

*Starting point for salinity bulletin [but see latest version of Nutshell for alternative view on cause of dryland salinity]*

*This is too long for a Bulletin*

## **Soil salinity**

### **Introduction**

Salt is an inherent part of the Australian landscape, occurring naturally in many environments. Enormous stores of salt have accumulated in the soil, groundwater and surface waters through the long-term influence of natural processes. Over hundreds of thousands of years, the native vegetation has evolved to successfully cope with the low rainfall and high salinity levels characteristic of the Australian environment. During the past 200 years, however, human activities have dramatically disrupted the natural hydrological balance in many areas, with significant consequences for the distribution of salt in the landscape. This has led to severe degradation of both natural and agricultural environments.

The salinisation of the land and water is now seen as a very serious threat to the health and utility of Australia's rivers, soil and vegetation. Human-induced salinisation is also of concern in many other countries around the world.

On the basis of current predictions, the total area of land affected by human-induced salinity in Australia is expected to increase dramatically over the next few decades, unless effective solutions are developed and implemented. These solutions would involve significant changes to our present systems of land use and management, as well as a major shift in approach, from one that focuses on the symptoms of salinisation to one that addresses the causes. The damage caused by human-induced salinisation is already creating serious economic and social impacts in rural and urban communities around Australia, and these will worsen unless effective remedial action is taken.

### **What is salinity and salinisation?**

Salinisation is a process that results in an increased concentration of soluble salts in soil and water. Of these salts, sodium chloride, or table salt, is the most common. Salinity is the state of soils that have a high concentration of such salts.

All continents have a wide distribution of what is known as primary salt-affected soils. *Primary salinisation* is when salts accumulate in the soil and groundwater of an area over a long period of time due to natural processes. For example, salt is released, re-deposited, and gradually concentrated in soils and surface and sub-surface waters through the weathering of rocks and sediments in which salts were incorporated at the time of deposition. In Australia, the weathering of sediments that have been periodically inundated or deposited by rising sea levels has been a major source of salt. Salt can also be caught in sea-spray and carried on wind as dust or rain and deposited inland, where it steadily accumulates over many thousands of years.

These natural processes create substantial concentrations of salt in the landscape, stored either in the groundwater, or in the soil just above the watertable. Many factors influence where the salt is accumulated and stored, including the nature of the parent material and the climate. In arid regions, where rates of evaporation exceed rainfall, there is enough sub-surface water percolating through the soil to dissolve and concentrate salts, but not enough to leach them from the soil profile below the root zone of vegetation. This situation is exacerbated by the flatness of the Australian continent and subsequent sluggish nature of its largely inland drainage system, resulting in the formation of extensive natural salt deposits across much of the arid and semi-arid interior.

Over time, through the processes of biological evolution, the native vegetation of Australia has adapted to the dry and salty conditions. This has involved the development of perennial trees, woody shrubs and grasses with deep and dense root systems which allow only a little water to leak past the root zone into the groundwater. In healthy ecosystems, naturally occurring salt in the soil or sub-surface waters is concentrated by plants through evaporation and transpiration. These salts are then slowly leached downwards and stored beneath the root zone. These processes maintain the hydraulic and salt balance of catchments – where the gradual discharge of salt and water from the deeper soils of the landscape is roughly equal to the input of salt and water to the catchment.

Various human activities have disrupted this natural hydrological balance, changing the distribution of salt in the landscape. Salinity problems occur when more water is added to the groundwater system than is discharged under natural conditions, as often occurs when the natural vegetation has been removed. This causes the level of the watertable to rise, bringing stored salts to the soil surface and waterways. Evaporation then draws the rising waters to the soil surface through capillary action, which concentrates the salts at or near the surface, affecting the root zone of native and introduced vegetation. This process is known as *secondary salinisation* (Figure 6.1)

Figure 7.1 Model of catchment hydrology demonstrating salinisation process

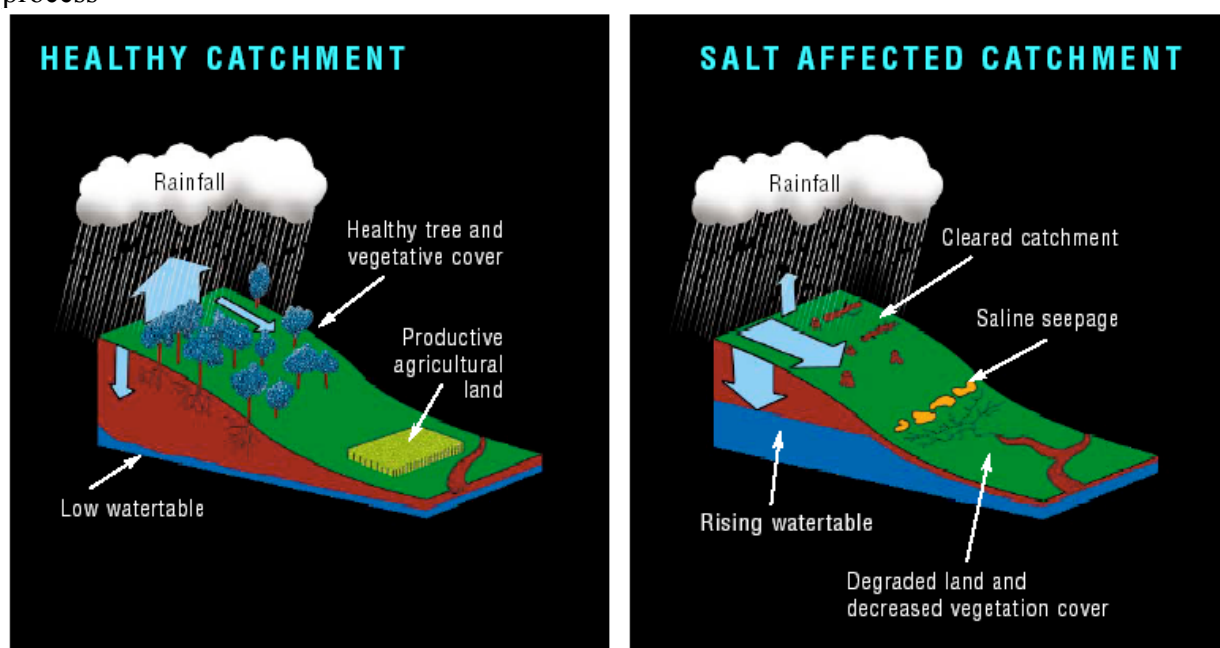


Diagram 1  
A basic model of catchment hydrology showing how the destruction of deep-rooted perennial native vegetation in one area can bring about salinisation quite some distance away. The precise picture of disturbed groundwater systems, waterlogging and salinity varies across Australia, but the basic cause of dryland salinity – land clearing – remains the same.

Source: [http://www.acfonline.org.au/docs/salt/salt\\_chapter1.pdf](http://www.acfonline.org.au/docs/salt/salt_chapter1.pdf)

Human activities, in particular agriculture, are largely responsible for these changes to the hydraulic and salt balance of catchments. Both dryland and irrigated agricultural practices and their associated activities have greatly contributed to the excessive recharge of groundwater and concentration of salts in the soil and surface water (see Box 6.1).

## Box 7.1

### Human activities that contribute to salinisation of soil and water

#### SOIL

##### *Activities that alter movement of water through soil*

- clearance of deep-rooted vegetation
- replacement of native vegetation with shallow rooted crop and pasture species
- compaction and disruption of soil structure
- storage, conveyance and disposal of surface waters
- addition of impediments to natural drainage patterns

##### *Activities that increase salinity levels in soil*

- application of saline irrigation waters
- disposal of saline wastewaters on land
- upward movement of water due to excessive additions to the watertable

#### GROUNDWATER

##### *Activities that disrupt natural recharge rates*

- clearance of deep-rooted vegetation
- urban development
- paving of surfaces
- irrigation with surface water
- leakage from irrigation channels
- leakage from farm dams and other surface reservoirs

##### *Activities that increase salinity levels in groundwater*

- disposal of saline or liquid wastes in basins or wells
- disposal of solid wastes that contain soluble salts in landfill that can be leached by rainfall into the groundwater, or buried beneath watertable
- extraction of groundwater, causing intrusion of saline water from another aquifer, and disrupting the saline/freshwater interface
- pumping of groundwater, or the use of saline surface water for irrigation- salinity of groundwater is increased if water returns to aquifer as recharge

#### SURFACE WATERS-

##### *Activities that alter the flow of water*

- diversion of water for consumption or inter-basin transfer resulting in decreased flow
- loss of water through evaporation of reservoirs
- changes in land use, soil and vegetation resulting in increased stream flow
- modification of instantaneous flows of water through the construction of reservoirs, weirs, dams and other changes to channels

##### *Activities that increase salinity levels in surface waters*

- changes to diversions and return flows, in addition to the gains and losses from groundwater in adjoining strata, especially in irrigation areas can increase salinity load of rivers and streams
- changes to management of soil and vegetation in non-irrigated areas can increase recharge of groundwater and discharge of salt into rivers and streams
- construction of weirs and reservoirs can increase leaching of salts downstream, and displace saline groundwater from underlying strata into rivers and streams

The telltale signs of land affected by salinity are dead or dying trees and declining vegetation. It can also be accompanied by the appearance of plants that are especially tolerant to salts. In areas of low rainfall, where vegetation loss results in soil erosion, dry saline scalds can appear as bare patches with little or no vegetation or topsoil. In areas of irrigation, saline soils develop where the watertable is within 2 metres of the surface, and waterlogging and saline seepages can appear if the watertable breaches the surface. Seepages occur where the saline groundwater intercepts the surface, usually on the break-of-slope, or in valleys, flats, creekbeds and lower areas in the landscape. This causes waterlogging of these areas and the death of vegetation, often accompanied by an increase in salt-tolerant vegetation.

### **Impacts of salinity**

The salinisation of soils and surface water and groundwater has significant effects on the surrounding environment, and also creates serious economic and social problems for both rural and urban communities.

High soil salinity adversely affects plant growth of both native and introduced crop and pasture species. This is due to the toxicity of the salt ions, as well as the general osmotic effect of the soil around the roots of the plant, which reduces the ability of the plant to absorb water from the soil. As noted above, high soil salinity can prompt the appearance of salt-tolerant species, which, like Sea Barley Grass and Spiny Rush, are often weed-like and unpalatable to stock.

Increased salinity poses a significant threat to the health and wellbeing of many ecosystems, and to biodiversity as a whole. It can destroy remnant vegetation, leading to the disappearance of animal species that are dependent upon this vegetation for habitat. It also impacts upon the vegetation along river banks that is critical to bank stability, and that provides wildlife corridors. It also threatens the integrity of wetland areas. All of these impacts have serious flow-on effects on the growing industry of eco-tourism.

High salinity not only makes the soil chemically toxic for plants, but it also affects the soil's physical properties. Saline soils are often associated with a secondary process of alkalinisation, a condition referred to as *sodicity*. This causes soil to swell and disperse into fine particles that block soil pores when dry. Sodic soils are often hard-setting, susceptible to erosion, water-logging and poor aeration, and the absorption of rain is reduced. They will be discussed in the next chapter.

Saline soils are also prone to erosion as a result of the death of vegetation that would otherwise have stabilised them. If left untreated, saline areas generally become bare and compact, and create conditions that lead to sheet and gully erosion. This results in huge salt and sediment loads in watercourses, degrading lower lands and reducing water quality downstream.

Highly saline water is quite unpalatable for humans and stock. It can also be toxic, due to the presence of particular ions (manganese and sulphate ions) causing gastro-intestinal irritation in livestock, and it can interfere with reproduction and contaminate milk products. Increasing concentrations of salt in streams and basins also have significant impacts on aquatic ecosystems like wetlands, and on other users who extract water from the environment, including for domestic consumption, mining, manufacturing and irrigation purposes.

Salinity causes the loss of productive land area, loss of production, and increased costs faced by landholders in protecting land and surface waters from salinisation, and in changing to alternative, more sustainable land uses. It is also causing significant impacts and costs to regional infrastructure. Rising watertables damage roads, and 34 per cent of state roads and 21 per cent of national highways in NSW are currently affected by increasing salinity. Rising saline damp affects many buildings and other structures by eroding bricks, mortar and concrete. Saline water corrodes the foundations and materials used in the construction of

bridges, sewerage pipes and water maintenance equipment, and it sometimes results in the loss of local water supplies.

Salinisation can cause a general reduction of income and expenditure of rural families and communities, with significant social and economic implications for regions as a whole. These impacts are more notable in small rural towns, where opportunities for adjustment of the local economic base are limited.

Urban areas, for example Wagga-Wagga and some outer suburbs of Sydney, are also beginning to be seriously affected, as saline soils and waters are causing the decay of house and building foundations, and structural damage from rust in motor vehicles. Salty water can damage and corrode hot water systems, household appliances, plumbing and septic systems, and require an increased use of soaps and detergents. Gardens and lawns suffer from the effects of salinity, and become difficult to maintain. Other effects of increasing salinity on urban areas include damage to ovals, parks, footpaths, cemeteries, sewerage pipes and industry. Ultimately, it results in a reduction of public and private property value.

### **Extent and Costs of Salinity in Australia**

Although awareness of increasing salinisation of land and waters has increased considerably over the past few decades, the problem has also worsened. Some scientists maintain that salinity, particularly dryland-induced salinity, will prove to be an almost intractable problem.

Saline soils account for 6 per cent of the land area in Australia, with over 2.5 million hectares of land currently affected by dryland salinity. Without effective treatment, the area of land affected by dryland salinity is predicted to increase to 15 million hectares in the next fifty years. Around 4.5 per cent of presently cultivated land has problems with salinity, some of it in the potentially most productive agricultural regions in the country.

Over 70 per cent of Australia's saline soils are in Western Australia, with 1.8 million hectares of land currently affected. Most of this salt originated from the ocean, and was brought in via the atmosphere and deposited inland as rain or dry fall-out. The removal of native vegetation for dryland agriculture has considerably increased the recharge of the saline groundwater, bringing salt to the surface soils and streams. Over half of the State's waterways are already saline, brackish, or of marginal quality. It is estimated that the area in WA affected by dryland salinity will double over the next twenty years before equilibrium is reached.

In South Australia, over 400 000 hectares of land are showing the effects of dryland salinity, and it is now present to a degree in all agricultural districts in the State. The area affected could potentially increase to around 600 000 hectares. Twenty percent of surface waters are already above desirable salinity levels for human consumption. According to a recent audit, 900 000 hectares of the small area of South Australia that is contained in the Murray-Darling Basin is experiencing rising groundwater, with 116 000 hectares likely to be affected by salinity by 2050.

Irrigated and dryland-induced salinity cover an area of approximately 120 000 hectares in both Victoria and New South Wales. If effective action is not taken, this area is expected to increase to 1.2 million hectares in Victoria, and 5 to 7.5 million hectares in NSW. In Tasmania 18 000 hectares, or 2 per cent of cleared agricultural lands, are affected by salinity, with significant risks of further areas becoming affected. Salinity is also a growing problem in Queensland as a result of the rapid rates of clearance over the past 60 years. Already 10 000 hectares of land are affected by dryland salinity.

Across the Murray-Darling Basin, it has been estimated that salt mobilised to the land surface will increase from 5 million tonnes a year in 1998 to 10 million tonnes in 2010. The movement of salt is likely to shift from irrigation-induced sources to dryland catchment sources, as irrigation-induced salinity can stabilise itself over time while dryland salinity processes tend to operate over longer periods.

The salinity levels in rivers and surface streams within the Basin are also increasing. It has been predicted that within 50-100 years the average salinity of the lower river Murray, Macquarie, Namoi and Bogan rivers will probably exceed the World Health Organisation's threshold for desirable drinking water quality.

The full economic costs of land salinisation are difficult to calculate due to the often indirect nature of impacts, but it has been suggested that it costs the nation as a whole more than \$150 million per year. Some estimates have been even higher; placing the overall cost of dryland salinity alone at \$700 million in lost capital value of land; \$130 million annually in lost agricultural production; \$100 million annually in damage to infrastructure; and at least \$40 million in loss of environmental assets.

## **Management**

Current approaches to the management of salinity in Australia concentrate on the need to minimise the mobilisation of salt by restoring the water balance and ensuring catchments are not "leaking" water in ways which mobilise salt. This has largely been addressed through the development of engineering schemes and drainage programs, of which a wide range of technical options over various scales is available. Many of these have been quite effective in reducing accessions to groundwater, lowering water tables, and reducing the discharge of saline water into rivers and streams. However, these technical solutions often require considerable initial outlays of finance, and tend to focus on the symptoms rather than the causes of salinity. Many of these techniques involve the interception of saline water that then needs to be disposed of, displacing the problem elsewhere. The scale of the problem calls for more effective and long-term approaches.

Increasing concern and evidence of the serious threats that dryland and irrigated salinity represent to land and water quality have led to a number of government initiatives within and between the states in Australia.

Water pricing has evolved from the need to make users pay the true cost of their water resources. Previously, as in most other countries, water for irrigation, has been underpriced, and often heavily subsidised by governments. This has led to the inefficient use of water supplies, and the development of such problems as waterlogging and salinity. Through policies of 'user pays', direct charges on, for example, volume of water used or area of land irrigated, water pricing can potentially increase irrigation efficiency, reducing the artificial recharge of groundwater.

The inefficient use of water resources has also led to the development of policies like transferable water entitlements (TWE), which aims to allocate water resources more effectively. TWE is a mechanism through which a market for water can operate by allowing water entitlements to be bought and sold without any attachment to land. It is hoped that this will transfer water resources to higher value uses and decrease use of water on land not suited to irrigation. TWE should result in the increased adoption of water-saving technologies, as water that can be saved, can be sold.

Salinity, along with other catchment-based issues in which the underlying processes are complex and the impacts occur some distance away from the cause of the problem, has highlighted the need for a more integrated approach by State and Federal Governments.

A number of catchment management models have been developed and implemented. Probably the most well-known catchment management entity in Australia is the Murray Darling Basin Commission, which covers an area of 1.6 million square kilometres across four states and the Australian Capital Territory, making up the largest integrated catchment management program in the world (SOE 1996:36). It is a structure where the Commonwealth Government, and the four state Governments within the basin (NSW, Vic, SA, Qld), along with the local and regional communities, work together to maintain and improve water

quality. This aim is achieved through research, control and reversal of land degradation including salinity, the protection and rehabilitation of the natural environment, and the conservation of natural heritage.

In 1998, the Murray Darling Basin Ministerial Council adopted the *Salinity and Drainage Strategy*, which set out specific targets against benchmark conditions for the reduction of salinity. This strategy is set within a framework of joint action between all the governments within the basin, except Queensland. It defines the rights and responsibilities of all governments involved, as each state is responsible for actions significantly affecting river salinity within its jurisdiction. It aims to improve the water quality of the river Murray for all beneficial uses, including the environment, and to control and minimise land degradation. It also aims to conserve the natural environment of catchment valleys and to protect sensitive ecosystems from salinity. Major actions under the management plans include drainage programs, reduction of seepage losses from irrigation, re-use systems for drainage from farms, land forming, adoption of farm plans using best practice, groundwater control by pumping, improved water management of wetlands, tree and deep-rooted vegetation planning. The most significant achievement of the strategy so far has been the reduction of river salinity without limiting the rehabilitation of degraded lands, and the undertaking of drainage programs to control the rise of groundwater.

Although engineering solutions, policy tools, and the integrated catchment management approaches of the State and Federal Governments have made significant headway in addressing the salinisation of land and water resources, ultimately salinisation will not be manageable without substantial changes to our existing dominant farming systems. This will require significant shifts in land use, as management priorities evolve from focussing on the symptoms to dealing with the causes. In some circumstances, it will need to be recognised that amelioration may be impractical or too expensive, and changed land use to manage and live with salted lands and saline rivers is the only option.

There are many agricultural practices that actively reduce the rate of recharge to groundwater systems, including the replacement of shallow rooted pastures and crops with deep rooted varieties, changing cropping and irrigation strategies, improved grazing management systems, use of suitable improved pasture species and maintenance of pasture quality, and the use of perennial pastures. There are new forms of cereals, pulses, oilseeds and forages selected or bred for characteristics that reduce deep drainage. There are also assessment tools for the placement of trees and other vegetation for optimal effect, and tools for land managers to monitor leakage. Revegetation of recharge areas and saline lands, and the development of agricultural production systems utilising salt-tolerant plants has been a major area of research in recent years. Tree-based land management strategies can reduce recharge of groundwater and the spread of salinity, providing a productive use of salt-affected land, and potential for use in saline drainage water reuse schemes.

Dryland and irrigated-induced salinity together pose considerable threats to the integrity of our natural ecosystems, and to human social and economic systems as well. The time scales over which salinity establishes itself, spreads and has effects can be long and very difficult to contain or reverse. Although the impacts and costs of secondary salinity have been considerable, these issues have provided a necessary 'spur' for the development of more sustainable farming systems.