A saline seep on a Western Australian farm.

Rising salt

A test of tactics and techniques

In many parts of Australia, farming is a risky business. The country's capricious climate has always made a gamble of decisions such as when to sow crops or sell livestock. More recently, trends in world commodity markets have caused scrambled shifts in enterprise, from wool to beef, grazing to grains.

Amid this air of uncertainty, pressure is mounting for farmers to address land degradation issues such as dryland salinity, a consequence of Australia's variable climate, unique geology, and the failure of agricultural systems to perform the ecological function of native vegetation.

Australia's geology has been relatively quiet for the past 60 million years. This has resulted in old, weathered soils, many of which have low conductivity, and a generally flat topography with low hydraulic gradients. Water movement through the landscape is so slow that sea salts carried inland by wind and rain have accumulated in the soil. (In more mountainous and wetter continents, salts are regularly flushed back out to sea.)

Before land clearance, most watertables were deep below the surface, and the undissolved salt was immobile in the soil. But in agricultural landscapes, deep-rooted perennial vegetation has been replaced with shallow-rooted crops and pastures.

Native vegetation is attuned to Australia's variable rainfall patterns because over a whole year it has the potential to transpire more water than actually falls. It doesn't matter if rainfall peaks in winter, or is dumped in severe storms. The vegetation's deep root systems even out the variation by drawing on the water year round.

In the case of agricultural crops and pastures, however, any water percolating deeper than about two metres will not be retrieved. This excess water moving below the root zone has thrown natural hydrological cycles out of balance, causing watertables to rise beneath catchments, much like the filling of a bathtub. In the process, salts are redissolved and carried with the water to the surface, concentrating in topsoil and leaching to waterways. Salinisation can take decades to emerge, and to reverse.

Dryland salinity affects almost 2.5 million hectares of Australian farm land, and is expanding at a rate of 3-5% a year, at an estimated annual cost of $270 million. By the time it stabilises, it is expected to have affected some 12 million hectares. Off-farm effects will be felt by all Australians through declines in water quality, habitat degradation, damage to buildings and other assets, and biodiversity loss.

Strategies for salinity management aim to reduce the amount of water recharging into watertables. They include increasing water use by crops and pastures, strategic tree planting, switching from annual pastures to perennial systems and enhancing remnant vegetation. Sometimes, drainage and pumping is used to collect and reuse or dispose of excess ground and surface water.

The choice of strategy, however, and its potential for success, depends on a baffling array of interconnected site factors. These include climate, soil type, the extent of salinisation and its position in the landscape, the size, geology and topography of the catchment, and the depth and salinity of the watertable.

Because these conditions vary widely across southern Australia, remedies must be individually tailored. Controlling dryland salinity is therefore a daunting prospect not only for landholders, but for governments, communities and scientists.

In 1993, a review of dryland salinity research, development and extension led to the establishment of the National Dryland Salinity Program (NDSP), a joint effort

Area of land affected by dryland salinity in Australia

state	area salt affected in 1996 (ha)	potential area affected at equilibrium* (ha)
Western Australia	1 804 000	6 109 000
South Australia	402 000	600 000
Victoria	120 000	unknown
New South Wales	120 000	5 000 000
Tasmania	20 000	unknown
Queensland	10 000	74 000
Northern Territory	minor	unknown
Total	2 476 000	>11 783 000

*The potential area affected at equilibrium is the likely area to be affected if the current levels of salinity are not treated. (Source: LWRRDC 1997.)

among the Land and Water Resources Research and Development Corporation, the Murray-Darling Basin Commission, the National Landcare Program, CSIRO and state governments.

The program's goal was to develop and implement integrated techniques and approaches for managing dryland salinity in Australia. According to a 1997 program review, major steps have been made in this direction through improved coordination among researchers in a range of disciplines, and stronger links between scientists, landholders and community groups.

A good example of this achievement is a multi-disciplinary study on the Liverpool Plains in northern New South Wales involving CSIRO Land and Water, the Australian Geological Survey Organisation (AGSO), state agencies, universities, community groups and landholders. The key challenge was to find out how the below-ground aquifers were replenished, stored and moved water. When this was ascertained, ways of modifying land-uses to reduce water movement to key aquifers were investigated.

'I've never before experienced such a high degree of community involvement: we were working with people (farmers) who were intently watching what we were doing and keen to learn from the outcomes,' Dr Hamish Cresswell, one of the project leaders says. 'I hope this integration between stakeholders and research agencies will become a model, more the norm of how we do this sort of work.'

On a less positive note, the NDSP program review outlined reasons for Australia's abject failure to manage dryland salinity. Chief among these was the lack of technically efficient and cost-effective solutions for the variety of hydrological imbalances for a range of locations.

According to the technical committee of the NDSP, the ability of scientists to prescribe effective remedies is hampered by a lack of spatial and temporal data on the extent and risk of salinity at almost every scale. Compounding this problem is the absence of 'short cut' approaches based on extrapolation and minimal data sets.

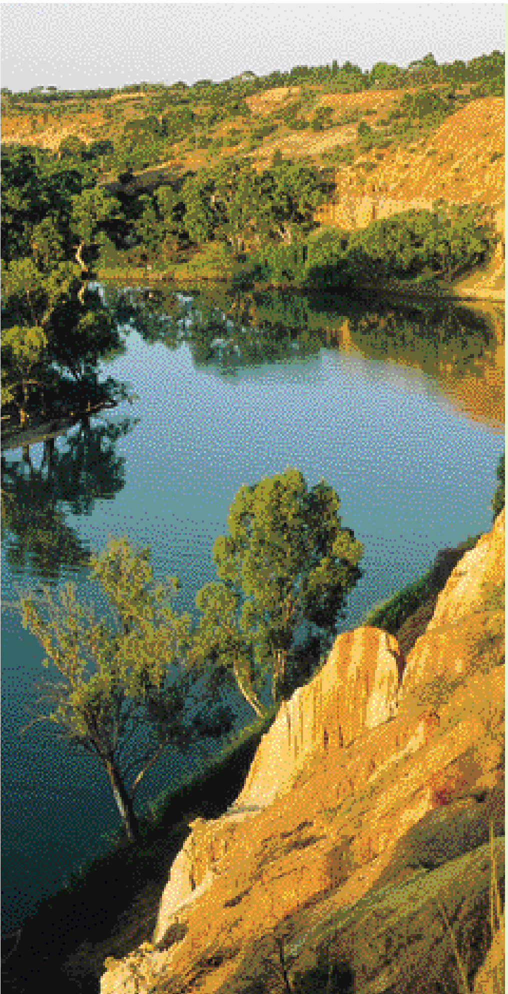
A number of projects undertaken during phase one of the NDSP have sought to redress this problem by developing portable methods for quantifying, understanding and treating dryland salinity.

In Western Australia, the CSIRO Mathematical and Information Sciences remote sensing group has developed techniques for mapping, monitoring and predicting the spread of dryland salinity by combining satellite imagery with details of local terrain and water flows.

Once salinity 'hot spots' are identified, the next step is to describe and model the underlying groundwater processes at a catchment scale, so that control strategies can be compared. But most existing hydrological models require more data than is commonly available at a regional scale.

In another project focussing on the Liverpool Plains, an AGSO-CSIRO research team is trading data-intensiveness for portability. Their predictive model captures key processes affecting salt and water movement at a catchment level, relying on available data. The model will be applied next in Victoria and South Australia.

Dr Joe Walker, manager of CSIRO's Sustainable Catchment Management Program, says the ability to broadly assess salinity risk using readily-available data sets and previously gained process understanding, will lead to a new generation of accessible models. He says current efforts in the Land and Water Audit could provide much of the missing biophysical data.



Calculating the flow-on effects

In the Murray-Darling Basin, at least 2000 km^2 of land is affected by dryland salinity, with an estimated 10 000 km^2 at risk of salinisation by 2010. As well as reducing the agricultural output, the mobilised salts enter the basin's streams and rivers, affecting water quality.

Water is the Murray-Darling's most precious resource. Each year it grows $3 billion worth of irrigated produce, and the Murray River is a major water source for some 1.25 million South Australians. To help authorities allocate resources for protecting water quality, dryland salinity 'hotspots' must be identified.

A useful guide to salinity trends across the basin is the fluctuation of saltloads in streams. This has been monitored regularly at several locations, including one at Morgan in South Australia which has provided daily observations since 1938, with few breaks.

Stream salinity is strongly related to river flow and seasonal patterns, but even when these variations are controlled, trends are often obscured by 'noisy' data. Statistical analysis is need to tease out the underlying pattern.

This ability was developed last year in a project of the CRC for Catchment Hydrology involving scientists from CSIRO Land and Water and CSIRO Mathematical and Information Sciences. The project developed statistical models for analysing changes in salinity at 78 locations in Murray-Darling tributaries. It enabled trends in stream salinity to be related to factors such as climate variability, salt mitigation schemes and trends in groundwater salinisation.

The analysis revealed increasing stream salinity in the southern portion of the basin during the past 20-30 years, at times exceeding the levels acceptable to irrigators and urban populations. The finding correlates well with known trends in land salinisation.

Results of the study will contribute to the upgrading of the Murray-Darling Basin Commission's Salinity and Drainage Strategy, which was developed in the late 1980s.

A salinity-control strategy implemented at Burkes Flat in Central Victoria has been effective in drawing down saline watertables by between one and four metres.

Centre for Land Protection Research

Another AGSO-CSIRO initiative is working with state agencies to classify catchments in relation to characteristics affecting dryland salinity such as geology, topography, land use and rainfall. The system will describe some 20 catchment types which are expected to respond in similar ways, enabling treatments to be prescribed more efficiently, and the targeting of catchments most at risk.

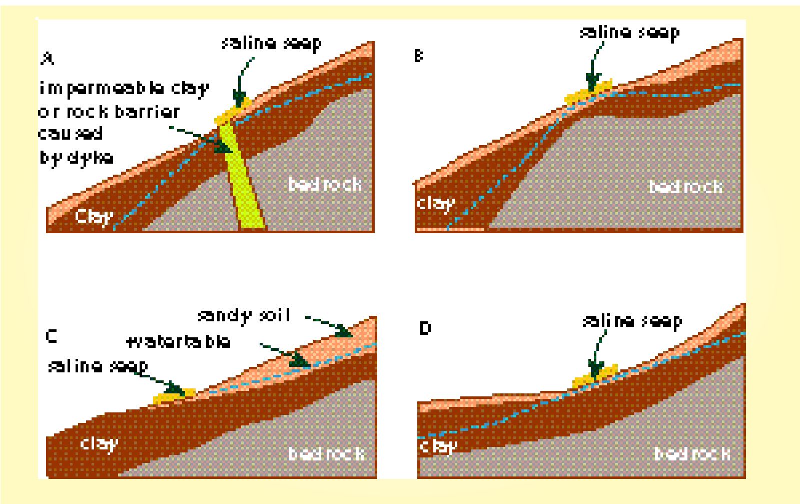
Several means of predicting the likely success of salinity control practices, without the need for copious experimentation, are being developed.

A method that uses readily available hydrogeological data and plant water-use modelling has been developed at CSIRO Land and Water by Dr Ramsis Salama and Dr Tom Hatton. An independent review suggests the method can be used in some 30% of salt affected catchments.

Another innovation being promoted by Hatton involves assessing the capacity of agriculture to mimic hydrological functions performed by natural ecosystems.

With Dr Bob Nulsen of Agriculture Western Australia, Hatton has looked at how water cycling in southern Australia may be made to mimic the natural ecosystem. Their conclusions mirror those of the NDSP review: that hydrologically effective and economic options do not exist for most of southern Australia's agricultural region.

The NDSP review highlighted a second major obstacle to managing dryland salinity, perhaps more intractable than the lack of technical solutions. It relates to the physical distance between the causes and effects of salinisation.



Saline seeps can emerge under a range of hillslope conditions, each of which will respond differently to tree planting. Below are four examples.
A: water flow is interrupted by a geological structure.
B: transmissivity is reduced by bedrock.
C: a change in materials with different hydraulic conductivities.
D: a change in slope leading to a lower hydraulic gradient.
(Diagram reprinted from *Agroforestry and Hydrology: What do we need to know?* with permission from RIRDC.)

Areas where rainfall enters groundwater systems (recharge zones) are often in elevated parts of catchments, well away from the visual impact of salinisation. Discharge zones are where watertables are close enough to the soil surface for water (and dissolved salts) to be drawn upward by evaporation and capillary rise.

Discharge can occur many kilometres from the source of recharge, and its costs, in addition to reduced farm productivity, are spread across the wider community. As a result, efforts aimed at reducing recharge would not necessarily benefit the landholders required to make them.

One lonely example of dryland salinity control, which stands as a model for Central Victoria, occurred in the 900-hectare Burkes Flat catchment, which by 1983 was 12% salinised. A salinity-control strategy implemented in the mid 1980s – which introduced trees and perennial pasture in recharge zones – has been effective in drawing down saline watertables by between one and four metres.

A major reason for success at Burkes Flat was that due to the catchment's small size, only four landholders were responsible for managing it. They all contributed to the salinisation, and they all experienced its effects, so their incentive to tackle the degradation was strong.

The costs and benefits of salinity management in larger catchments are less clear cut. But the success of technical solutions when they become available will depend on their broad-scale adoption.

In a recent report to the Department of Primary Industries and Energy, a team headed by Joe Walker showed that for many regions drastic land-use changes will be needed to significantly reduce areas of salinity, such as the reafforestation of more than 50% of a catchment. This can be expensive to implement.

According to Tom Hatton, few salinity-control techniques promise economic returns to landholders. For example, there is a popular perception that economically-viable tree plantations are limited to areas of at least 700 mm annual rainfall. This limits widespread commercial plantings to a fraction of the Australian landscape.

But Hatton says this view is driven by local economics. 'If policy and infrastructure considered regional benefits (downstream environments and users of water) and wider community values (rural communities, aesthetics, wildlife habitat), then such plantations would be more attractive to land managers in lower rainfall country,' he says.

It seems that ultimately, communities will have to determine socially acceptable rates of salinisation as a basis for setting regional management targets. These will need to achieve a balance between salinity prevention and appropriate uses of saline land.

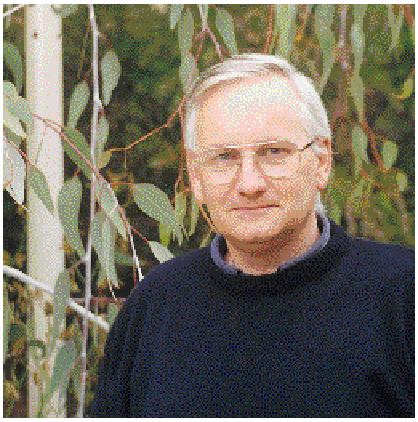
Where impacts cross regional boundaries, for example affecting water quality, federal or state governments may select 'hotspots' where control efforts are subsidised to achieve higher salinity reduction targets. Such decisions will require thorough audits of the costs of dryland salinity, the opportunity cost of changing agricultural practices, the cost of control measures and their rate of success. Guidelines and models for improving the accuracy and analysis of this information are being developed.

In some regions, landholders are taking the initiative by investigating the possibilities of industry self-regulation. For example, the Liverpool Plains Land Management Committee is sponsoring research examining how communities might share the costs of land degradation.

While governments, and landholders affected by salinisation, are crying out for action, many scientists are saying further research is needed to underpin salinity strategies and to improve their likely rate of adoption.

Every region of Victoria has its own salinity management strategy, but according to the former director of the Centre for Land Protection Research at Bendigo, Phil Dyson, adoption rates in some catchments are as low as 2-3%.

Manager of AGSO's integrated catchment modelling program, Ray Evans, says the impact of trees in terms of environmental management is unknown. 'We can say that planting trees will reduce recharge, but we can't predict the impact on streams,' Evans says. 'And we don't know how transportable the research is: it's like a giant patchwork quilt.'



Ray Evans: 'It doesn't matter how good a plan is, if landholders don't adopt, it won't happen.'

Evans says a technical framework for implementation is needed. He says in an ideal world, communities would be encouraged to develop catchment management plans. Using knowledge of biophysical relationships, these would be assessed for their capacity to achieve control targets.

'Then we'd have to overlay the economics at paddock scale, the non-market externalities and the social factors affecting the plan's likely implementation,' he says. 'It doesn't matter how good a plan is, if landholders don't adopt, it won't happen. We will need high adoption rates to get change to happen, higher than there is now.'

Tracking salt by satellite

At Perth's Leeuwin Centre for Earth Sensing Technologies, CSIRO Mathematical and Information Sciences (CMIS) researchers, working with landholders and colleagues from state agencies, have developed a more powerful tool for detecting and predicting salinity.

Dr Norm Campbell, project leader of CMIS remote sensing group, says the technology relies on a large archive of satellite observations amassed since the early 1980s. These show changes in vegetation, land clearing and the spread of salt-affected areas over time.

The CMIS remote sensing group has learned to interpret this satellite record through a series of projects in Western Australia supported by the Land and Water Resources Research and Development Corporation.

'Satellite images provide information about past and present vegetation cover and land condition,' Campbell says.

'When combined with other datasets which describe the terrain and the movement of water through the landscape, it is possible to predict areas at risk of salinity. At any position in the landscape, salinity risk is related to the amount of water flowing to that position and the slope at which the water drains away.

'We use digital elevation models to create a three-dimensional view of an area and work out regional drainage patterns. The satellites show us the extent of clearing .'

Techniques developed by the group have been used to map salinity and salinity risk in the Upper Kent region, a focus catchment of the National Dryland Salinity Program, located 350 kilometres south-east of Perth.

Landsat images were used to map vegetation and existing salinity changes between 1977 and 1994. This was superimposed on a three-dimensional terrain model. The result was a map revealing areas where water tended to accumulate and salinity was likely to develop. Expert systems were then used to identify areas most at risk of becoming salinised in the next 10 years.

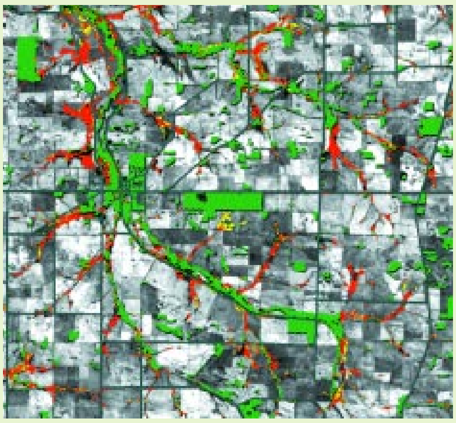
Another of the group's projects is mapping salinity in WA's Blackwood and Frankland-Gordon catchments. In this study, data provided by hydrologists are being used to determine local rules for defining relationships between land cover, landform and salinity.

For example, one rule is that for sites more than 125 metres from known salinity and on a hilltop, upper or lower slope with low to high vegetative cover, there is no risk of salinisation. Another rule points to salinisation risk in a valley floor with a catchment area greater than 4.5 ha.

Maps showing changes in salinity over time have been distributed to catchment groups and Agriculture WA officers for use in management planning and on-ground validation. Farm-scale maps showing areas at risk of salinity, waterlogging and low productivity have also been developed.

The CSIRO approach has also been adapted to interpret satellite observations of the Liverpool Plains in Northern New South Wales.

'Though we do not claim our salinity predictor can be used by everyone just yet, in skilled hands it can help interpret what is going to happen in a landscape,' Campbell says. 'And that buys time in which to take preventive measures such as tree planting, which are necessarily slow to take effect.'



In this salinity change map, the green areas are remnant vegetation, the red areas were salted in 1989/1990 and the yellow areas were salted in 1993/1994.