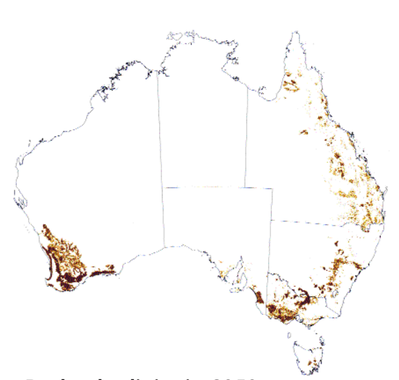
Reinventing agriculture

Bill van Aken, CSIRO Land and Water

Can southern Australia be saved from dryland salinity?

Steve Davidson checks the view from the frontier.

As the tendrils of dryland salinity snake their way across the catchments of southern Australia, scientists involved in salinity research are seeking new ways of returning life and productivity to damaged land.



Joint Venture Agroforestry Program, RIRDC

The National Land and Water Resources Audit (2001) predicts that, within 50 years, 17 million hectares of Australian land will be at risk of dryland salinity.

The seriousness of dryland salinity has been an unpalatable enough message for scientists to convey. But now that governments, resource managers and rural communities are geared for action, the scale and complexity of the challenge precludes a simple blueprint for remediation.

Dr Tom Hatton of CSIRO Land and Water is one of several scientists investigating the evolution and control of dryland salinity in the WA wheatbelt, with findings that resonate in salinity trouble spots across southern Australia.

'The challenge is to arrest the degradation of the Australian landscape while maintaining rural communities,' Hatton says. 'This challenge is on a daunting scale that perhaps no other nation has faced.'

Some 2.1 million hectares of Australia is salinised, and another 10–12 million hectares are at risk of succumbing in the next century.

By 2050, salinisation will have claimed about one-third of the Western Australian wheatbelt, a region that yields about half the nation's grain.

Most of Australia's inland and southern rivers are becoming saltier. This is manifest in the Murray-Darling, our largest river system, which is salinising at an accelerating rate due to changes in hydrology brought on by the removal of 12–20 billion trees.

The salt that threatens much of southern Australia has been blowing in from the sea as a fine aerosol and accumulating in the soil and groundwater for thousands of years, in some cases since the late Pleistocene, about a million years ago. It was kept at bay for millennia by the water-pumping action of millions of deep-rooted native trees and shrubs, such as eucalypts and acacias, that dominated the landscape.

In the past 200 years, however, native vegetation has been largely replaced by annual crops and pastures with shallow-roots unable to access rainwater that soaks deep into the soil during winter.

Upsetting an **ancient cycle**

Bill van Aken, CSIRO Land and Water

AUSTRALIA has been in geological slumber for the past 60 million years, with little uplift, mountain-building or renewal of surface material. This geologic history has produced the flattest continent on Earth, with ancient soils and mostly low hydraulic gradients.

Water cannot move quickly through the landscape, on the surface or as groundwater. Across large, semi-arid areas of the landscape, rain that falls on a given piece of land tends to evaporate from that same surface: a vertical pattern. Over time, this has meant that large quantities of atmospheric salt have accumulated in the soil below the root zone, rather than washing back to the sea.

In its natural state, with a mantle of perennial, evergreen and deep-rooted vegetation over the land, the hydrological cycle in drier parts of Australia has some unusual attributes.

Virtually all yearly rainfall is evaporated or transpired by plants and surface run-off to streams is small and episodic. Net groundwater recharge, that is, the addition of water to aquifers, is usually less than 1 mm a year, except in high-rainfall areas. It was this remarkably low recharge rate that kept salt out of circulation, until extensive land clearing occurred.

Under annual crops and pastures, groundwater recharge typically increases massively compared to that under native vegetation, typically by two orders of magnitude.

In much of southern Australia, increased groundwater recharge now exceeds the lateral discharge capacity of aquifer systems and if the water can't move sideways, it goes up, taking deadly salt with it.

It is ironic that on our basically dry continent, excess water is causing unmitigated landscape degradation and threatening the sustainability of agriculture.

Bill van Aken, CSIRO Land and Water

Above: The salt that threatens much of southern Australia was kept at bay for millennia by the water-pumping action of millions of deep-rooted native trees and shrubs that dominated the landscape.

Left: The shallow roots of annual crops and pastures capture much less water than native vegetation. This excess water filters down to deep aquifers, causing salty water tables to rise toward the surface, collecting additional salt from the soil and groundwater along the way.

Counting the **costs**

THE National Land and Water Resources Audit predicts that 5.7 million hectares of land in Australia has a high potential for suffering dryland salinity (salinity on unirrigated land). This is expected to rise to 17 million hectares by 2050. The worst affected state is Western Australia.

The WA State Salinity Strategy (2000) estimates that the value of lost agricultural production to WA in 2050 will be $300–400 million, (in 2000 terms), and puts the lost capital value of farmland in that state at $3–4 billion.

Thirty rural towns and their infrastructure and transport systems are at risk, and the life expectancy of sealed roads is likely to be reduced by 75% in areas with rising water tables. The replacement of water storages and pipeline construction in the state will cost some $150 million, and flood volumes under the new hydrological equilibrium are predicted to rise two to fourfold.

Biodiversity will also decline. The south-western corner of the state is one of 10 megadiverse biological regions on the planet and some 450 plant species unique to WA are under threat of extinction. About 220 aquatic invertebrates of the wheatbelt will disappear.

It is little wonder the strategy proposes widespread changes to farming systems. There appear to be just two options: either agriculture will have to change to fix the salinity problem, or it will need to adapt to saline land. Both require a revolution in the way we farm the land where salinity is a threat.

. . . the effective control of catchment recharge in much of southern Australia will be achieved only if most or all of the catchment is revegetated.

This untapped water recharges deep, salty aquifers, causing water tables to rise toward the surface, collecting additional salt from the soil and groundwater along the way.

A logical solution to the problem of rising water tables is the replacement of original native vegetation.

Certainly, a study in the Darling Ranges by the WA Water Authority led by Dr Robin Bell, has shown that planting trees can lower local water tables at a rate that increases almost proportionally with the area of reforested land.

During a 10-year period, water tables declined at a rate of 0.8 metres a year beneath plantations covering more than 50% of the cleared area in the catchment.

It was estimated that at a regional scale 11% of the land would need to be revegetated to maintain groundwater levels, and that 46% revegetation would be needed to reduce them by 0.2 m a year.

But many hydrologists believe the remedy is not so simple, particularly in relatively flat landscapes with heavy-textured soils. They say Bell's results are probably specific to the Darling Ranges, where slopes are steeper.

Dr Christopher Clarke and his colleagues at Murdoch University in WA argue that tree planting may not be a universal panacea for rising water tables.

They say that to have an impact at a catchment scale across the WA wheatbelt, the revegetation effort would have to be enormous, the plantings almost ubiquitous. This may apply to most of salt-affected Australia.

After reviewing numerous revegetation trials in the agricultural areas of Western Australia, Dr Richard George of Agriculture WA and others have reached a similar conclusion.

They say that only extensive plantings, depending on the type of landscape, perhaps covering as much as 70–80% of some catchments, will lead to significant scaled reductions in water tables.

Tom Hatton and his colleague Dr Bob Nulsen of Agriculture WA are also cautious. 'Our work and that of others indicates that however trees are returned to the landscape, the effective control of catchment recharge in much of southern Australia will be achieved only if most or all of the catchment is revegetated,' Hatton says.

They add that the control of salt loads to Australia's major southern river systems following revegetation could take hundreds of years. This is due to the low gradients and the great length of these systems.

Nothing happens quickly in our long, flat, meandering river valleys. Salt may be flushed out of rivers with the first flooding rains, but it is soon replaced with additional saline groundwater discharge from surrounding lands.

This is not to say that tree planting is futile. At the local scale, re-introduction of deep-rooted, summer-active, perennial vegetation is essential to reduce run-off and groundwater recharge, Hatton and Nulsen say.

Putting back trees and shrubs can achieve this, although debate surrounds the best place to replant, whether in recharge areas or at saline seeps (discharge areas).

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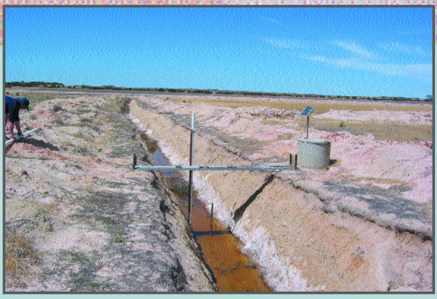
Salinity-affected paddocks at Bruce Rock in Western Australia. Local remediation of saline seeps can show results in a few years, but an enormous revegetation effort would be needed to have an impact at a catchment scale across the WA wheatbelt.

Putting **salt** to good use

The main engineering approach has been the construction of deep, open groundwater drains that discharge into natural drainage lines.



ENGINEERING options for addressing salinity in streams and on land have different goals. In the case of recovering waterways, the struggle is to keep salt out of the stream. On the other hand, engineering to save land focuses on the protection of assets: infrastructure, agricultural land or biodiversity. In either case, salinity engineering involves a form of enhanced discharge (drainage) and the disposal of, usually salty, water.

The main engineering approach has been the construction of hundreds of kilometres of deep, open groundwater drains, often linked in networks, that discharge into natural drainage lines.

One scheme, in Western Australia's Wakeman catchment, is reported to discharge some 400 tonnes of salt and six megalitres of groundwater each day. Surely this has serious environmental impacts downstream?

Tom Hatton of CSIRO Land and Water says this may not always be true in Western Australia. In much of the WA wheatbelt, where the worst of Australia's dryland salinity occurs, small rivers may not flow for years at a time. There is sometimes even disagreement about which way a water course flows!

The larger rivers in the wheatbelt usually cease flowing in summer, except when extreme cyclonic events or thunderstorms occur. This means that the effluent from drains or pumping doesn't always travel very far, the upper salt-affected portions of catchments mostly being disconnected from the lower reaches.

Hatton says that when these water courses do flow, it usually follows flooding rain which flushes salt out of the streams in a much-diluted load, perhaps with little environmental impact further downstream. More research is needed on this and other aspects of engineering.

Scientists and industry are also beginning to look at the commercial use of saline effluent. Large-scale opportunities include aquaculture, salt and mineral harvesting, desalinisation and energy production.

Beyond this, three examples of commercial use are topical in WA.

The first of these is the desalinisation of groundwater that has been pumped from under the town of Merredin for town use. This is economically attractive because the town normally obtains its fresh water from distant coastal catchments at great expense, and the saline groundwater has to be pumped anyway to protect the town's infrastructure.

Secondly, CSIRO has a plan to extract a variety of valuable minerals from saline groundwater using natural evaporation and solar energy. Ordinary salt can be used to make chlorine, hydrochloric acid, sodium metal, sodium bicarbonate, table salt, and other compounds. Some of the substances can then be used in the processing of titanium and zirconia.

Once the salt is removed from groundwater, the remaining 'bittern' contains numerous chemicals. These range from epsom salts, worth $400-800 a tonne, to fertiliser and cement ingredients. Bittern itself can be used as a dust suppressant in the mining industry.

CSIRO estimates that an early-stage industry adding value to Murray-Darling salt could be worth $200 million a year.

Another ambitious proposal is to transport saline drainage water, by pipeline, to the Kalgoorlie goldfields, to satisfy the demand for water for mineral processing. This would provide both commercial and environmental benefits and would be an alternative to bringing seawater from the Southern Ocean.

A project known as OPUS (Options for the Productive Use of Salinity), funded by the National Dryland Salinity Program, aims to identify and assess a range of potentially productive industries using saline land or saline water. The OPUS database brings together a range of case studies of innovative saline industries from across Australia and elsewhere (see www.ndsp.gov.au).

The other good news is that local remediation of saline seeps can show positive results in a few years. And native vegetation also provides other important ecosystem services apart from recharge control.

However, the problem of stopping or reversing recharge and salinisation at a regional or national scale remains.

Given that large-scale revegetation requiring 70% or more revegetation is at odds with traditional agricultural practices, other approaches are being tried.

They include engineering solutions, and farming innovations such as phase farming and the use of deep-rooted, perennial pastures.

Engineered solutions

Farmers and others with assets at risk to salinity are seeking engineering solutions including interceptor drains, groundwater pumping and deep drainage.

In the WA wheatbelt, hundreds of kilometres of groundwater drains have been constructed to save farmland. The state government has programs involving groundwater pumping that aim to protect nature reserves and towns.

Engineering can be effective in controlling salinity, but in addition to its expense is the problem salt-water disposal (see story on page 21). Research partnerships between CSIRO and state agencies are evaluating the effectiveness of drainage, and construction and siting of salt-disposal basins that is scientifically based.

These efforts recognise that no matter how successful other research is in controlling recharge, for some time to come the water and salt already on the move must be managed.

Mimicking nature

An alternative approach is to modify agricultural practices so that in addition to revegetation, farmers adopt farming systems that mimic healthy natural ecosystems, particularly their hydrology.

'The idea is to reconstruct ecosystems in such a way as to provide sustainable farm income,' Hatton says.

Managing to reduce runoff from **crops and pastures**

THREE studies by Dr John Angus and colleagues at CSIRO Plant Industry during the 1990s evaluated new dryland crop and pasture systems for their effect on yield and water use.

The first study made 13 comparisons of wheat crops on farms in southern New South Wales that were managed either by conventional methods, or by the improved methods of following a break crop or applying optimum nitrogen fertiliser. Improved management resulted in 10% increases in yield and water use, and resulted in the soil being left significantly drier.

These experimental results were followed up in a study that used a model called SIMTAG to simulate 50 years of cropping using weather records from Wagga Wagga. The simulations confirmed that high-yielding crops lost less water as runoff and infiltration than low-yielding crops.

The final study made by the Plant Industry team was a long-term experiment near Junee that compared water use by crops, lucerne pasture and subclover pasture. The results showed that lucerne provided a soil-water 'buffer' of about 200 mm more than annual pasture. This means that a lucerne pasture can accept 200 mm more rainfall before draining as much as an annual pasture. The equivalent buffer for well-managed crops was about 100 mm.

Based on these findings, the researchers suggest that growing high-yielding crops, alternated with lucerne-based pasture when the subsoil becomes wet, can reduce or possibly eliminate the risk of groundwater recharge in this environment.

The Plant Industry group points out that the historically high recharge levels in dryland farming systems reflect the performance of the annual pastures, low-yielding crops and fallows typically in use since the land was cleared. Increased crop yields during the 1990s, reduced fallowing and a tenfold increase in lucerne sowings in parts of southern NSW, inferred from seed sales, suggest that recharge rates may decline in future.

More about soil water extraction

Angus JF Gault RR Peoples MB Stapper M and van Herwaarden AF (2001) Soil water extraction by dryland crops, annual pastures and lucerne in south-eastern Australia. *Australian Journal of Agricultural Research*, 52:183–192.

Bill van Aken, CSIRO Land and Water

Growing high-yielding crops, alternated with lucerne-based pasture when the subsoil becomes wet, can reduce or possibly eliminate the risk of groundwater recharge on farms in southern New South Wales.

. . . even heroic levels of recharge control, when modelled, have only an average affect on salinity.

One option is alley farming, in which conventional crops or pastures are grown between rows of edible shrubs such as tagasaste. The deep-rooted shrubs should provide forage for stock and control groundwater recharge.

Dr Richard Stirzaker of CSIRO Land and Water and Dr Ted Lefroy of CSIRO Sustainable Ecosystems are investigating this approach (see story on page 25).

Another approach being assessed is Phase Farming with Trees, a system that uses trees in three to five year rotations with annual crops.

The trees – planted in blocks, strips or whole paddocks – rapidly dewater farming catchments at risk of salinity by depleting stored soil water and reducing groundwater recharge. At the same time, they produce timber, pulp or fuel wood. The de-watered land is then returned to conventional crops, such as wheat, or pastures.

A recent scoping study concluded that Phase Farming with Trees presents a major opportunity for sustainable agriculture, although work needs to be done to increase its profitability and to identify the best situations for its adoption.

Perennial pastures can also be used to restore hydrological balance. Lucerne plants in particular are deep-rooted and so mimic the activity of native trees and shrubs. Unfortunately, lucerne will not support the biodiversity associated with native vegetation, but neither does severely salted country.

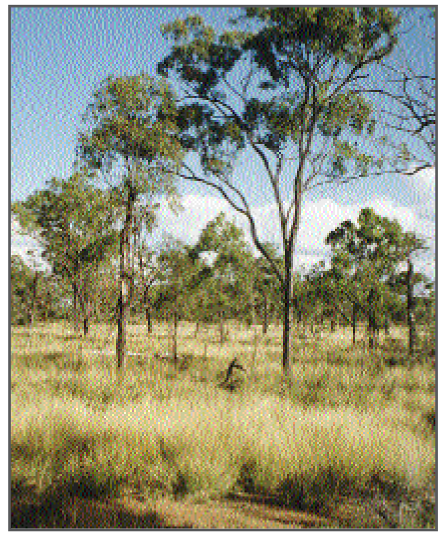
A simulation study for a site near Wagga Wagga in New South Wales showed almost no recharge under eucalypt woodland, and 135 mm of recharge beneath grazed annual pasture. Recharge beneath grazed lucerne pasture, at 3 mm per year, was much closer to the natural state.

Dr John Angus and his colleagues at CSIRO Plant Industry have examined soil water extraction by dryland crops and pastures. They suggest that tactical use of lucerne-based pastures in sequence with well-managed crops can contribute to dewatering of soil and reduce the risk of recharge (see story on page 22). Other agricultural plants or novel plant species for recharge control require investigation.

Seeking guarantees

In the absence of long-term, large-scale trails to demonstrate the effectiveness of salinity control measures, computer models of groundwater flows are being used to predict the impacts of complex interactions between land, water, vegetation and climate.

According to Richard George, even 'heroic' levels of recharge control, when modelled, have only an average affect on



One approach to countering dryland salinity is is to modify agricultural practices so that in addition to revegetation, farmers adopt farming systems that mimic healthy natural ecosystems, particularly their hydrology. Various methods of increasing profitability through planting trees are being assessed.

Bill van Aken, CSIRO Land and Water

Dryland salinity at Meckering, WA.

The most pessimistic view of dryland salinity is that some of the damage is essentially irreversible . . .

Abstract: Dryland salinity is a dramatic consequence of the rapid conversion of native bush to agricultural land in southern Australian during the last 200 years. Rising water tables carry salt that has been immobile for millennia upwards in the soil profile and this eventually kills plants. The economic, social and environmental costs of salinised land and waterways are enormous. Scientists are investigating options for revegetation and new ways of farming the land that mimic the hydrology of pre-existing natural ecosystems. This is a daunting task and farmers will need convincing that new agricultural systems will work. Governments and landholders are also adopting engineering approaches to protect assets at immediate risk.

Keywords: salinity, dryland salinity, revegetation, land rehabilitation, WA, groundwater, waste water use, hydrology, crop yield, crop management, wheatbelt.

salinity. 'Our results show just how difficult it is to reverse groundwater trends,' George says.

'Long-term salinity risk in relatively flat catchments in low-to-medium rainfall areas of WA responds only to significant reductions in recharge. Lower levels of intervention buy some time.

'By contrast, modelling suggests that catchments in less-common undulating landscapes respond more quickly. Here, groundwater and salinity levels decline in 10-20 years.'

He adds that the adoption of most of the treatment options modelled (combinations of revegetation, alternative cropping and groundwater pumping) is unlikely because they are underdeveloped and less profitable than present farming systems.

The most pessimistic view of dryland salinity is that some of the damage is essentially irreversible and that Australia's southern landscape will not be renewed until the next geologic orogeny (period of mountain building), or until a large change in climate.

But Hatton and Nulsen say there is an ethical compulsion to bring to our agriculture as much of the original hydrologic function as possible and that it is difficult to envisage sustainable systems not involving trees or other perennial vegetation.

More about dryland salinity

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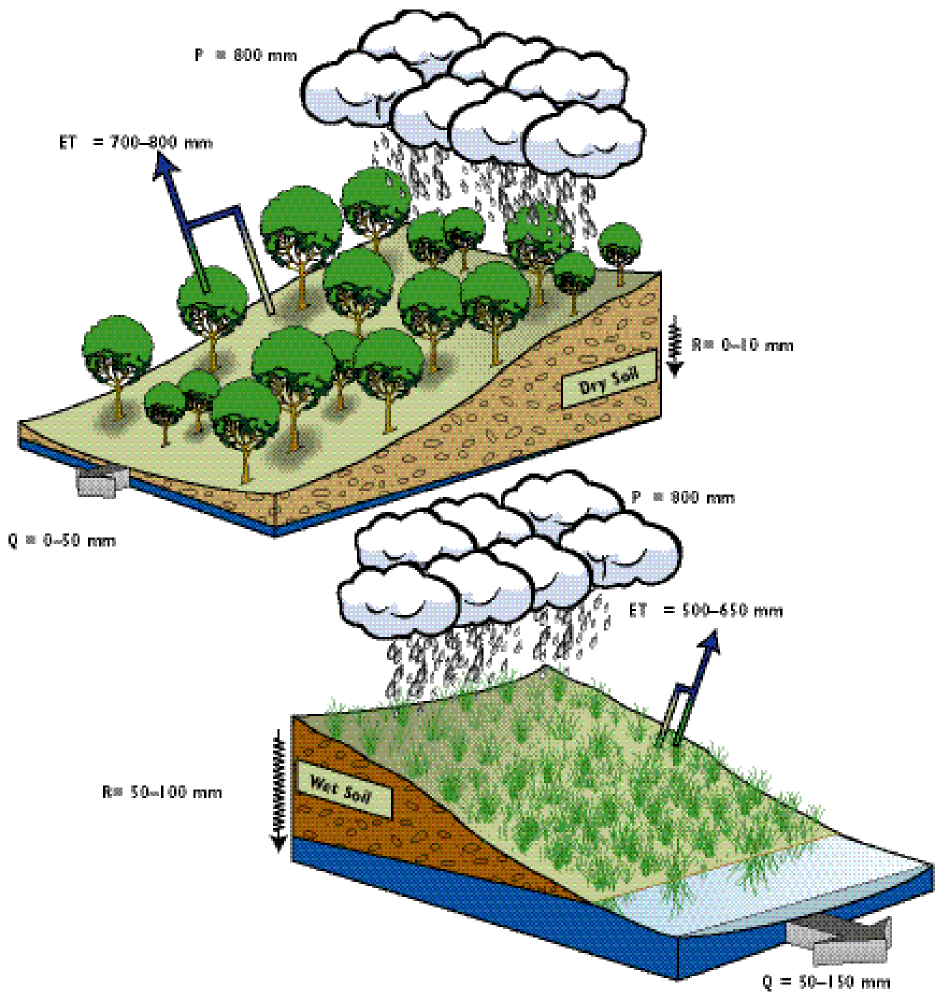

Vegetation and water balance

These diagrams compare the typical water balance in southern Australian catchments receiving 800 mm of annual rainfall (P) under native eucalypt vegetation and under grasses or crops. Reduced evapotranspiration (ET) under traditional agriculture leads to greater groundwater recharge (R=drainage through soil to the water table), rising water tables and hence dryland salinity problems. Q=streamflow and groundwater flow combined.

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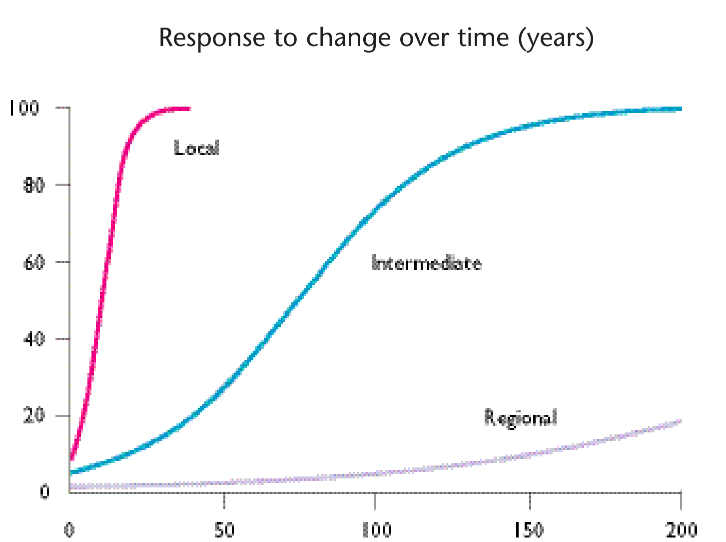

A scaled response

The time-lag between land clearing and the onset of rising groundwater – or between revegetation and when ground-water starts to fall – depends on the scale of the catchment

The lag may be as short as 5–10 years at a local scale, but hundreds of years for regional-scale groundwater systems.

A considered approach to **returning vegetation**

A FIVE-STRAND framework for surmounting the seemingly insurmountable problem of dryland salinity is outlined in a new guide to the use of trees in farm production and catchment management.

The book provides a starting point for serious attempts to manage dryland salinity by showing how revegetation targets of up to 70% can become more feasible with judicious location, arrangements and choice of trees.

The five strands of the framework are:

- understanding catchment-scale salt and water balance;
- assessing the costs and benefits of revegetation;
- determining the optimal area, location and arrangement for revegetation;
- finding commercially valuable perennials; and,
- capturing multiple benefits.

Trees, water and salt: an Australian guide to using trees for healthy catchments and productive farms is produced by the Joint Venture Agroforestry Program initiated by the Rural Industries Research and Development Corporation, Land and Water Australia and the Forest and Wood Products RDC with support from the Murray Darling Basin Commission, Agriculture Fisheries Forestry Australia, Grains RDC, the Australian Greenhouse Office and the Natural Heritage Trust.

More about trees on farms

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