Restoring the Murray–Darling Basin

A rather strange thing is going on now. One day all the creeks and little watercourses were covered with a large tussocky grass, ... but... now the only soil is getting trodden hard with stock, springs of salt water are bursting out in every hollow... and as it trickles down the watercourses in summer the strong tussocky grasses die before it...

Before returning to his native Scotland, Mr John Robertson attempts to describe in a letter to Lt-Governor C.J. La Trobe* what has happened to his 20 000-hectare property in south-western Victoria. The date is 1853 — a poignant reminder that land degradation and salinity have dogged Australians since early settlement.

Today, 140 years on, the land degradation Mr Robertson observed has become much more severe and widespread. But in one sense we are better placed than he was: we now understand the processes underlying salinity and erosion and can take steps to ameliorate them. Reforestation is one important strategy.

In the current Decade of Land Care, planting trees on those parts of the landscape where they will most effectively counter land degradation will be a major goal of government agencies and scores of community groups. To get the best out of people's enthusiasm, time, and money, revegetation projects will need to be carried out on sites where they will do the greatest good. Two complementary CSIRO projects will help in this by developing methods to identify such sites.

In the first, funded by the National Afforestation Progam (NAP), scientists are using data gathered from the whole of the Murray–Darling Basin to track down which landscapes are most susceptible to salinity and to determine where extensive reforestation has the most potential to arrest rising water tables. In the second, part of CSIRO's Land and Water Care initiatives on land degradation, which began last November, they are carrying out research to develop and test techniques that will predict what blend of plants should be established — and whereabouts within a catchment — for the greatest ameliorative effect.

Salty problem

A simple equation helps explain much of Australia's land degradation problem: on one side is the amount of water that falls as rain or snow; on the other is the amount that evaporates, runs off the surface, percolates downwards, soaks into soil, or is used and transpired by plants. Change just one of the quantities and something else has to change too. Early settlers like Mr Robertson were not to know that, when they replaced native forests with plants that used less of the rainfall, Australia's unique geological formations and history would reward them with rising salty water tables.

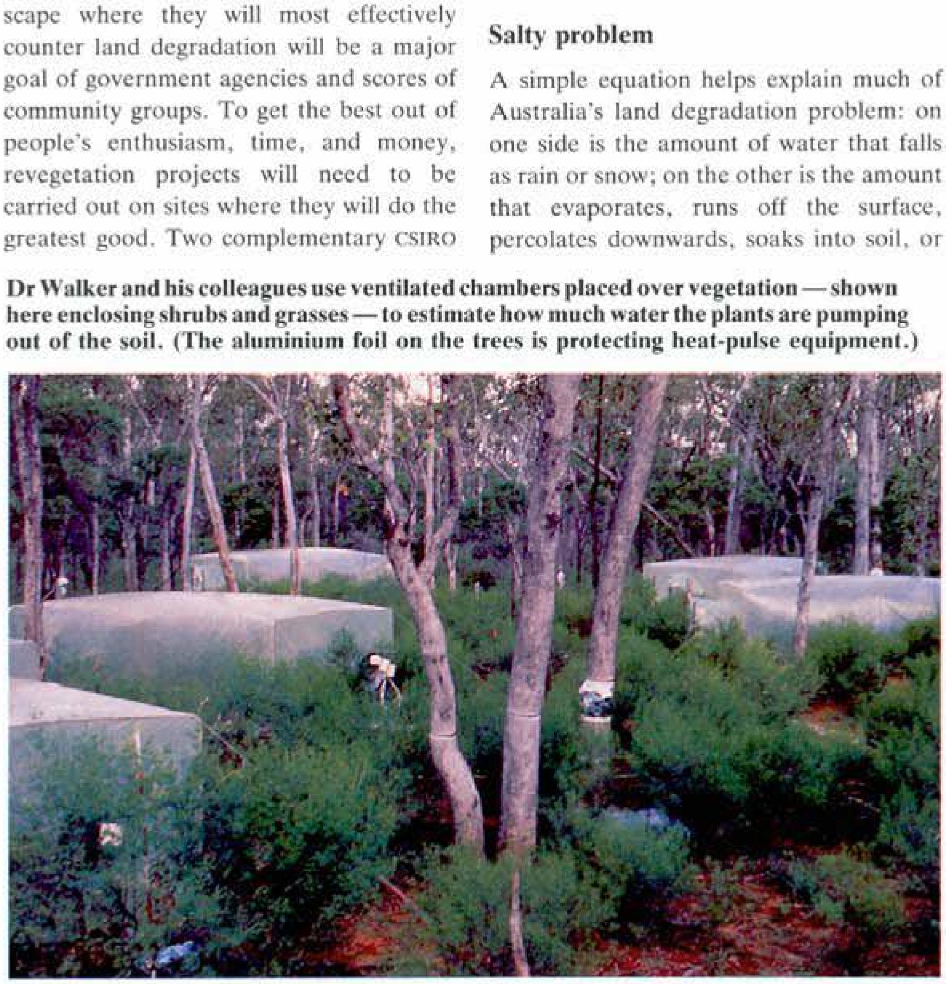
Beneath the catchments of the Murray–Darling lie some of the world's largest aquifers, containing huge groundwater reserves. But, for much the same reason that a large leaking bath filled only by a dripping tap will never overflow, groundwater usually stays below ground. For example, it's believed that, over the past half million years, these groundwater aquifers in the south of the Murray–Darling Basin have overflowed across the riverine plain only six or seven times. Normally, they stay in a state of equilibrium, discharging slowly into the Willandra Lakes in western New South Wales or at sites along the River Murray east of its confluence with the Murrumbidgee.

However, since European colonisation, that equilibrium has been upset. With agricultural development we've gradually turned on the tap over the bath and watched as the water has overflowed, poured into the basement, and gradually risen through the floor of the lounge-room all over our best wool carpet. In the case of our troubled catchment the problem is much worse than a soggy Berber; the rising groundwater has brought to the surface heavy deposits of naturally occurring salt. These high salt levels, previously kept at bay by low water tables, have killed the vegetation, damaged the soils and exposed them to erosion, and degraded the quality of the surface water.

Large-scale irrigation was one of the two 'tap-turning' actions that have been mainly responsible for this salinisation. The other was the removal of deep-rooted evergreen trees that once used up soil water for growth and transpiration, reducing the amount percolating down to recharge the groundwater reserves. The latter has resulted in dryland salinity.

Slowing the rate of this recharge in order to lower water tables and to reduce soil moisture content is the main purpose behind any amelioration strategy. Engineering works that pump groundwater directly from aquifers or that capture saline water and divert it to evaporation lakes provide effective (but short-term and expensive) remedies. Manipulating the

Dr Walker and his colleagues use ventilated chambers placed over vegetation — shown here enclosing shrubs and grasses — to estimate how much water the plants are pumping out of the soil. (The aluminium foil on the trees is protecting heat-pulse equipment.)



* quoted in 'Watering the Garden State: Water, Land and Community in Victoria 1834–1988', J.M. Powell. (Allen and Unwin: Sydney 1989.)

Land care and community action! Children at the Hall Public School, on the A.C.T./N.S.W. border, growing trees in their nursery for the Yass Valley Revegetation Project.

water balance by increasing evapotranspiration through the restoration of deep-rooted vegetation offers a longer-term solution.

How many trees?

If planting trees is the solution to dryland salinity, do we need to replant the whole of the Murray–Darling Basin? A quick look at the way we use the land there shows that this proposition is hardly realistic; the Basin supports one-quarter of the nation's beef and dairy herds, half of its sheep and cropland, and nearly three-quarters of its irrigated land. Annual production is valued at some $12 000 million. Besides, as the map on page 7 shows, not all of the Basin originally carried forest.

Mapping apparent electrical conductivity is a technique the researchers are using to find out which parts of a catchment contain the most salt. In this map of a 40-ha paddock, the red areas are high in salt and the green ones are low.

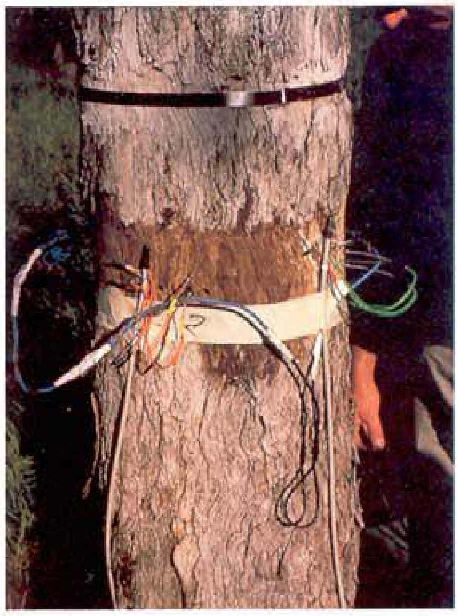
The map is a composite of two, produced by Dr John Carnahan of the Australian National University and Mr Frank Bullen and others of the Division of National Mapping (now AUSLIG). The original maps plot Australia's vegetation cover — in broad structural and floristic types, such as eucalypt forest, acacia woodland, etc. — as it was before European settlement and is at the present time. The scientists have recently digitised this information, making it possible to quantify how much forest and woodland has been lost during the last 200 years.

The simplified map shown here illustrates the extent of the change — forest areas have been reduced by 56% and woodlands by 58%. Using field information about tree densities typical of present-day forests and woodlands, Dr Joe Walker of CSIRO's Division of Water Resources and Mr Bullen have calculated that between 15 and 18 billion trees have been cleared from the Basin. Fortunately, recent research indicates we won't have to replant anything like that number to restore the health of our most important catchment.

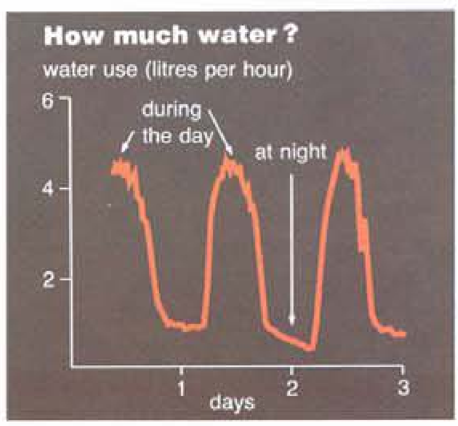
In the past, keen tree-planters wishing to grow trees to control salinity had little information to draw on that would help them decide where to plant, which species to plant, and at what density. Given the long lead time between action and effect, trial-and-error plantings can be pretty discouraging. The two CSIRO projects, which combine field information and local knowledge with computer modelling, offer real hope that future reforestation programs won't rely solely on enthusiasm and good intention.

The big picture

The first, a 3-year project that includes mapping the salinity hazard for the whole of the Murray–Darling Basin, has already been running for nearly 2 years. It has drawn together researchers with a range of expertise from CSIRO's Division of Water Resources and Division of Wildlife and Ecology. Mr John Ive, Mr Doug Cocks, Mr Chris Parvey, and Mr Richard Dunworth, of Wildlife and Ecology, are using their land use computer program LUPIS (Land Use Planning and Information Systems) to prepare a salinity hazard map that will show



With a heating wire and sensors installed into the sapwood of a tree, scientists can calculate water flow in the stem.



This plot from the heat-pulse meter shows the volume of water used (in early October) by a large poplar box tree growing near Goondiwindi, Qld.

Land Care needs community action

Restoring the health of the Murray–Darling Basin will, of course, take time and money. But, more than that, it will take some dedicated nursing and commitment from land-owners, scientists, government, and the community at large. The Land and Water Care programs emphasise the need to draw on the knowledge that we have now and quickly implement research results. It's a view shared by others.

Last year, Mr Richard Eckersley of CSIRO's Office of the Chief Executive produced a report that suggested that a large national program to 'regreen Australia', involving the growing of billions of trees and other plants, and extending over 10–20 years, would offer Australia a range of environmental, economic, and social benefits. A recent House of Representatives Standing Committee reporting on the effectiveness of land degradation policies and programs has supported Mr Eckersley's proposed reforestation program and has recommended the formation of a working group to identify ways in which it can be implemented.

While the Committee was collecting evidence for its report, its members visited five successful land care groups around the country, including one Mr Ive has chaired for the past 4 years — the Yass River Valley Revegetation Project. Yass has the unenviable status of being the dryland salinity capital of New South Wales. Stream salinity levels are rising by 7% a year — about twice the State average. But, through the efforts of large numbers of volunteers — helped along with funds from a range of sources including the National Soil Conservation Program, the National Tree Program, and the Commonwealth Employment Program — the local community is attempting to change all that.

Since 1984, the project has produced 10–20 000 trees a year in its nursery, and these have been planted throughout the Yass Valley on public and private land. It has an educational as well as a practical role; about 20 schools — from Albury to Orange — are involved in its activities. Participating schools are provided with a shadehouse (financed by Lions), propagation equipment, instruction sheets, and, if they need them, propagation demonstrations. Schools are encouraged to integrate the nursery activities with the school curriculum, and an annual book prize is awarded to the school with the greatest achievements.

The project, which received the coveted Greening Australia National award in 1988, is being used as the model 'land care group' for the federal government's 'One Billion Trees' program and the Murray–Darling Basin Communities of Common Concern network.

Regreening Australia: the environmental, economic and social benefits of reforestation. R. Eckersley. *CSIRO Occasional Paper* No. 3, 1989.

'The Effectiveness of Land Degradation Policies and Programs. Report of the House of Representatives Standing Committee on Environment, Recreation and the Arts.' (Australian Government Publishing Service: Canberra 1989.)

areas at risk to dryland salinity should water tables rise.

Back in 1981, Mr P. Greig and Mr P. Devonshire, of the Victorian Forests Commission (as it was then), reported research findings that showed salt concentration in a stream is related to three variables in the surrounding landscape: rainfall, the proportion of forest cover, and the proportion of sedimentary rock in the stream's catchment area. The CSIRO researchers, drawing on this work, reasoned that stream salinity levels should reflect the dryland salinity hazard appearing in landscapes upstream.

Mr Ive, Dr Cocks, and their Divisional colleague Mr Paul Walker used this relationship to map salinity hazard in Victoria. After dividing the State into 1595 equal areas (cells) — each about 140 sq. km — they modelled the contribution of each to stream salinity and made comparisons with the occurrences of dryland salinity recorded by the then Victorian Soil Conservation Authority, which had categorised the cells as being severely, moderately, or minimally affected.

They found that, while 109 cells had areas within them that were severely salt-affected, a further 341 could through time deteriorate into this category. As well as the 259 cells now moderately salt-affected, a further 646 had the potential to degenerate to this status.

From their model the scientists estimated that to change the majority of severely (or potentially severely) salt-affected areas to the moderate category would require complete reforestation on less than 10% of the total land area. Most moderately salt-affected areas (both currently and potentially) would require more than 50% of the area to be replanted to take them back to the 'minimal' category.

Confident that the model gave accurate predictions of salinity hazard in Victoria, the scientists used the same model to map the areas of salinity hazard for the whole of the Murray–Darling Basin. They are still refining this Basin-wide map, but first estimates indicate that to keep salinity at a level of moderate or better, 15% of it — 150 000 sq. km — will have to be reforested. They are confident that the final map will produce a clear and reliable estimate of where dryland salinity has the potential to increase.

Salinity, plants, and water use

In another part of the same project, scientists from the CSIRO Division of Water Resources are attempting to get a clearer picture of the link between salinity, water use by plants, and vegetation type. Dr Baden Williams is using a technique he developed that employs electromagnetic conductivity meters (EM) (see *Ecos* 54) to map saline areas. The technique enables the scientists to map relative salt concentrations from site to site within a landscape and, hence, locate the best places to drill to obtain more detail about the salt distribution down the soil profile.

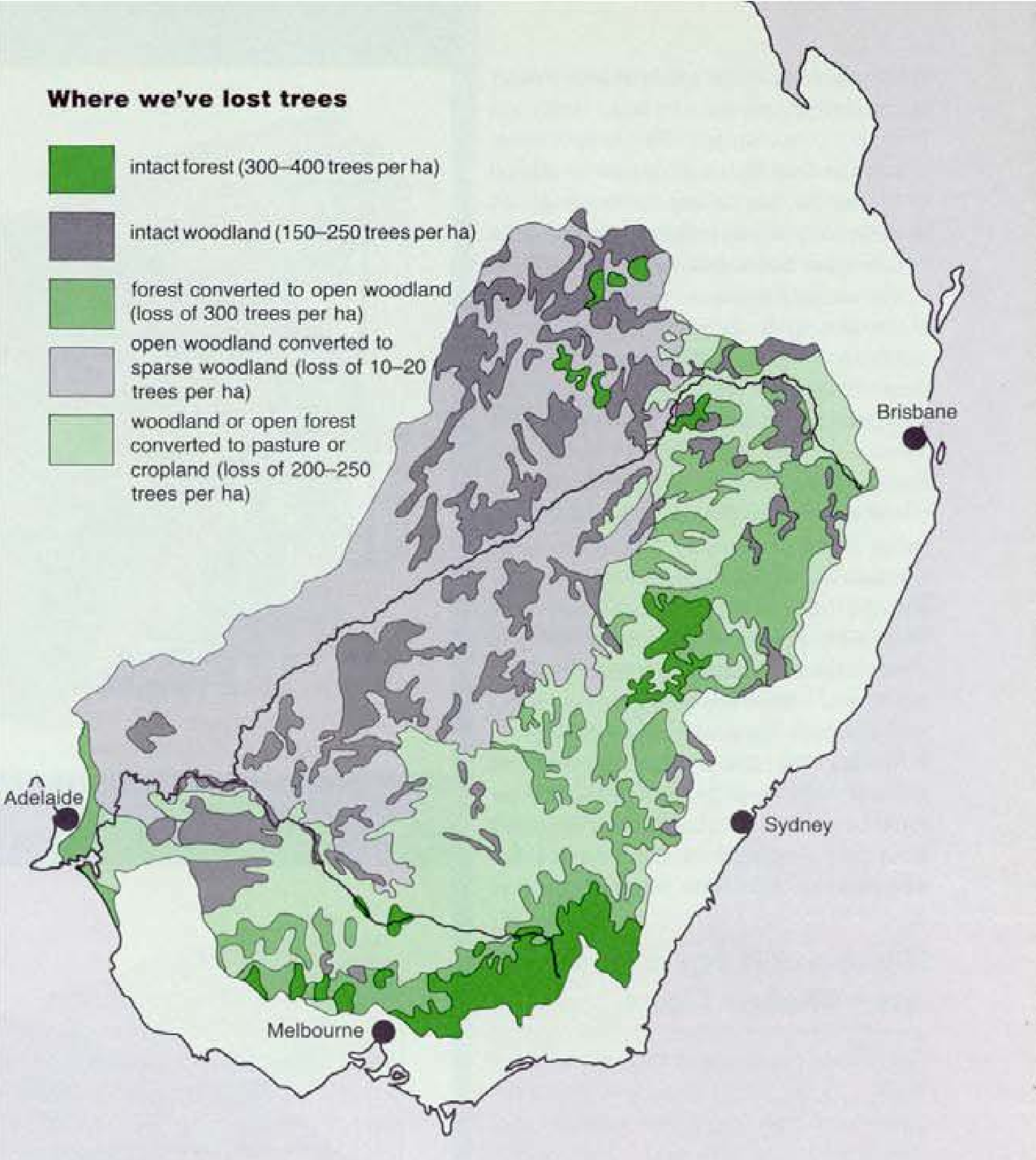
The Water Resources team has used the EM technique to investigate the impact of tree-clearing for matched pairs of sites. Their results emphasise the need to consider the total composition of the landscape in predicting likely impacts of tree-clearing and in assessing the benefits of reforestation. They have shown, for example, that near Lake Cargelligo, N.S.W., although most cleared sites registered large increases in EM values, some areas cleared of trees had lower EM values than uncleared sites.

Another key part of the team's research is determining, in the field, the amount of water used by vegetation — not only trees, but also shrubs and grasses. The scientists are using various approaches to help them estimate water use directly, including enclosing areas of vegetation in ventilated chambers (big polythene bags with air forced through them) — a technique pioneered by Dr Eric Greenwood, also of the Division of Water Resources (see *Ecos* 58). Although this approach has been used with trees, it is generally difficult and expensive to completely enclose a large number within a chamber.

Instead, the researchers estimate water loss from individual trees using a heat pulse technique, which accurately records the amount of water passing a single point in

Since 1788, between 15 and 18 billion trees have been cleared in the Murray–Darling Basin. Putting some of them back will help restore the catchment's health, but we must plant them where they will be most useful.

Where we've lost trees



the sapwood of a tree trunk (see the box on page 7). With this instrument they can estimate the daily and seasonal use of water by trees of various sizes — a big poplar box tree in summer will use 50–70 litres per day. These data provide the team with a means to quantify the amount of water that trees will mop up following reforestation.

The final step of the NAP project is to combine information on landscapes, climate, and plant water use to predict the gradual effect of reforestation in different parts of the Basin. For this they are using computer models of plant growth — RESCOMP and FOREST BGC — developed in collaboration with overseas researchers Dr Peter Sharpe from Texas A&M University and Dr Steve Running, Mr Lars Pierce, and Mr Joe Coughlan, from the University of Montana.

The models simulate the way in which plants respond to available soil water, light, temperature, relative humidity, nutrients, and salinity. They are designed to predict — given these various inputs — the amounts of water used per week by a developing forest anywhere in the Murray–Darling Basin. Using output from these models, the team will be able to identify not only which areas are most likely to benefit from a reforestation program, but the required tree density. Present results suggest that the areas most likely to benefit are on the southern and eastern fringes of the Basin.

A closer focus

Other research in the Division of Water Resources has focused on developing individual guidelines that will help land-owners plant trees where these will be most useful in controlling salinity on the property.

The project utilises a landscape-wetness model — TOPOG — developed by the Division's Australian Centre for Catchment Hydrology under the direction of Dr Emmett O'Loughlin. By simulating the flow of water through soils the model can predict locations where soil moisture will reach high levels (or have a high 'soil wetness') under actual or simulated rainfall.

The TOPOG model has numerous practical applications. For example, Dr O'Loughlin has used it to determine suitable locations for all-weather forestry access tracks and to position safe liquid-waste disposal trenches on hillslopes. In relation to dryland salinity, the scientists assume

How much water does a tree use?

The development of tree-planting strategies aimed at reducing the salinity hazard in the Murray–Darling Basin requires an understanding of how much water different plants use and at what rate. To help them develop that understanding quickly and cheaply, scientists from the CSIRO Division of Water Resources are using a technique known as the heat pulse method, which is designed to measure the rate of water flow through sapwood.

The technique is based on the assumption that all of the water that a tree uses must pass through the sapwood in the trunk. By injecting a small local pulse of heat into the bole to 'label' the water, the scientists can determine its subsequent rate of ascent, and estimate its flux up the tree and the daily and seasonal pattern of water use.

Dr Eric Greenwood and Mr Greg Bartle are among scientists from the Division of Water Resources who have used and modified the technique. They have applied it to a wide range of trees across Australia and obtained estimates of how much water trees use in different environments. Dr John Marshall has also used the technique to address questions regarding forest practices and water quality in the Darling Ranges of Western Australia.

And recently, Dr Tom Hatton and Mr Ivor Durham have improved the mathematics and electronics associated with the technique, enabling them to develop a new heat pulse device — SAPZAP — that is more powerful and robust than current commercially available technology. Scientists are using SAPZAP to measure water use by a variety of tree species across the Murray–Darling Basin.

Information regarding the device may be obtained from the Division.

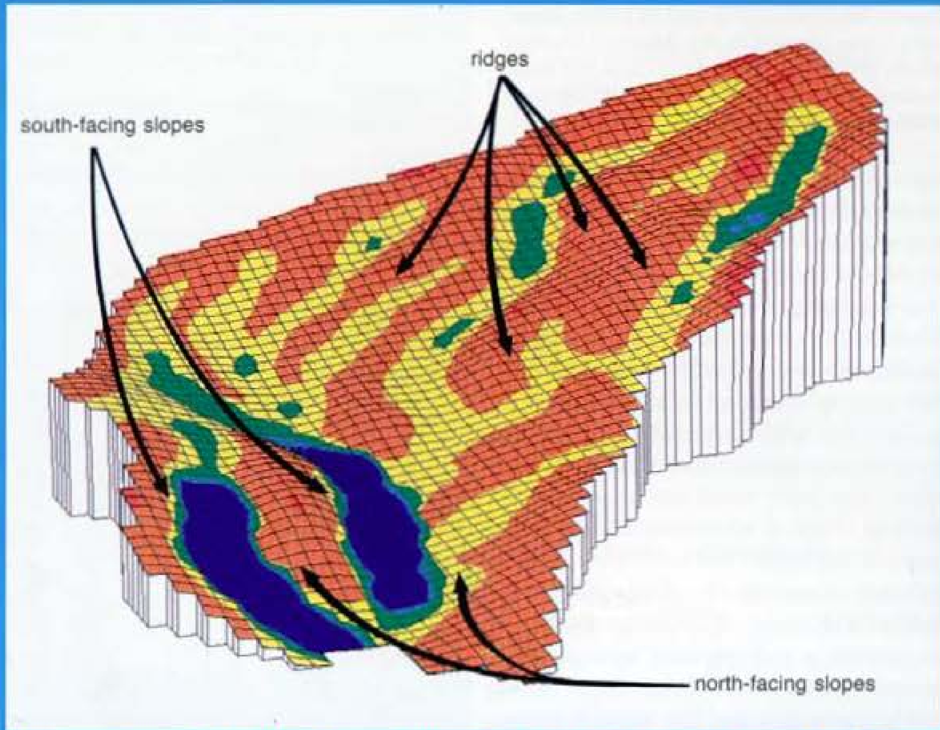
that, where sub-surface flow leads to water accumulating at the surface, salt will become concentrated by evaporation. Water used up by trees can be simulated in the model, permitting the investigation of different planting strategies on the areas where water and salt accumulate.

The scientists have tested TOPOG's ability to help devise planting strategies for salinity control on an 80-ha farm catchment near Rylestone, N.S.W. The site was mapped for soils and topography by Mr Jim Salmon of the New South Wales Soil Conservation Service, and the distribution of salt mapped by Baden Williams and Mr Peter Richardson using EM techniques. Emmett O'Loughlin and his colleagues Mr Rob Vertessy and Mr Patrick Lane used TOPOG to predict where wet areas should occur in the landscape. They found that the model was indeed predicting the wet areas in the correct landscape positions.

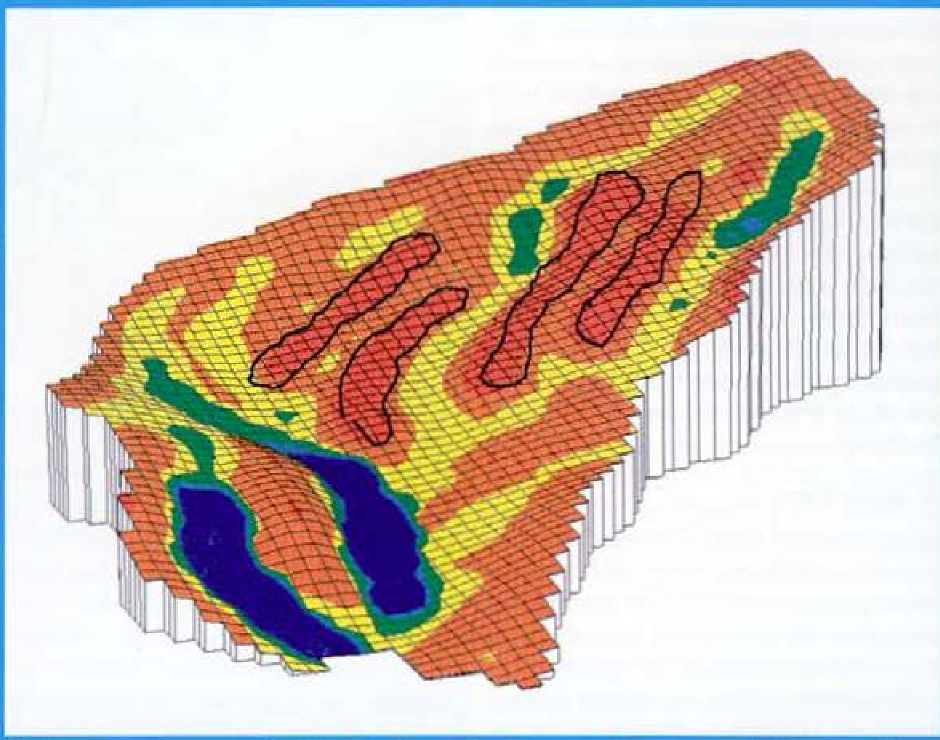
Making the assumption, on practical grounds, that up to 15% of the catchment could be planted to rehabilitate a degraded area, they simulated the effects that three tree-planting strategies would have on sub-surface drainage. These different strategies involved plantings on ridges, or on north-facing or south-facing slopes adjacent to wet areas.

Conventional wisdom suggests that planting trees on ridges reduces wet areas the most. But the simulation showed that such plantings had virtually no effect on saline seepages. The reason is that very little of the water in the wet areas originated from the upper part of the catchment. Planting on north-facing slopes also had little effect.

By contrast, planting on south-facing slopes dramatically reduced the wet areas (and hence the area of potential salinisation) because these receive less solar radiation than those facing north and therefore have a greater reserve of soil moisture, which is moving down the slope. Trees planted on the south-facing slopes efficiently use up the excess water.



The computer model TOPOG successfully predicted where salt would accumulate (shown here in blue) on an 80-ha farm catchment near Rylestone, N.S.W.

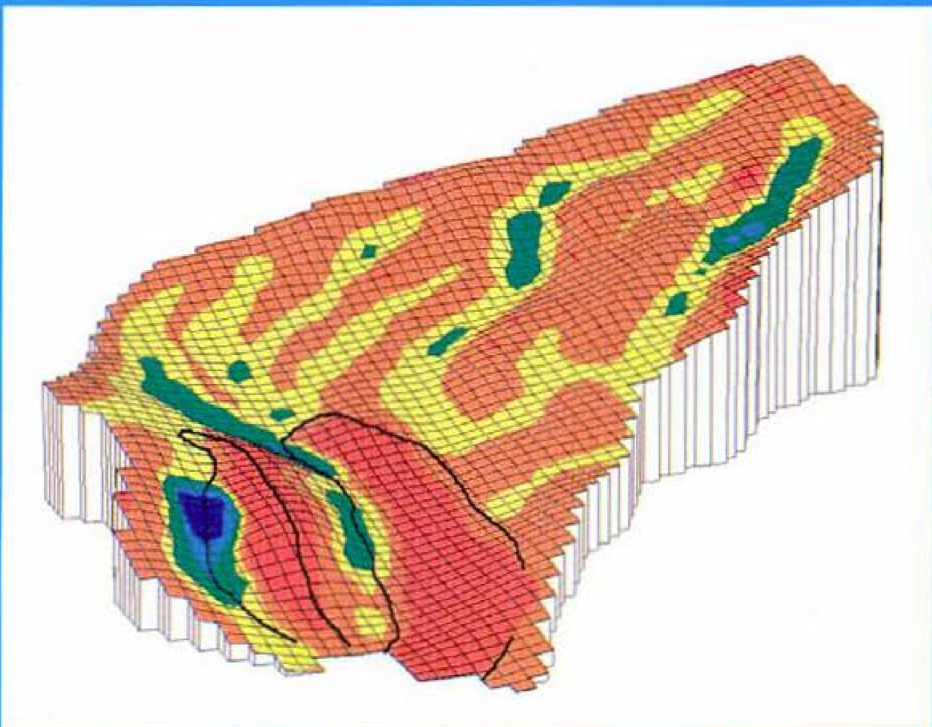


Planting trees (area outlined in black) on the ridges would not successfully control salinity...

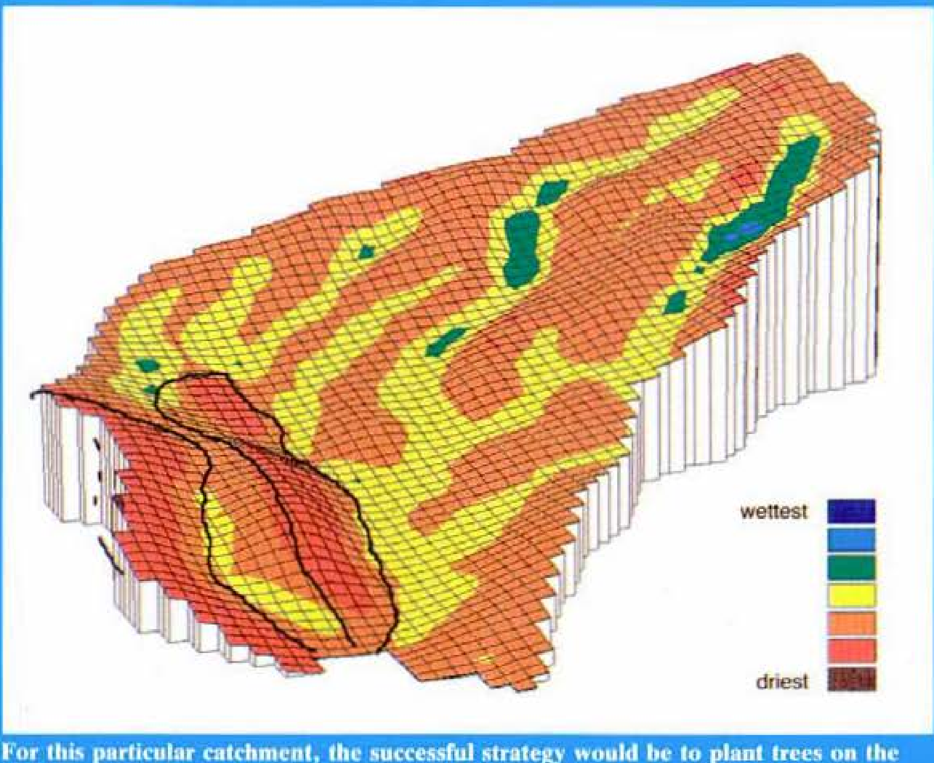
Research for Land and Water Care

The salinity control program, led by Dr Joe Walker, is one of six programs within the CSIRO Land and Water Care initiative that commenced late last year. The salinity control projects are listed below.

- ▷ Which tree or shrub species to plant for salinity control — Dr Nico Marcar and Trevor Booth, Division of Forestry and Forest Products.
- ▷ Strategies to reduce irrigation salinisation — Dr Wayne Meyer, Griffith Laboratory, Division of Water Resources.
- ▷ Prediction of salinisation risk following tree-clearing in the Upper Burdekin catchment in northern Queensland — Dr Ross Coventry and Dr John Williams, Townsville Laboratory, Division of Soils.
- ▷ Control of dryland salinisation by enhancement of groundwater discharges — Dr Ramsis Salama, Perth Laboratory, Division of Water Resources.
- ▷ Vegetation manipulation for salinity control — Dr Joe Walker, Dr Emmett O'Loughlin, and Dr Baden Williams, Division of Water Resources, Canberra.



...nor would planting on north-facing slopes.



For this particular catchment, the successful strategy would be to plant trees on the south-facing slopes.

Land and Water Care

The second major project mentioned at the start of the article, led by Dr Joe Walker, addresses a range of questions relating to salinity control in many parts of the country (see the box on the facing page). Work on vegetation manipulation for salinity control will draw on findings and methodologies developed in the NAP project and the Australian Centre for Catchment Hydrology research.

A key piece of work will combine the soil wetness model (TOPOG) with the land cover models to better cope with mixtures of vegetation, including reforestation of parts of the landscape. This modelling approach is essential; we simply do not have enough time to wait for the results of conventional rehabilitation trials. (These would take a minimum of 20 years to complete and not all landscape combinations could be planted.) A major component will be working with Land Care groups to transfer research findings to the user as quickly as possible.

The scientists have targeted an area of 38 000 ha near Young, N.S.W., as a test area for application and demonstration of research findings. The modelling methods developed will be combined with EM surveys to define the best places to establish trees, shrubs, pastures, or crops. Once the broad possibilities are defined, the researchers will select appropriate trees and shrubs for planting.

They will do this using a decision support program being developed especially for saline-affected areas by Dr Trevor Booth and Dr Nico Marcar, of the Division of Forestry and Forest Products. They will also make use of general-purpose tree-selection programs, as well as the experience of local landholders and Land Care groups. The researchers will then run their model again to test the effectiveness of various vegetation combinations and planting strategies.

Members of the team hope this work will produce a simple method for deciding on the best mixture and distribution of vegetation types to combat salinity. Their plan is to extend the results to other catchments in the Murray–Darling Basin. Finally, after consultation with various user groups, they hope to develop a simple meter — much like the well-known Fire Danger Meter — that will show landholders where to establish the vegetation prescriptions that will lead to a healthier catchment.

David Brett

More about the topic

Modelling the hydrological response of catchments to land use change. E.M. O'Loughlin, D.L. Short, and W.R. Dawes. *Hydrology and Water Resources Symposium, University of Canterbury, Christchurch, N.Z. 23–30 November, 1989.*

Rural land degradation in Australia: the role of trees in ecological solutions. J. Ive and D. Cocks. *The Australian Conservation Farmer*, 1989, **1**, 18–22.

Prediction of surface saturation zones in natural catchments by topographic analysis. E.M. O'Loughlin. *Water Resources Research*, 1986, **22**, 794–804.

Effect of neighbouring trees on eucalypt growth in a poplar box woodland. L.K. Penridge and J. Walker. *Journal of Ecology*, 1986, **74**, 925–35.

Ecological field theory: the concept and field tests. J. Walker, P.J.M. Sharpe, L.K. Penridge, and H. Wu. *Vegetation*, 1989, **83**, 81–95.