Effectiveness of Current Farming Systems in the Control of Dryland Salinity

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Why do we need to worry about dryland salinity?

Dryland salinity is a serious problem in many parts of Australia, including the Murray-Darling Basin.

In 1998, the Prime Minister’s Science, Engineering and Innovation Council estimated that the costs of dryland salinity include $700 million in lost land and $130 million annually in lost production. The effects of dryland salinity include increasing stream salinity, particularly across the southern half of the Murray-Darling Basin, and losses of remnant vegetation, riparian zones and wetland areas. Salinity is degrading rural towns and infrastructure, and crumbling building foundations, roads and sporting grounds.

The problem is not under control—we can expect the effects of dryland salinity to increase dramatically. For example, if we do not find and implement effective solutions, over the next fifty years the area of land affected by dryland salinity is likely to rise from the current 1.8 million hectares to 15 million hectares.

Stream salinity is also a major concern. Projections for the town of Morgan, a key location used to monitor the effect of salinity in the lower part of the Basin in South Australia, illustrate the problem. Here, the salinity of the River Murray is expected to increase by a further 240 EC units (microSiemens/cm) over the next 50 years. This will bring salinity in this part of the river close to the World Health Organization’s limit of 800 EC units for desirable drinking water, and create concern for its long-term sustainability for urban water use. In some northern parts of the Basin it is expected that river salinity will rise to levels that seriously constrain the use of river water for irrigation.

The enormous level of intervention needed to deal with dryland salinity, and the landscape’s slow response to any changes, mean that now is the time to devise new ways to manage the problem.

The government of Western Australia is developing a dryland salinity action plan for that State. The Murray-Darling Basin Commission is currently setting in place a process to develop new natural resource management strategies to address salinity issues in the Basin.

This report is a contribution to that process. It seeks to establish the role we can expect our current farming systems to play in salinity control in the future. Further, it sets out what is required of new farming systems if they are to be part of strategies to control salinisation by treating its cause.
What is dryland salinity?

Australia is a dry country. Its landscape contains large amounts of salt from the ocean, introduced into the landscape through rainfall and the chemical weathering of rocks, and built up over thousands of years.

Our clearing of native vegetation for dryland agriculture (such as grazing and cropping systems) has allowed too much rainfall to leak into the groundwater systems of these landscapes. This leakage causes watertables to rise and brings saline groundwater close to the land surface. The movement of salt to the land surface with rising groundwater in non-irrigated lands is known as dryland salinity.

The warning signs of a landscape affected by dryland salinity include sick or dying trees, declining vegetation, the appearance of salt-tolerant volunteer species such as Sea Barley Grass and Spiny Rush, bare salty patches, and saline pools in creek beds. Any of these can affect crop productivity, the sustainability of agriculture and the quality of water in rivers and streams, or crumble the foundations of buildings and roads.

Australian landscape and salinity

Differences between the Australian landscape and landscape in most other parts of the world mean that agricultural systems that are sustainable elsewhere do not necessarily transfer to our unique conditions.

One major difference is that most of our groundwater and surface water systems are poorly drained, leading to the storage of enormous amounts of salt in the landscape.

Dryland salinity does occur in other countries, but to a lesser extent. A combination of natural factors has led to Australia's significant problems with dryland salinity: the continent is geologically old and stable, and the climate is very dry (that is, there is a low rainfall compared to potential evaporation). Our native vegetation has adapted to these unique conditions.

Australia's low rainfall means that we have one of the lowest amounts of runoff in the world. As a result, most of our rainfall is used by plants where it falls and only very small amounts leak to the groundwater. In addition, poor drainage and older, less permeable landscapes are conducive to the accumulation of salt. Combined, these conditions mean that salts are not flushed from the landscape by leaching. Vegetation further inhibits leaching because it uses the rainfall. The consequence is that saline lakes, streams and land are a natural part of the Australian landscape.

The way it was...

In most cases Australia's native vegetation comprises trees or woody shrubs. This perennial vegetation, with its relatively deep roots, has become effective at taking full advantage of any available water. As a result, it can use most of the water entering the soil. The 'leakage' of excess water into the deeper soil below the roots is usually quite small, if it happens at all. Various studies have shown that over most of Australia's current dryland grazing and cropping areas, this leakage was commonly between 1 and 5 mm/year.

Over thousands of years the minimal leakage has allowed the salts introduced through rainfall or rock weathering to build up in the soil below the depth of plant roots.
Changing the natural conditions

European settlers have changed the Murray-Darling Basin to a remarkable degree in a relatively short time. Large-scale clearing of native vegetation and its replacement with crops and agricultural systems have substantially increased the amount of water entering the groundwater systems of the landscape.

These increased amounts of water now entering the groundwater under current agricultural production systems greatly exceed the capacity of the groundwater systems to discharge the additional water to the rivers and streams. As the input to the groundwater exceeds the output, the watertable must rise. As it rises, more water is discharged to the land surface as seepage surfaces (usually at lower positions in the landscape). Wherever this groundwater contains salt or intercepts salt stored in the landscape, salt is mobilised to these seepage faces, and hence to the land surface, rivers and streams.

The amount of water leaking into the groundwater system depends on various factors that include the climate (particularly the amount of rainfall), the permeability of soils and subsoil, and vegetation characteristics. For example, any water leaking beyond the root zone does not always end up in groundwater, since in certain situations it can move laterally through the soils and end up in surface streams. In other situations, leakage can occur from the base of the streams into groundwater systems.

There is too much leakage

Leakage can be much greater under current agricultural systems than under natural vegetation. It occurs when the plant/soil system cannot cope with the amount of water that has fallen over a period of time. Leakage is caused by a complex combination of climate and rainfall patterns, vegetation cover and soil properties.

Climate

The effect of climate and rainfall on leakage to groundwater can be simplified into two different types, as follows.

1. In wetter areas, normal rainfall can exceed potential evaporation for a period of the year, leading to leakage when the excess water cannot be stored in the soil.

2. In drier areas, leakage is likely to occur mainly as a result of exceptional circumstances, such as intense rainfall and flooding that may only occur once every 3–20 years.

In determining leakage, the distribution of rainfall is as important as the total amount of rain. The sequence of rainfall events is critical, particularly for the episodic nature of deep drainage and recharge. Seasonality—the particular time of year when most rainfall occurs—is another major climatic factor that affects leakage amounts.

In the winter rainfall dominated southern parts of the Basin, most of the rainfall occurs during the cooler part of the year, when evaporation and hence the amount of water the vegetation is using is likely to be low. Under these circumstances, the rainfall infiltrating the land must be stored in the soil if leakage is to be prevented. If the soil already contains water that was not used by agricultural plants in the growing seasons, leakage will occur more readily.

Replacing native vegetation with shallow rooted annual crops and pastures has led to substantial increases in the amount of water ‘leaking’ into the soil. The consequences are rising groundwater levels and dryland salinity.
This map shows the differences in rainfall seasonality in the Murray-Darling Basin, with the rain in the northern parts falling predominantly in summer, and in the south, in winter.

In the summer rainfall dominated northern parts of the Basin, most of the rain coincides with the period of highest evaporation, thus increasing chances for the vegetation to use the rainfall. However, rainfall can often be distributed in short periods. In this case, water moves through the profile more rapidly than the plants can extract it, causing significant leakage. Thus while leakage is often lower in summer dominated rainfall areas, it is also more episodic, and depends on the rainfall sequence. Summer rainfall can be as effective in causing leakage as winter rainfall if it is concentrated over short periods.

**Vegetation**

Vegetation affects the amount of leakage to groundwater in two key ways: the depth of plant roots and whether the plants are perennial.

1. **Plant root depth.** Deeper roots allow plants to extract water from deeper in the soil, reducing the opportunity for water to leak below them. For example, the roots of Eucalypt trees have been found to depths of 30–40 metres. Unfortunately, as the roots of most of our dryland agricultural plants are less than 1–2 metres deep, they have much less opportunity to extract water from the soil before it flows below their reach and becomes leakage.

For example, a water balance study at Katanning in south-west Western Australia showed that shallow rooted clover and deep rooted lucerne both dried out the shallow soil (0–45 cm) to the same extent, while the deeper rooted lucerne was able to dry out the deeper soil (45 cm–1.2 m) to a much greater extent. Leakage from 80 mm under the clover was reduced to 30 mm because the lucerne was helping to dry the deeper soil.

Even with deeper rooted crops, leakage can occur during the early growing stages when they have established only their shallow roots. A study at Wagga Wagga showed that in the first year of lucerne in rotation with wheat, there was a similar amount of leakage past 1 m to that under wheat, but in its second and third years, when the deep root system became established, leakage was dramatically reduced.

2. **Perennials.** If a plant does not have leaves that are transpiring and using water when the soil is wet, it is difficult for the plant to use the water before it leaks below the root zone.

Annual plants grow, flower, set seed, then die. They use water while they grow. Most annuals are shallow rooted and do not use any of the summer and early autumn rainfall. They do not need roots in the deeper soil because they are not present over the drier period of the year.

![Rain, Plant growth, Leakage](image)

In this example, the summer active vegetation is unable to control the leakage that occurs over the winter months, when most of the rain falls.
In contrast, perennial vegetation grows all year round. It can send down deeper roots to use extra water from deeper in the soil. While perennials may shut down during dry periods, they can respond to occasional rainfall opportunities in the dry season. So overall, they have the chance to use more water than annuals.

Eucalypts in the lower rainfall areas have adapted to this cycle very well, although perennial crops such as lucerne and phalaris have the potential to perform in similar ways in lower rainfall areas. However, it is extremely difficult for even perennial pastures to reduce leakage in winter dominated rainfall areas that have an annual rainfall of more than 600 mm.

**Soils and geology**

Soils can affect the amount of leakage in three main ways.

1. **Water holding capacity.** This is the amount of water the soil can hold in between wet and dry conditions. For example, because sandy or rocky soils have a low water holding capacity, we would expect greater amounts of leakage in these types of soil than in heavier clay or loam soils, all other things being equal. While clay soils can store large amounts of water, comparatively little of it may be available to plants because the clay holds the water more tightly than the plants can extract it.

2. **Soil permeability.** The amount of leakage depends on how easily water can move through the soils and sub-soils. For example, some subsurface clays may be less permeable and reduce the rate that water can leak into the groundwater systems. Under these circumstances more water may move laterally rather than leak vertically into groundwater systems.

3. **Impeding plant growth.** The physical or chemical characteristics of a particular soil may impede plant growth, thus restricting the depth of plant roots and hence the opportunity for plants to use water before it becomes leakage. Physical factors include soil density, or the presence of hard soil layers. Chemical factors include soil acidity, salinity or nutrient changes.

Clearly, estimating the amount of leakage under different climates, soils and land management systems is important in designing farming practice strategies to control dryland salinity. One difficulty in devising simple ways to determine the precise value of leakage is that it is highly variable from season to season and can vary over small distances because of the factors discussed above. In addition, leakage depends strongly on climate and Australia has large variations in climate, further complicating the measurement and estimation of leakage into our landscape.

**Current Farming Systems and Managing Dryland Salinity**

**KEY QUESTIONS**

1. How do the current leakage rates under best practice in our farming systems compare with leakage rates under the native vegetation?

2. If best practices are adopted over the majority of our farming systems, how effective are these likely to be in controlling salinity, over both the short and long term?

3. How does this effectiveness vary throughout the Murray-Darling Basin?

4. How long will it take the salinisation rates to decrease in response to the reduced leakage (at rates of native vegetation, and at rates of current best practice)?
Leakage below farming systems

Careful soil physical measurement and analysis combined with techniques to measure water balance have given us the capacity and confidence to measure the relative magnitude of water leakage beneath our agricultural systems compared to that under native vegetation.

However, leakage is difficult to measure, particularly when comparing how much it varies under different farming systems and management strategies. Leakage is often only a relatively small component of the overall water balance, and can vary dramatically between seasons.

Nevertheless, a substantial set of measurements clearly show that our current agriculture is very leaky, that is, its leakage values are very high compared to those of our native forests and woodlands. CSIRO has collated the final results of many of the leakage studies undertaken throughout Australia. Figure 1 shows the high leakage under annual pastures and crops in comparison to leakage under native vegetation. It also illustrates that although the leakage under perennial agriculture is generally lower than for annuals, it is still much higher than for native vegetation.

The high variability and complexity of factors affecting leakage mean that we need long-term estimates over decades to have confidence in the ability of current farming systems to control leakage sustainably, and hence salinity. The use of computer models that simulate the behaviour of plants, soils and water use over these much longer time scales can help reveal the complexity, episodicity and relative magnitude of the effect of changes in farming systems on the amounts of long-term leakage.

One example is the results of a simulation study of the annual leakage amounts under three different farming systems—annual pasture, perennial pasture and trees—at Hamilton in Victoria. The modelling shows (Figure 2) the great variation in leakage between years. It also highlights that although there is generally less leakage under well managed perennials than under annuals, there is much more leakage under both systems than there is under trees alone.

In other words, the leakage under pasture systems remains many times greater than leakage under the original vegetation or the discharge capacity of the landscape.

While gains are made in moving from annual to well managed perennial pasture, our agriculture can not sustainably put more water into the landscape than the groundwater systems can discharge into rivers and lakes. Once our

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Figure 1. This figure combines the results of many leakage studies throughout Australia to show the relationship between annual rainfall and the amount of leakage for three types of vegetation: annuals, perennials and trees. Generally, while leakage under perennials is lower than for annuals, it is significantly higher than for trees.

Figure 2. This figure shows the annual amounts of leakage simulated for three vegetation types over 26 years. While the amount of leakage varies considerably between years, leakage under perennials is generally less than it is under annuals, while leakage under trees is significantly less than it is under annuals or perennials.
agriculture exceeds the discharge capacity of the landscape, water tables will rise. In most Australian landscapes this will eventually result in salinisation.

The following results and case studies can help us understand the interactions between soils, water and vegetation, they are good tools for comparing the relative differences between various management options. The overall results of the studies provide greater insight into the long-term behaviour of leakage to groundwater under agricultural systems.

**Grazing systems**

The Murray-Darling Basin has extensive areas of grazing systems over climatic conditions that range from the high rainfall high input systems in the east and south to the semi-arid pastoral systems in the west.

In the **high rainfall** (>600 mm) regions, leakage under farming systems can be high (90–100+ mm/year). There are significant differences between the water use of trees and agricultural systems. Work carried out by researchers from the Department of Natural Resources and Environment at sites near Rutherglen (Victoria) estimated that the deep drainage under perennial grasses ranged between 50 and 120 mm per year depending on grazing management and nutrition. This is far more than the 5–10 mm of leakage estimated for the woodland replaced by these pastures. Hence pasture management options could make only small reductions in leakage to groundwater. A high proportion of trees will need to be incorporated into the landscape to achieve a significant reduction in leakage. Should salinity be a problem in those areas. In this case, where to plant the trees becomes the issue.

In the **medium rainfall** (400–600 mm) zone the differences in water use between trees and agriculture are less distinct. As a result, the variation in leakage rates between different grazing systems is important, as is the variable nature of the rainfall. Studies have shown that in some situations, perennial systems are controlling leakage in these areas to around 10 mm/year. In most of these cases, perennials reduce leakage by around 20–50% when compared to annuals, except for lucerne grown continuously, which can reduce leakage by up to 90%. While perennial systems reduced leakage rates, the rates remained two to three times greater than under the woodland vegetation that the pastures replaced.

In the **low rainfall** (<400 mm) regions of the western and southern Murray Basin (Upper South-East and Cooke Plains areas of South Australia), the use of deep rooted lucerne has been shown to reduce leakage rates to the level of natural Mallee vegetation (less than 1 mm/year). In the western lands of New South Wales, a study found that clearing trees for grazing seemed to cause little or no increase in leakage rates for well managed systems (which are not over grazed) with heavier soil types (less than 1 mm/year), and also for sandy soils (2 mm/year).

**Cropping systems**

Cropping systems are generally found in a rainfall belt that is narrower than that of areas used for grazing alone (250–500 mm in the southern Basin; 400–600 mm in the northern parts). Leakage amounts vary from a few millimetres per year in the Mallee to more than 80 mm/year in the higher rainfall cropping areas. Removing the long fallow period has had the biggest impact in reducing leakage in these cropping systems, accounting for a possible reduction in leakage of around 20–40%. Traditionally, the long fallow has been used to enhance water storage before cropping and as a disease break. Incorporating lucerne as part of a long-term or shorter-term rotation is another strategy to reduce the leakage under cropping. However, variability in rainfall reduces the effectiveness of lucerne in rotations, leading to deep drainage when lucerne is not part of the rotation.
Agroforestry systems

Researchers and farmers are increasingly interested in the potential benefits of agroforestry systems. These systems can range from small blocks of trees, to belts of trees, to scattered trees in paddocks. It has been suggested that a small percentages of trees over the land area can reduce leakage over the entire area. Two general possibilities exist: tree belts and break of slope plantations.

1. The roots of tree belts extend laterally into the cropping systems to use water that is excess to crop requirements.
2. Break of slope plantations intercept the shallow lateral movement of groundwater before it discharges at the surface.

In the low rainfall Mallee region, a University of Adelaide study of several rainfall areas has shown that mature trees can control leakage 20–50 m into the cropped area. This suggests that in such low rainfall areas, a typical agroforestry system (using 10 m tree belts at 100 m spacing) would halve annual leakage from 20 mm to 10 mm. This is still much greater than the estimated average leakage of only 0.6 mm/year under native vegetation. Having said this, close (<50 m) tree belt spacings could be expected to completely control leakage, although crop production will be severely reduced.

In some types of catchments it is possible to intercept shallow local groundwater flows before they reach the more saline aquifers by placing belts of trees across the flow path and using them as pumps. The ability of trees to reduce leakage will vary dramatically, depending on specific catchment characteristics. However, the groundwater systems in many catchments in Australia have low permeability. In these cases, the ability of trees to use water before it becomes leakage is limited to water lying directly beneath them.

Plantation forestry

Leakage rates under mature plantations in the low to medium rainfall areas (<600 mm/year) are close to zero in most cases. This means that for any particular catchment, the volume of leakage should reduce in accordance with the increase in plantation area. Although, for the first few years of a plantation, leakage may be greater.

Agriculture on saline land

It has been a popular belief that plants are able to use large volumes of groundwater when a shallow groundwater table is present. Several studies have shown that this is not true, even where the groundwater is not particularly saline. In some cases there may be seasonal recharge and discharge. This means that recharge occurs quickly during the wetter season then is used by the plants over the dry season. However, generally the net effect has been only small.

A possible role for vegetation in groundwater discharge areas is to minimise recharge so as not to exacerbate the salinity problem. Often, much of the water that leads to salinity problems is in the vicinity of the saline land. Reducing this recharge, while not preventing the fundamental cause of the problems, may reduce the likelihood of them becoming worse.
Leakage varies throughout the Basin

The Murray-Darling Basin encompasses a range of rainfall and climate conditions over a large area. This means that while similar patterns of leakage behaviour would be expected across the Basin, we would not expect all areas to behave in exactly the same way.

The following results and case studies illustrate the consistent and widespread increases in leakage throughout the Murray-Darling Basin as a result of agricultural practice. Most of these studies are based on detailed field measurements supported by modelling scenarios. The overall results of these studies provide greater insight into the long-term behaviour of leakage into groundwater under agricultural systems.
Leakage for several case studies

1 Liverpool Plains

The Liverpool Plains is a productive agricultural catchment near Tamworth in northern New South Wales. CSIRO and NSW Agriculture have undertaken an extensive study in this area to assess alternative land-use systems. Scientists used APSIM (Agricultural Production Systems Simulator), a computer modelling program developed by CSIRO, to simulate alternative farming systems, including their water balance and crop production. The research included a detailed field experimentation program over four years on a farm called ‘Hudson’ to check the model predictions. Following the field verification, APSIM was applied to simulate alternative farming systems over a range of soil types and rainfall zones within the Liverpool Plains catchment. Mean annual rainfall for the cropped regions of the catchment ranges from 625–740 mm/year. Eighteen different soil types used to support cropping were differentiated, characterised, and used in the analysis.

Results from the study (Table 1) suggest that some cropping system options, when appropriately matched with soil type and location, were able to reduce leakage to a nominal 2–3 mm/year. However, all the cropping systems had significant rates of leakage if implemented on inappropriate soil types. Some soil types (usually shallow with low water holding capacity) and locations were unsuitable for cropping and needed to be sown to perennial grasses or trees.

Table 1. Predicted mean annual leakage values over a 41-year period for alternative cropping systems in the Liverpool Plains.

<table>
<thead>
<tr>
<th>CROP</th>
<th>LEAKAGE HUNSON SITE (mm/yr)</th>
<th>LEAKAGE LIVERPOOL PLAINS CATCHMENT (mm/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>long fallow wheat</td>
<td>29</td>
<td>14–192</td>
</tr>
<tr>
<td>continuous wheat</td>
<td>36</td>
<td>19–175</td>
</tr>
<tr>
<td>opportunity cropping</td>
<td>2</td>
<td>2–127</td>
</tr>
<tr>
<td>continuous sorghum</td>
<td>3</td>
<td>1–179</td>
</tr>
</tbody>
</table>

* Mean annual rainfall is 678 mm, mean annual potential evapotranspiration is 1718 mm.
* Range in mean leakage for all combinations of 5 climatic zones (mean annual rainfall 625–740 mm/yr) and 18 different soil types.

Figure 3. Year-to-year variation in predicted leakage under alternative cropping systems at the Hudson trial site in the Liverpool Plains.

The long-fallowing cropping and continuous wheat cropping systems result in more leakage than would have been expected under the native perennial grasses that used to cover much of the area now cropped. Opportunity cropping and continuous sorghum make better use of the summer rainfall—they can reduce leakage to acceptable values providing they are on soil types appropriate for this type of cropping (Table 1, Figure 3).

For some soils types, appropriate cropping and pasture systems in the Liverpool Plains climate appear capable of maintaining leakage rates approximating those of the native vegetation, although current land-use in the catchment is not achieving that aim.
2 Wagga Wagga

CSIRO undertook a comparison of different cropping systems for the Wagga Wagga region in southern New South Wales, where the average annual rainfall ranges from < 480 to > 660 mm/yr. In collaboration with the Australian National University, detailed measurements were made of wheat and lucerne grown in rotation at an experimental site at Charles Sturt University. The APSIM model was used to simulate each of these phases and the output compared against measurements including crop yield, soil water storage, and evapotranspiration measured using weighing lysimeters. Although still preliminary, agreement between the model and the measurements was good. Runoff is negligible at the measurement site, so that good prediction of evapotranspiration and change in soil water storage implies good prediction of leakage.

Scientists then used APSIM to simulate the behaviour of both a continuous wheat cropping system and a wheat-lucerne rotation (three years of wheat, three years of lucerne) using the 36-year weather record from Forest Hill, just east of Wagga Wagga. There was a 53% reduction in leakage from an average of 87 mm/yr for continuous wheat to 41 mm/yr when lucerne was included in the rotation. Figure 4 compares leakage from the two cropping systems in each year and shows the variation of the reduction from year to year, depending on rainfall and the phase of the rotation. The reduction resulted partly from less leakage during the lucerne phase, and partly from the creation of a dry buffer, which reduces leakage during the first wheat years. Growing lucerne continuously reduced the average leakage to 4 mm/yr, which is comparable to leakage from natural vegetation.

The effectiveness of lucerne in reducing leakage depends on annual rainfall. For an average rainfall of 480 mm/yr (Narrandera) the reduction was 66%, while for an average annual rainfall of 660 mm/yr (Cootamundra) the reduction was only 48%. Only at the lower average rainfall did the wheat/lucerne rotation reduce leakage to a value (14 mm/yr) approaching that from natural vegetation.

The absolute values of leakage presented here are indicative only. Leakage depends not only on rainfall, but also on crop management factors (such as fertilisation and weed control) and soil type. While certain combinations of these factors could result in leakage values being up to half of the values shown in Figure 4, the relative difference between leakage under wheat and that under wheat/lucerne will remain unchanged.

3 Burkes Flat

The Burkes Flat catchment covers 900 hectares. It is a subcatchment of the Avoca River in the 450 mm rainfall belt in the foothills of northern Victoria. The area has had dryland salinity problems for the past 70 years.

The Victorian Department of Natural Resources and Environment (NRE) undertook an extensive project to map the areas of leakage to groundwater as well as areas of groundwater discharge. Between 1983 and 1986, native trees were planted on high leakage areas, perennial pastures were established on low–moderate leakage areas, and groundwater discharge areas were fenced off and planted with salt tolerant grasses.

![Figure 4: Comparison of annual leakage from wheat and lucerne.](image-url)
Groundwater levels have dropped significantly in comparison to the neighbouring untreated catchment. Water tables in the mid-catchment region at Burkes Flat fell more than 5.5 metres over the six years following the establishment of dryland lucerne in 1984.

Since the start of the project, inspections have shown considerable improvement in the condition of the groundwater discharge areas. The Centre for Land Protection Research (part of NRE) in Bendigo estimates that the salinised area would have increased by up to 25% without the catchment treatment. In this light, it is promising that there is not yet clear evidence of changes in salt affected areas within the treated catchment.

This evidence confirms the salinity control and productivity benefits of projects such as the one at Burkes Flat. This study indicates that well managed perennial pastures and trees on ridges in a local groundwater system of this type can provide some control of dryland salinity.

4 Mallee

A modelling and field study was carried out as part of a joint project between NSW Agriculture, Agriculture Victoria and CSIRO to study leakage rates under fallow and non-fallow systems in the Mallee at both Walpeup (Victoria), and Hillston (New South Wales).

Model results at Walpeup indicated that by removing the fallow and including mustard into a wheat-pea crop rotation, long-term average leakage was reduced by between 25% and 40%. The variation in the recharge figures is due largely to differences in rooting depth.

<table>
<thead>
<tr>
<th>CROP</th>
<th>LEAKAGE mm/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotation with fallow</td>
<td>12–25</td>
</tr>
<tr>
<td>Non fallow</td>
<td>7–19</td>
</tr>
</tbody>
</table>

The study concluded that removing the fallow period reduced the number of small rainfall events that led to leakage. It also found that none of the cropping systems were able to remove the effects of the larger rainfall events, although eliminating the fallow period could reduce the amount of leakage for large rainfall events. However, much of the Mallee overlies large regional groundwater systems for which this reduction in leakage is insufficient.

**Managing salinity**

Dryland salinity generally occurs when a groundwater system cannot carry all the water put into it through leakage. It has various causes. In the Australian landscape there are often many physical restrictions to groundwater systems. They include geological formations that reduce the size of the aquifer and prevent sufficient groundwater from leaving the catchment. Also, as the groundwater moves from the upper hills of a catchment to its lower plains, a combination of flatter slopes and impermeable soils further restricts the capacity of the groundwater systems to carry water.

The amount of water that a groundwater system can carry is called the discharge capacity. If the total leakage from an entire catchment to the groundwater system is less than the discharge capacity, salinity should not occur because the groundwater system can cope with the supply. This concept can provide a useful method for estimating a leakage target—the allowable leakage for a catchment to avoid dryland salinity. This can be done by estimating the discharge capacity and then using the result to estimate the average leakage over an entire catchment. Previous CSIRO studies have used this method for groundwater systems in the Murray-Darling Basin and
estimated the maximum amount of leakage for which there would be no dryland salinity. For example, the leakage target for the Upper South-East region (South Australia) was only 2 mm/year (0.4% of rainfall), while for the Liverpool Plains catchment (New South Wales) it was 1 mm/year (0.1% of rainfall). These values are comparable to those found under native vegetation.

It is clear from the results of the case studies that generally, the leakage rates under our current agricultural systems far exceed these targets. The Burkes Flat example is an exception.

As we do not know the precise discharge capacities of our groundwater systems, a conservative approach to controlling dryland salinity is to aim for leakage values comparable to those under native vegetation.

In any case, changes are not likely to produce quick results. The excess water that has been leaking into groundwater systems combined with the time scale of groundwater processes means that it is unlikely that the effects of an instantaneous reduction of leakage will be discernible immediately. Even if we reduce leakage to below the discharge capacity, it still will take some time to influence the current salinisation rate.

For example, the results of groundwater modelling scenarios for catchments in the Liverpool Plains suggest that even if the leakage to groundwater were reduced to zero, the levels of groundwater in the lower parts of these catchments would begin to drop only after 20–60 years. The slow response means that when we reduce recharge rates, even if they are greater than the discharge capacity, we would still expect dryland salinisation to persist and in many cases, to expand.

The discharge capacity and time responses will vary according to the type of groundwater system and the individual aquifer characteristics. The large groundwater systems that characterise the Riverine Plains and Mallee regions generally have low discharge capacity (<5 mm/year) and response times ranging from hundreds to thousands of years. The local groundwater systems that predominate in many of the upland areas may have higher discharge capacities (<100 mm/year) and quicker response times (5–50 years).

Using biological control of leakage is one of three broad options for controlling dryland salinity. The other two options include engineering options (such as groundwater pumping or surface drainage), and adapting to the more saline conditions. A combination of all three of these types of options is likely to be needed.

**What are we aiming to achieve?**

In designing options for controlling dryland salinity it is important to consider what realistic result we aim to achieve. There are four broad options.

**Option A—continue to expand.** This is a ‘do nothing’ scenario, where salinity continues to increase in area and magnitude, until it reaches a new ‘more saline’ equilibrium.

**Option B—buying time.** This is where the management strategies we implement slow down the onset and expansion of dryland salinity, but eventually reach the same salinity equilibrium as Option A, the ‘do nothing’ approach.

**Option C—continue to expand, but not as much.** This is where our management strategies make sufficient change to reach a stable salinity equilibrium, with fewer saline areas than for Option A, the ‘do nothing’ approach.

**Option D—improve the situation.** This option is to reverse the trend of expanding salinity and recover saline land.
These scenarios can be considered at scales ranging from local groundwater systems to the whole of the Murray-Darling Basin. When considering individual groundwater systems, Option B would correspond to a situation in which we have reduced recharge, but it is still much greater than the discharge capacity. This would be equivalent to half-turning off a tap when filling a bath. The bath still fills, but takes longer to do so. Option C corresponds to the situation where recharge is reduced enough to decrease the discharge significantly. Option D corresponds to the situation where the system begins to drain.

For example, suppose we are growing wheat over a regional groundwater system with a discharge capacity equivalent to 1 mm/year. If the deep drainage is 80 mm/year and we reduce this to 40 mm/year by incorporating lucerne in rotation, the groundwater system will still fill up, but it will take twice as long. This is equivalent to Option B.

On the other hand, if we replace annual pasture with a combination of perennial pastures and trees over a local groundwater system with a discharge capacity equivalent to 60 mm/year, we may achieve a situation similar to Option D.

When we aggregate the effects over the whole Murray-Darling Basin, the most likely outcome is Option C, but how much of an improvement this is in comparison to Options A or B needs to be determined.

Conclusions

The large mismatch between the leakage below current farming systems and the capacity for groundwater systems to accept this leakage is the fundamental cause of our expanding dryland salinity problem.

Many of the best management practices for our current agricultural systems cannot reduce current leakage rates at a catchment scale to anything approaching leakage rates under native vegetation. Some of our groundwater systems of most concern can only accept leakage comparable to that of native vegetation.

If we are to use biological measures alone to control salinity we need to significantly modify agricultural practices. We can only achieve the necessary level of control in some local situations. In the higher rainfall parts of the Basin, a high proportion of trees needs to be incorporated into the landscape to significantly reduce leakage. In the medium rainfall zones, the variation in leakage rates between different grazing and cropping systems may have potential to slow salinisation.

However, there is little evidence that there are current farming systems that can reduce leakage to levels similar to those of native vegetation. Other farming systems that have large leakage reductions, such as opportunity cropping, need to be targeted at those groundwater systems with the greater capacity for leakage. That will control leakage and hence salinity for a wider range of conditions. With intensive focus on redesign of new farming systems it may be possible to build systems that will control leakage, and thus salinity.

Even if we were to find and adopt suitable practices immediately, we cannot return to conditions identical to the natural system. In many cases, improvements in dryland salinity would occur very slowly, if at all. Although smaller, local scale catchments may respond to best management practice within several years, the larger regional and intermediate systems may take much longer.
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Further reading


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