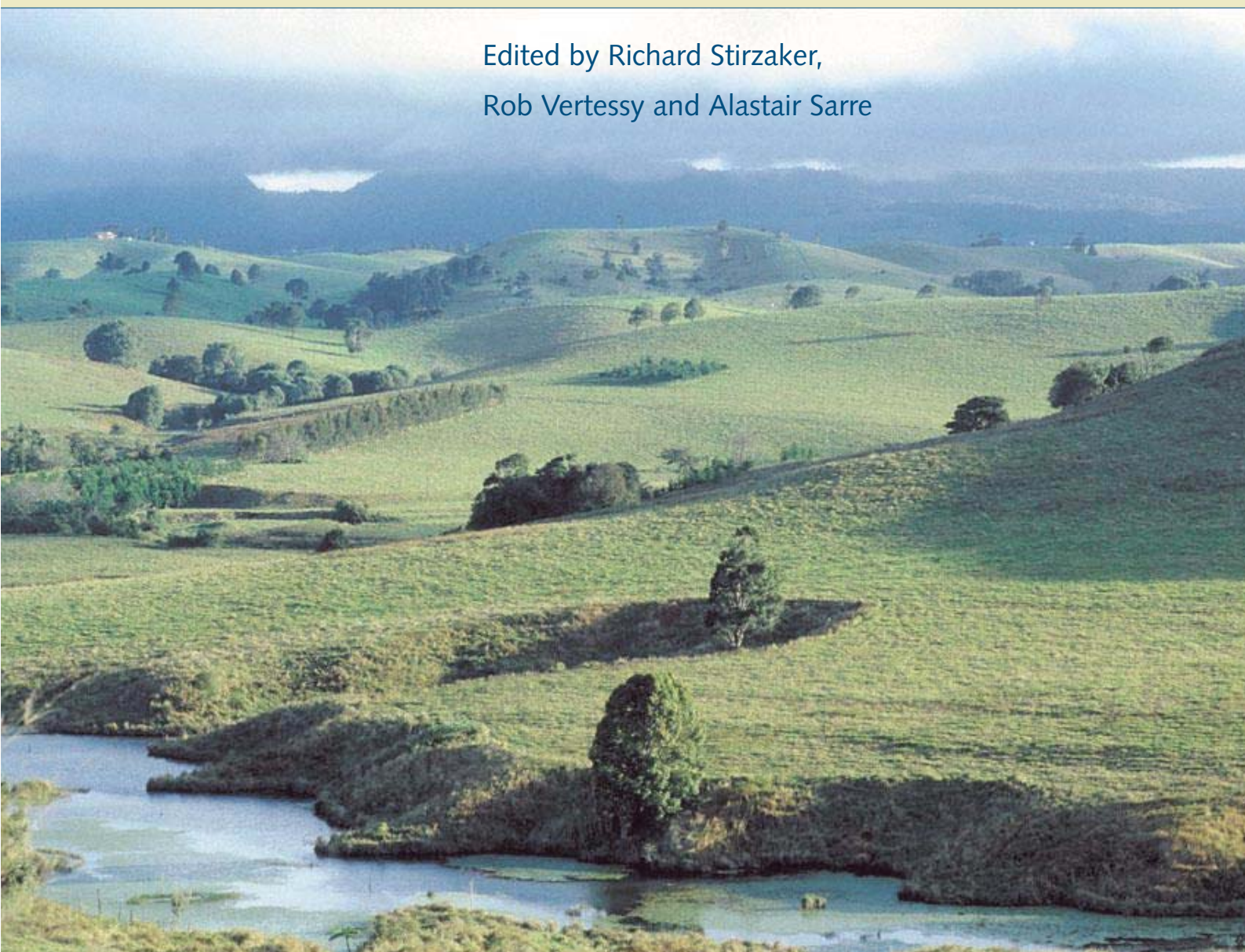


Trees, water and salt

An Australian guide to using trees for
healthy catchments and productive farms

Edited by Richard Stirzaker,
Rob Vertessy and Alastair Sarre



Trees, water and salt: an Australian guide to using trees for healthy catchments and productive farms

Edited by Richard Stirzaker, Rob Vertessy and Alastair Sarre

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Foreword

Agroforestry has an important role to play in the sustainable management of Australia's natural resources. It can help conserve biodiversity, improve soil structure, sequester carbon and rehabilitate land degraded by erosion, salinity, sodicity and acidification.

In many regions the biggest threat to sustainable agriculture is salt. Perhaps the most important task for agroforestry, then, is to help restore the hydrological balance within catchments affected by salinity and the associated problem of waterlogging.

The Joint Venture Agroforestry Program (JVAP) supports and coordinates agroforestry and farm forestry research and development at the national level. It is managed by the Rural Industries Research and Development Corporation on behalf of its co-funding partners the Land and Water Resources R&D Corporation, the Forest and Wood Products R&D Corporation, the Murray-Darling Basin Commission and the Natural Heritage Trust. The objective of the program is to promote the integration of sustainable and productive agroforestry systems and traditional farming practice to alleviate environmental problems and increase farm productivity.

The JVAP has commissioned a number of projects to contribute guidelines on different aspects of agroforestry design and practice for farm advisers, catchment managers and landholders. Titles under development include *Farm forestry and biodiversity design*; *Trees for shelter: a guide to using windbreaks on Australian farms*; *The Australian farm forestry site selection manual*; and *Irrigated eucalypts incorporating salinity*.

This book, *Trees, water and salt: an Australian guide to using trees for healthy catchments and productive farms*, is the first in the series to be published. The culmination of four years' research by a team of CSIRO and other scientists, it adds considerably to the already large body of knowledge developed by state and federal resource management agencies, the CSIRO and universities. It is the most up-to-date, readable and useful book yet published on agroforestry and salinity. We hope and expect that it will make a major contribution to restoring the balance in our agricultural lands.

Peter Core
Managing Director
February 2002

Preface

This book has been written in a period during which the salinity debate has moved from relative obscurity to the front pages of major newspapers. The debate is controversial: some think the dire predictions of saline catastrophe are far too alarmist. Others feel we are just coming to grips with how big the salinity issue really is.

The National Land and Water Resource Audit concluded in April 2001 that about 5.7 million hectares are at risk or affected by dryland salinity; this could increase to just over 17 million hectares in 50 years. Dryland salinity threatens 41 300 km of rivers, 20 000 km of major roads, 1 600 km of rail, 68 towns and 130 important wetlands.

Dryland salinity is indeed a major environmental challenge for the nation and its cause is the removal of native vegetation. But what is the solution?

Some catchments will benefit relatively quickly from revegetation, others will not. In most cases we will see almost no benefit until a threshold proportion of a catchment is planted. The location and arrangement of trees within the catchment will have a major impact on our success, as will our ability to build new, profitable industries based on tree products.

The authors of this book were all involved in field experiments investigating the link between agroforestry, hydrology and salinity. Our work over the past few years has taught us one thing: that tackling the salinity problem is a complex and monumental task. We devote a considerable part of the book to explaining the physical and physiological interactions between trees, water and salt, because a thorough understanding of the issues is essential if we are to make progress in dealing with them.

As editors and publishers, together with our review team, we had to ensure that the fundamentals in each chapter were sound. However we had to go further and make the book as 'user friendly' as possible. The need to deliver a simple message about such a complex problem was a tension for us and the risk of over-simplification was a constant companion.

The removal of trees from our landscapes caused the problem in the first place; putting them back will be part of the remedy. We believe that the guidelines presented in this book will help land managers design and implement better agroforestry systems and will thereby assist in the battle against salinity.

Richard Stirzaker, Rob Vertessy, Alastair Sarre, Sharon Davis and Roslyn Prinsley.

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Thanks are due to Dan Figucio for drafting many of the fine illustrations. Joe Landsberg, John Knight and Freeman Cook contributed many valuable ideas during the early phases of the project.

We are grateful to a number of ‘users’ who reviewed a close-to-final draft of the manuscript and made many useful suggestions, most of which have been incorporated in the finished product. The users were: Rowan Reid – University of Melbourne; Ray Borschman – private consultant; Hugh Stewart – Treecorp; Peter Taylor – WA Agriculture; David Bicknell – WA Agriculture; and Tracey Jarvis – Victorian Department of Natural Resources and Environment.

Finally, we thank Roslyn Prinsley and Sharon Davis of the Joint Venture Agroforestry Program for their support, patience and guidance.

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The purpose of this book

Richard Stirzaker, Rob Vertessy and Alastair Sarre



Tree-clearing has been common practice in Australia for nearly two hundred years. In that time we have transformed our landscape from one dominated by deep-rooted and evergreen woody vegetation to one in which shallow-rooted annual crops and pastures are the norm. This has generated significant national prosperity but at growing environmental cost.

Dryland salinity is the most obvious consequence of this land-cover conversion. Salinity causes losses in agricultural production, increases the risk of flooding, degrades habitats and water quality, and damages infrastructure such as roads, pipes, cables, bridges and buildings.

This book provides guidance for those wishing to replant trees to curb these problems. In particular it addresses the challenge of replanting trees in areas that are marginal for conventional forestry. We use our knowledge of hydrology to decide the best location and arrangement of trees in a catchment; good design will ensure the greatest impact on watertable levels for a given area planted and, in most cases, will produce better tree growth. The book is targeted at those people managing or advising at the catchment scale, although much of the information should be useful to smaller-scale managers, including farmers and private forest growers.



9

Balancing productivity and catchment health

Richard Stirzaker and Rob Vertessy





What this chapter is about

Agroforestry design for salinity management is about knowing which options hold the most promise for each part of the catchment. This chapter summarises these options and how they can be implemented at the catchment scale. It also sets out a five-strand framework for optimising the role of trees in the fight against salinity.

Over the last ten years, a huge effort has gone into understanding, quantifying and predicting the future extent of the salinity problem. There is still much uncertainty and missing information. Nevertheless, most hydrologists agree that the prognosis is as serious and intractable as their worst fears. We are witnessing a process that fundamentally challenges the way we use the land. At the same time, the rural community is not going to sit back and do nothing while the worst-case scenario unfolds. People want to know what action to take now, and its chance of success.

In the rainfall zone below 700 mm, the most profitable land use is based around annual crops and pastures. We also know that leakage under crops and pastures exceeds the discharge capacity of many catchments. So the productivity of current agriculture is at odds with the quality of our land and water resources in the future. This book is about using trees to slow down the advance of salinity. We summarise the key points below.

Agroforestry design

The area requiring revegetation is vast and the cost of displacing traditional agricultural enterprises immense. Agroforestry design therefore has twin goals. First, we must achieve the best hydrological control with the least displacement of valuable agricultural land. Second, we must maximise the profitability of tree products.

There are five ways to achieve the first goal. Leakage per unit area planted to trees is minimised when:

- 1) trees are located on areas with preferential recharge;
- 2) woodlots are moved around the landscape to create a buffer that reduces leakage from subsequent crops;
- 3) tree belts on sloping land use water moving laterally;
- 4) tree belts in alley designs access soil water from land occupied by crops or pastures; and
- 5) trees use water from the watertable.

Agroforestry design for salinity management is about knowing which options hold the most promise for each part of a catchment – and their benefits and risks.

The second goal of maximising the profitability of the tree-growing enterprise can complement the first. Areas of preferential recharge are often characterised by thin, sandy or stony soils where annual crops and pastures perform poorly (point 1 above). Where trees capture more water due to their siting or arrangement they are likely to grow faster than would be the case from incident rainfall alone (points 2–5 above). Thus, profitability will be assisted if tree-planting displaces the least productive agricultural lands and/or achieves tree productivity greater than we might expect from incident rainfall alone.



Catchment hydrology

Choosing an appropriate revegetation design is pointless unless we have a defined goal for groundwater control and some idea of its chance of success. That's why this book started with a strong emphasis on catchment-scale hydrology and the classification of catchments into local, intermediate and regional flow systems. From this we get a feel for the two most fundamental characteristics of a groundwater system:

- its *discharge capacity*, which describes the maximum amount of water that can leave the groundwater system. Watertables will rise to the surface if leakage across a catchment exceeds the discharge capacity; and
- *the response time to change*: there is an inevitable lag between on-ground action and a fall in watertables and in salt loads delivered to rivers.



It is also important to be specific about what we want to achieve. Are we trying to dry up transient, localised patches of waterlogging? Do we want to reclaim saline areas or stop them from spreading? Are we trying to reduce the amount of salt entering rivers? Such distinctions are important because they determine the scale of intervention and how costs may be apportioned.

Viewing the salinity problem at the catchment scale quickly brings an appreciation of some of the difficulties in dealing effectively with it. In some cases, the costs and benefits of taking action will be seen on the same farm; more often than not, though, they will occur on different farms in the same catchment. The cost of managing river salinity may be borne by irrigators or urban water users many hundreds of kilometres away.

Revegetation at the catchment scale

Figure 9.1 shows where different agroforestry designs may be appropriate in a hypothetical catchment. There is a danger here in over-simplifying a very complex issue, but the figure is presented to illustrate where the different designs may be employed at the catchment scale. Note that the diagram shows where a design might be appropriate but says nothing about the chance of success – this will depend on the specific site details and the principles set out in chapters 4–7.

The depicted catchment is large: the annual rainfall of 1 200 mm in the upland sloping country falls to 300 mm on the flat riverine plain. We see two separate groundwater systems, a fresh local system A and a regional saline system B. The

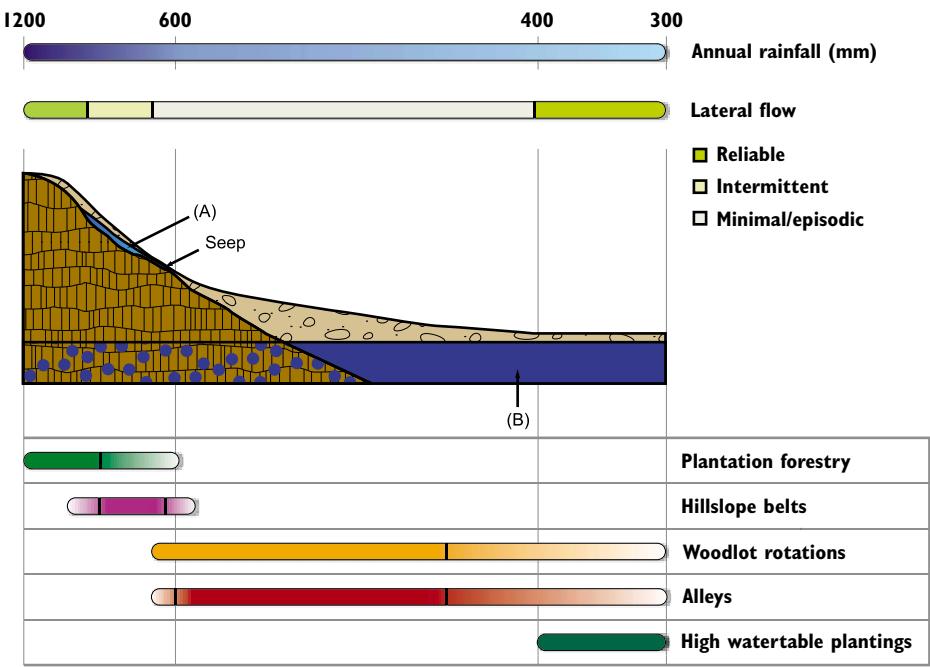


Figure 9.1: A hypothetical catchment depicting steep, wetter uplands at the extreme left through to flat plains on the right. The bars above the diagram show the rainfall gradient and the zones where movement to trees is of importance. The bars below the diagram show the zones in the catchment suited to the five different agroforestry strategies.



local system is perched above a fractured rock basement. The fractured rock is itself an aquifer, and the soil layer immediately above the bedrock is finely weathered with very low hydraulic conductivity. Water moving through the fractured rock and the soils on the slopes and plains contributes to the regional saline groundwater system. The discharge capacity of the regional aquifer is less than the leakage summed over the entire catchment, so the watertable is rising.

How would a revegetation strategy be designed for this catchment? As discussed in Chapter 3, a start would be to focus on those sub-catchments with the greatest potential for benefit and the areas at greatest risk. As part of this process, it is important

that the groundwater systems are understood so that expectations are appropriate. All available land resource assessment information should be employed to determine areas that are likely to leak more than average, such as those on thin or sandy soils. These should be reforested first. Also, areas with known or predicted salinity problems should be targeted. These issues are discussed in Chapter 2.

In the wetter, steeper parts of the hypothetical catchment, conventional plantations growing wood for existing markets are a clear option; continuous tree cover uses more water than does any other form of cover. An exception to this plantation option would be when a cleared sub-catchment is producing fresh water and thereby diluting downstream salinity: large-scale revegetation would reduce this beneficial effect.

As annual rainfall declines toward 600 mm, conventional woodlots become more susceptible to drought death. Hillslope belts, which can intercept water moving laterally on the surface or above the basement rock, will be more productive than woodlots per unit area planted as long as there is a reliable lateral flow within reach of tree roots. This will depend on the slope of the basement and the conductivity of the soil (as shown by the green bar in Figure 9.1). Design guidelines for tree belts on hillslopes are given in Chapter 5.





As the land becomes flatter there is less opportunity for the lateral flow of water. Since water will not move to the trees we have to move the trees to the water. There are two ways of doing this. When woodlots are rotated with crops they can make use of water that has accumulated in the subsoil beneath crops and pastures. By mining this water the trees can grow faster during the first few years than they would on contemporary rainfall alone. When the trees are harvested they leave behind an empty buffer of subsoil that can accommodate leakage from the agricultural phase before recharge to groundwater recommences. At present we have very few experimental data on this option. Its implementation is limited by a lack of markets for short-rotation wood products and by the practical difficulties of alternating between the woodlot and agricultural phases. Modelled examples of the rotation strategy are given in Chapter 4.



Another way of moving trees to water is to grow belts of trees in cropping or pasture lands – alley farming. The trees have access to rainfall in the area occupied by their canopies, but their roots can also explore the soil occupied by crops. The key here is to have the correct proportion of land covered by trees so that there is sufficient perennial leaf area to use all the



excess water. The chief drawback of alley farming is that we cannot control the extent to which the trees rob the crops of water and hence the degree and timing of competition. At dry times within seasons or in drier-than-average years, the trees by virtue of their perennial infrastructure are likely to prosper at the expense of the crops.

Chapter 6 provides guidelines for determining when it may be worth mixing trees with crops in an alley formation and when it would be better to grow them in larger woodlots.

The agroforestry design discussed in Chapter 7 may also be deployed in our hypothetical catchment. It comprises the growing of woodlots or alleys over shallow, saline watertables. When trees consume such groundwater they create a local drop in the watertable but leave most of the salt in the soil. In this situation, the lateral flow to the trees is variable and depends on the conductivity of the soil. The key design criteria for these plantings are an estimate of the rate at which salt builds up under the plantation and an assessment of whether there is likely to be any effective leaching of salt.

We stress that Figure 9.1 depicts a hypothetical and highly simplified catchment. In real systems, salty groundwater does not only appear in the dry, flat, riverine plains, nor are transient fresher systems confined to the upland sub-catchments. Real catchments often have several groundwater systems at different depths, some confined and some unconfined, bearing water that ranges from highly





saline to reasonably fresh. Even in a simple catchment it is important to know how different groundwater systems interact. A concerted effort in plantation forestry and hillslope plantings in the wetter parts of our hypothetical catchment may dry up the seep at the base of the slope, but this victory would not solve the

wider salinity problem. In all likelihood, some water would still drain through the low conductivity layer above the fractured rock aquifer, so the groundwater in the large regional system would continue to rise.

A way forward

The current profitability of agroforestry in Australia's lower rainfall zones will not drive revegetation at the scale needed. Salinity must be accepted as a national rather than a rural problem: the threat it poses to infrastructure, biodiversity, irrigation and drinking water is undoubtedly a threat to the national interest. This shift in thinking is now happening: agricultural producers are increasingly viewed as natural resource managers who should be rewarded as such. As a nation we rely on them not only for food and fibre but also to provide clean water and air, to conserve habitat for wildlife, to tie up carbon, and to maintain the aesthetic, spiritual, cultural and recreational values of the land.

A growing commitment to do something about salinity is certainly heartening, but it seems certain that the cost of revegetation at the required scale will be many times more than the Australian community is currently prepared to pay. Below is a five-strand framework that shows how we could get from where we are to where we want to be – and how we might surmount what appears now to be an insurmountable problem.

Strand 1: Understanding catchment-scale salt and water balance

Each catchment stands to lose a certain amount of land to salinity and exports a certain amount of water and salt. Knowing which catchments are exporting significant amounts of salt to valuable rivers will give us a good idea of where to focus attention. Hydrologists can estimate the reduction in recharge that



would produce an outcome acceptable to the catchment and river system as a whole. They can also estimate the time lag between on-ground action and when the export of salt will start to diminish.

Strand 2: Assessing the costs and benefits of revegetation

Although our ability to value ecosystem services is in its infancy, economic analyses can tell us what the within-catchment and downstream users are paying for revegetation and what they might get in return. Such analyses should encourage public and private sector commitment towards paying an appropriate share of the costs and will help set national and regional priorities for revegetation expenditure.

Strand 3: Determining the optimal area, location and arrangement for revegetation

There is not a *pro rata* relationship between the land revegetated and the reduction in leakage. Identifying areas of preferential leakage, capturing water moving downslope, mixing trees with crops, using groundwater and phase farming are all ways in which we can protect a greater area of land from leakage than we plant to perennial vegetation.





Strand 4: Finding commercially valuable perennials

As long as we obtain low-value products from trees grown in drier areas they are unlikely to match the value of annual crops and pastures. To help fund revegetation, we must foster industries that derive higher-value products from perennial vegetation.

Strand 5: Capturing multiple benefits

Water management is an urgent necessity but it is by no means the only service provided by revegetation. Clever strategies will aim to capture the range of services provided by trees – including biodiversity conservation – and will devise ways of paying for such services.

The five strands of our response to salinity are intertwined, and an advance in any one will benefit the others. For example, if we apply an economic analysis (Strand 2) to catchment reality (Strand 1) we will generally find that the cost of revegetation is many times more than the community is prepared to pay and we will be forced to prioritise. If we find that our Strand 1 criteria can be reached with less perennial vegetation by using the clever design strategies in Strand 3, the cross-subsidy will be reduced. If the value of products from perennial vegetation starts to approach that of annual agriculture because of advances made in Strand 4 then the gap narrows again. If we identify all the other benefits of revegetation and revegetate with the species and in the locations that maximise such benefits (Strand 5), then the cross-subsidy is achieving multiple valuable goals.

Natural resource management is about starting now with the best information we have. This book is about agroforestry design (Strand 3) and how it interfaces with catchment hydrology (Strand 1). It is a starting place for a serious attempt to manage salinity.