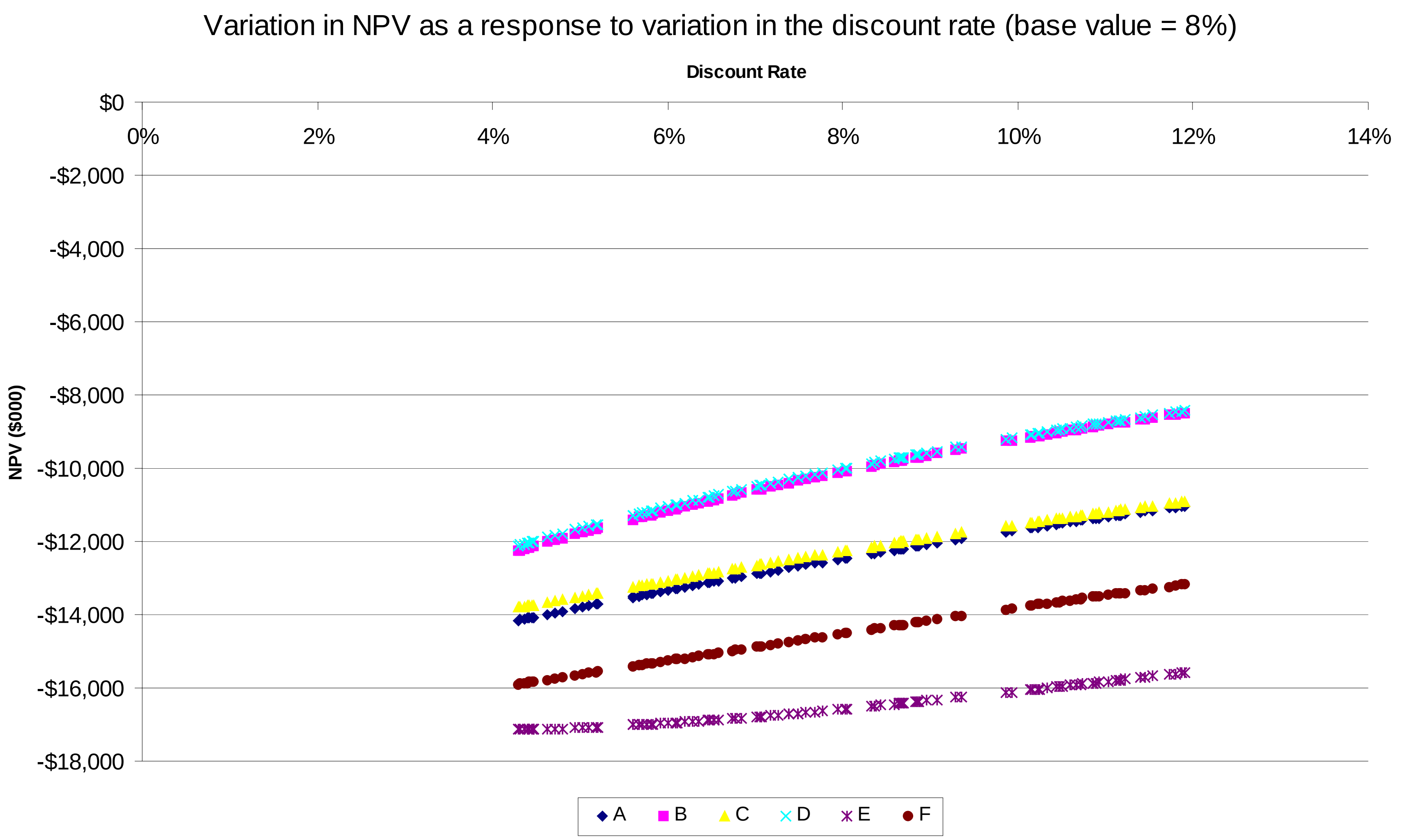
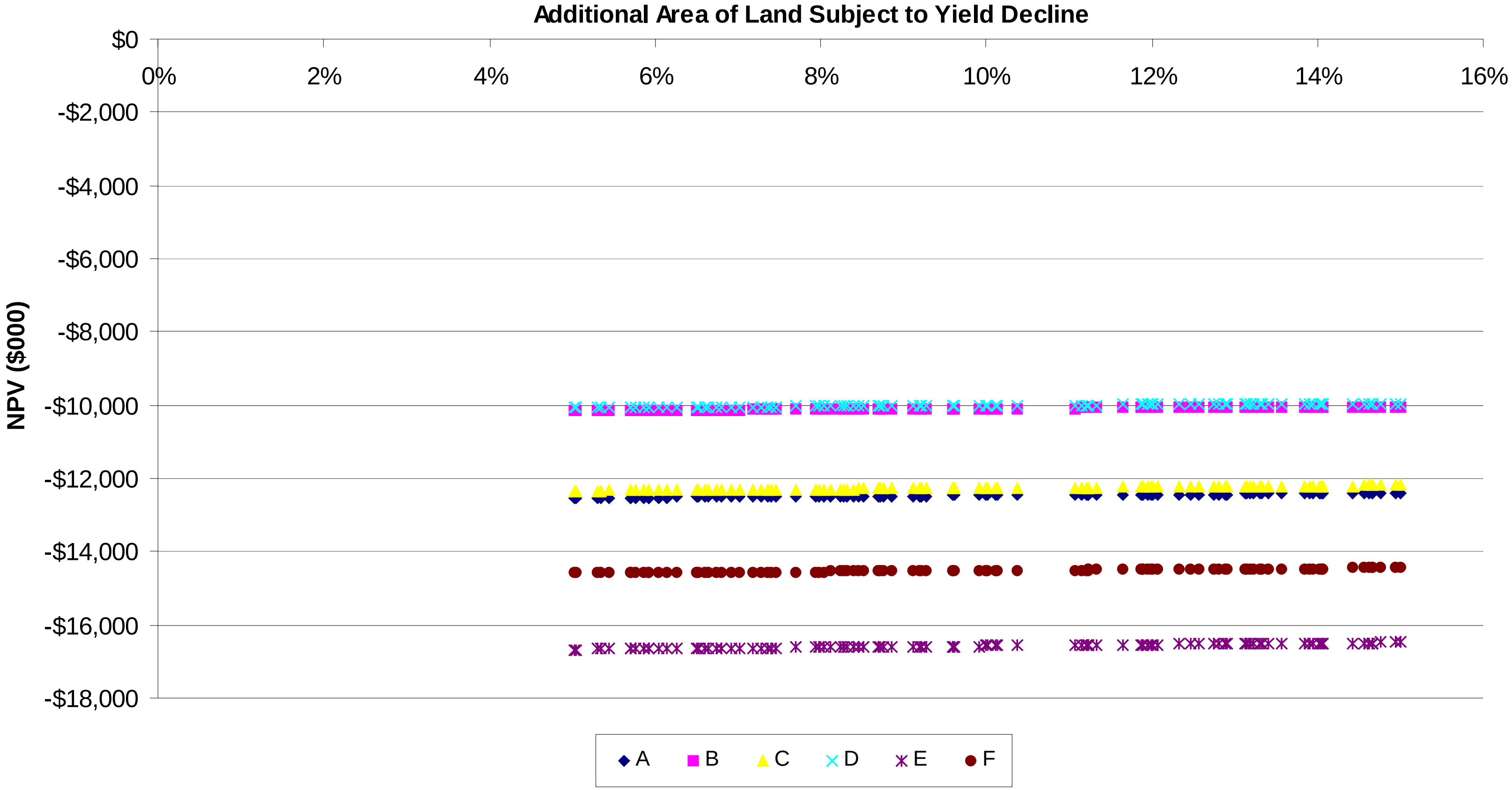
APPENDIX A

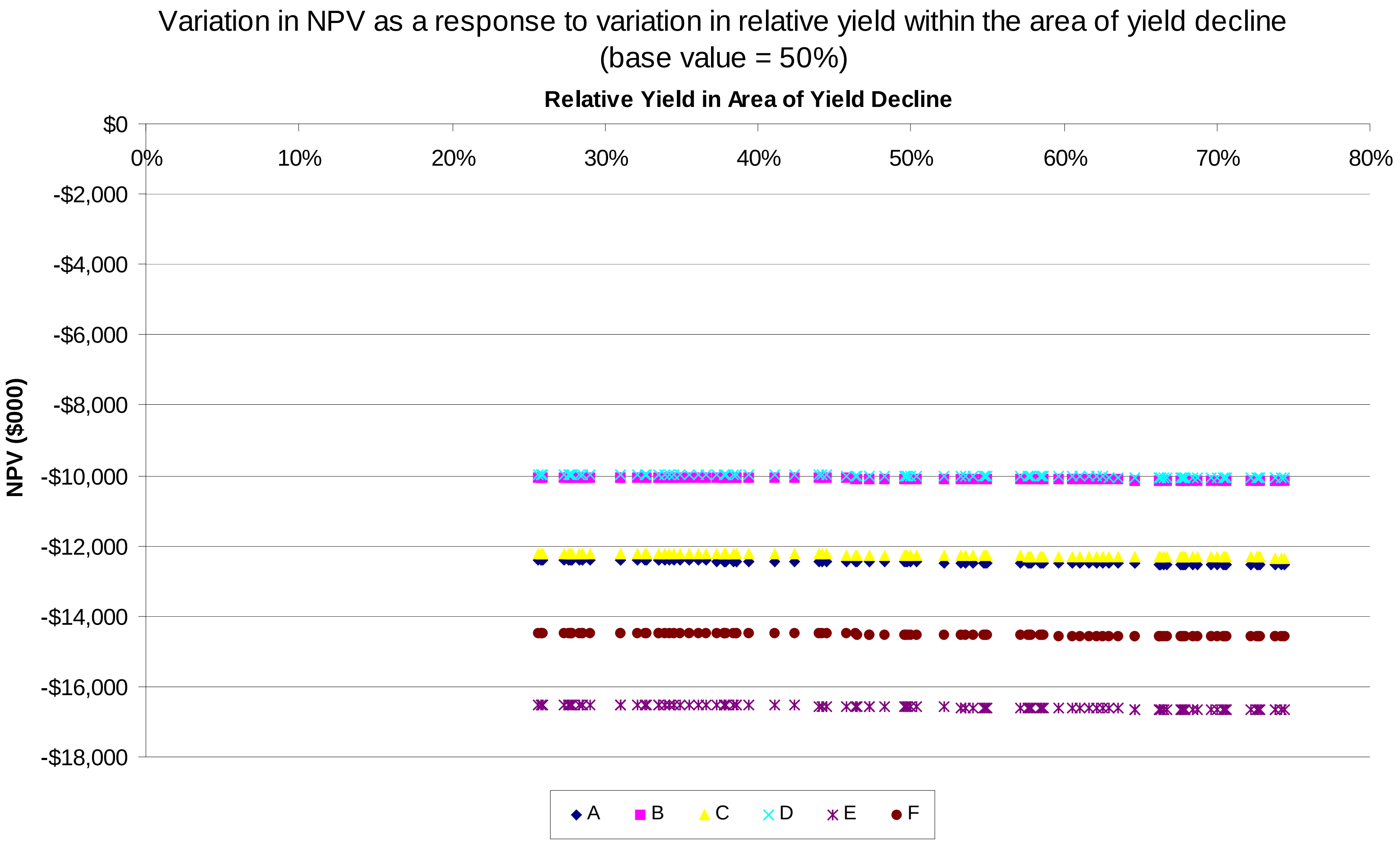
GRAPHS SHOWING THE RESULTS OF SENSITIVITY ANALYSIS FOR THE WANILLA CATCHMENT



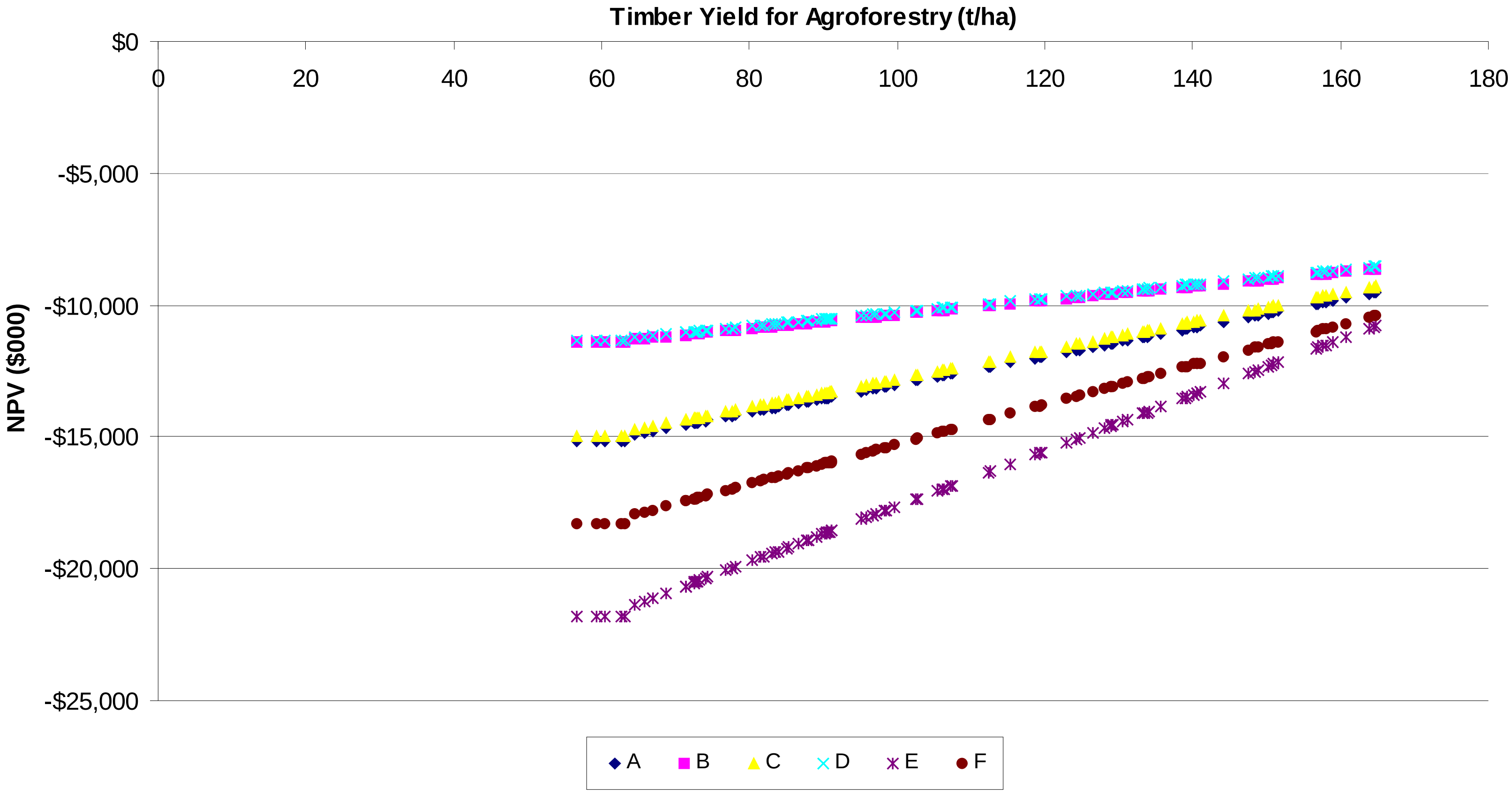
Variation in NPV as a response to variation in the discount rate (base value = 8%)
Discount Rate
$0
0%
2%
4%
6%
8%
10%
12%
14%
-$2,000
-$4,000
-$6,000
-$8,000
-$10,000
-$12,000
-$14,000
-$16,000
-$18,000
NPV ($000)
A
B
C
D
E
F

Variation in NPV as a response to variation in the additional area of land subject to yield decline (base value = 10%)




Variation in NPV as a response to variation in relative yield within the area of yield decline
(base value = 50%)
Relative Yield in Area of Yield Decline
$0
0%
10%
20%
30%
40%
50%
60%
70%
80%
-$2,000
-$4,000
-$6,000
-$8,000
-$10,000
-$12,000
-$14,000
-$16,000
-$18,000
NPV ($000)
A
B
C
D
E
F

Variation in NPV as a response to variation in timber yield (base value = 110 t/ha)



Variation in NPV as a response to variation the agroforestry timber price (base value = $20/t)