Chapter 1 — Salinity and sodicity

Salinity is the presence of soluble salts in soils or waters. Salinity processes are natural processes closely linked with landscape and soil formation processes. However, human activities can accelerate salinity processes, contributing to long-term land and water degradation. Salinity usually becomes a land use issue when the concentration of salt or sodium adversely affects plant growth (crops, pastures or native vegetation) or degrades soil structure. It becomes a water issue when the potential use of a water is limited by its salt content.

Salt is derived from the weathering of the earth's crust and is transported and deposited in the landscape by hydrologic mechanisms (rainfall and water movement above and below the terrestrial surface). Although the salt content of rainfall is low, rainfall can be the dominant source of salt in some areas. Over millennia, salt has accumulated in areas where water drainage has been very slow, or where shallow watertables occurred during wetter geologic periods.

Because land uses such as agriculture disturb the natural hydrologic equilibrium in a landscape, salinity processes are also affected. Human activities in developing land and water resources can change the hydrologic equilibrium in sensitive areas. Salt problems in agriculture are not new; the decline of civilisations in ancient Mesopotamia has been associated with soil salting under irrigation with rising saline watertables (Jacobsen & Adams 1958).

Salinity usually develops gradually over an extended period of time. Often, landholders become aware of salinity on their land only after observing a gradual loss of productivity over a number of years.

Although salinity can cause production losses, seasonal variability in factors such as rainfall, temperature, solar radiation and incidence of pests and diseases have a much greater effect on yields than salinity in the short term. However, salinity can be an important issue for individual landholders depending on the position of their property in the catchment because substantial proportions of individual properties can be affected.

Sodicity in soil or water is defined as the presence of a high proportion of sodium ions relative to other cations (in exchangeable and/or soluble form). As sodium salts, such as sodium chloride (NaCl), are leached through the soil, some sodium remains in the soil bound to clay particles, displacing other cations such as calcium. A high proportion of exchangeable sodium attached to clay mineral exchange sites weakens the bonds between soil particles when the soil is wetted. As a result, the clay particles swell and often become detached and disperse. The small clay particles move through the soil, clogging the pore spaces.

Sodicity is a condition that degrades soil properties by making the soil more dispersible, restricting water entry and reducing hydraulic conductivity (the ability of the soil to conduct water). These factors limit leaching so that salt accumulates over long periods of time, giving rise to saline subsoils. A soil with increased dispersibility becomes more susceptible to erosion by water and wind.

Sodic soils become dense, cloddy and structureless on drying because natural aggregation is destroyed. The dispersed clay at the soil surface can act as a cement, forming crusts that are relatively dense and hard but typically thin (up to 10 mm thick). The crust impedes seedling emergence and can tear seedling roots as it dries and shrinks. The degree of crusting depends on the soil textural composition, the mineralogy of the clay, the exchangeable sodium content, the energy of raindrop impact, and the rate of drying. Soils with high montmorillonite clay contents will crack on drying.

The genesis of some soils has resulted in sodic subsoils, often with a columnar structure. Sodic subsoils may be dense, with reduced soil water storage, poor aeration and increased soil strength, and can be susceptible to tunnel erosion.

Sodic soils occur naturally in Queensland. Sodicity can also be associated with **irrigation water salting** (page 82) or **erosion scalding** (page 9). In this handbook, the term 'salinity', when used to describe salinity issues in general, usually encompasses sodicity as well.

Types of salinity

Primary salinity is salinity that occurs naturally in soils and waters. **Secondary salinity** refers to salting that results from human activities, usually land development and agriculture. (**Salting**, also called **salinisation**, is the process and result of soluble salts accumulating in soils or waters.)

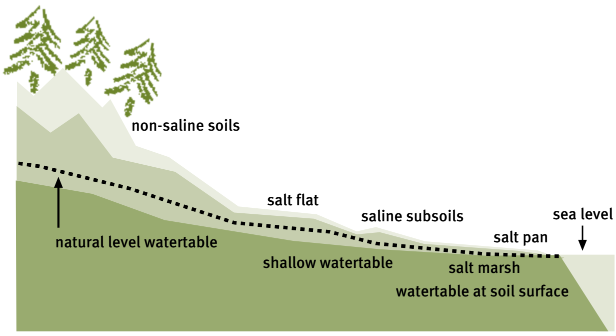
The division between primary and secondary salinity is useful for separating areas where human activities do not appear to be affecting salinity processes (primary salinity) from areas where salinity is clearly influenced by human activities (secondary salinity), frequently associated with quite rapid changes in the environment. However, it is often difficult to categorise salting outbreaks as one or the other type because secondary salinity is often primary salinity accelerated by human activity. Many areas that now exhibit secondary salinity show considerable evidence of having been affected by primary salinity in the past.

Primary salinity appears as naturally occurring saline areas and saline soils. Salt lakes, salt pans, salt marshes and salt flats are all examples of naturally occurring saline areas (Figure 1).

Secondary salinity can be divided into three groups on the basis of the processes contributing to salting (Figure 2):

- **Watertable salting** is a concentration of salts associated with evaporation of water from a shallow watertable (that is, the upper surface of the groundwater). This process contributes to salinity in both irrigated and dryland (non-irrigated) areas. **Seepage salting** is a type of watertable salting that occurs when groundwater seeps at the ground surface.

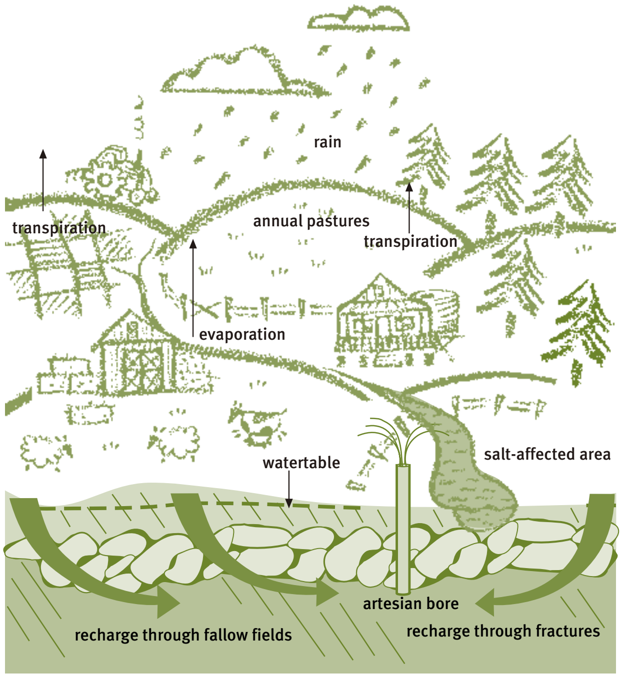
Figure 1. Examples of saline areas which occur naturally.



- **Irrigation water salting** is salting associated with the accumulation of salts from irrigation water in the soil and the effect of the water composition on soil properties. The sodicity of irrigation water and the properties of irrigated soils are important components of irrigation water salting.
- **Erosion scalding** is salting primarily caused by erosion processes. This occurs when surface soils are eroded by surface water flow or wind, exposing saline and/or sodic subsoils.

This handbook will deal mostly with the first two types of secondary salinity, **watertable salting** and **irrigation water salting**, and with **sodicity**.

Figure 2. Diagrammatic representation of processes contributing to dryland salinity.



Naturally occurring saline and sodic soils

The distribution of naturally occurring saline soils in Australia is closely related to the occurrence of geomorphic basins with closed drainage and low hydraulic gradients. About 5.3% of the land area of Australia is naturally saline (Northcote & Skene 1972).

Saline soils occur naturally in Queensland in the south-west, associated with springs of Great Artesian Basin waters, and in very flat areas around the coast, such as in the Gulf of Carpentaria around Normanton (Figure 3). In 1972, approximately 0.35% of the total land area of Queensland was estimated to be affected by naturally occurring saline soils (Northcote & Skene 1972).

Although factors such as reduced accessions of sodium in rainfall in northern latitudes (see **Climate and rainfall patterns** page 55) would suggest that Queensland would have less sodic soils than southern Australian States, the relative proportion of sodic soils in Queensland is in fact similar to that in other States (Northcote & Skene 1972). This is largely because past soil forming processes appear to have dominated sodic soil formation.

On an area basis (Figure 5), 55% of Queensland soils are described as non-sodic, 24% as strongly sodic, 1% as sodic, and 20% as having variable sodicity in the root zone (Shaw et al. 1994).

Figure 3. Distribution of naturally occurring saline soils in Queensland (Northcote & Skene 1972). Used with permission from CSIRO.

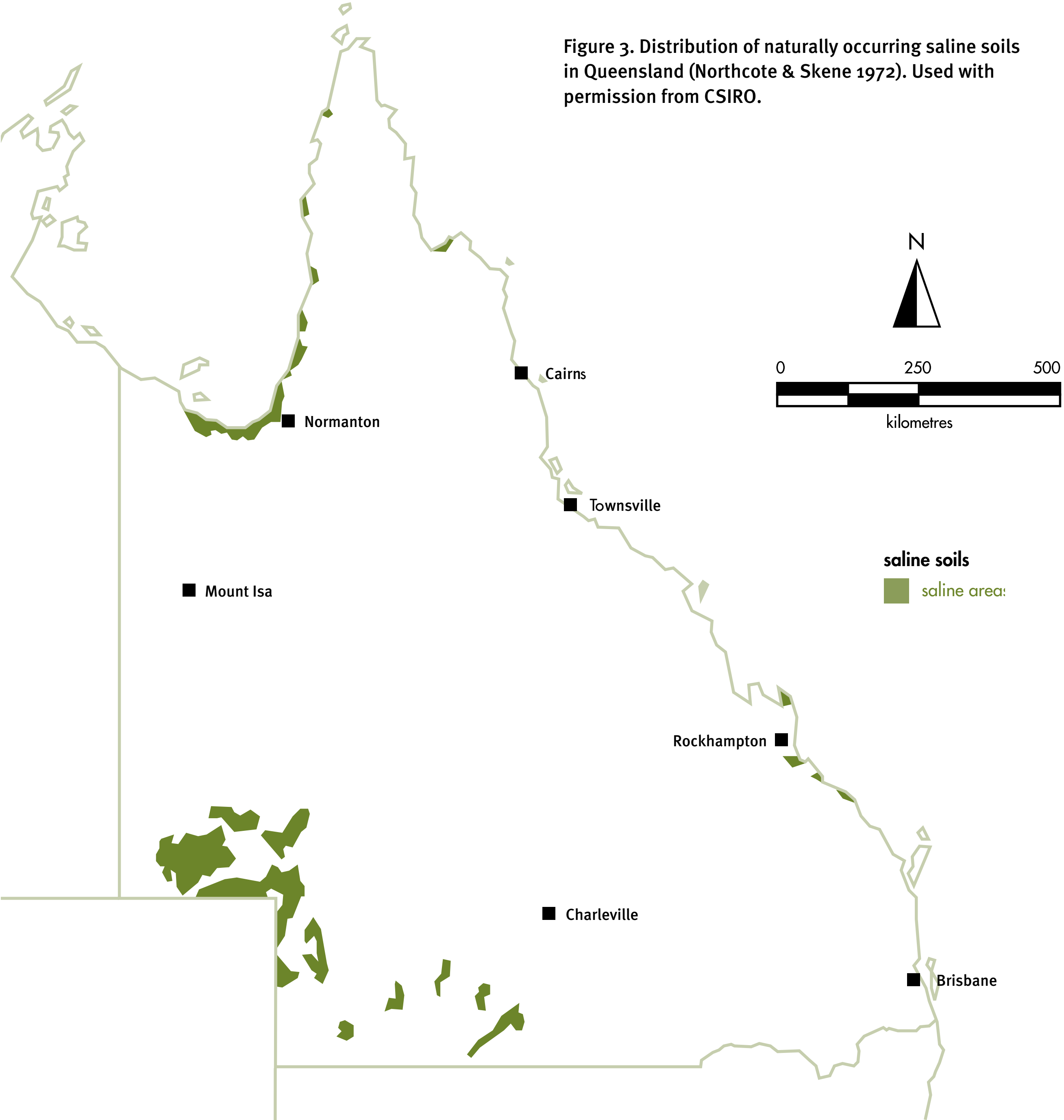
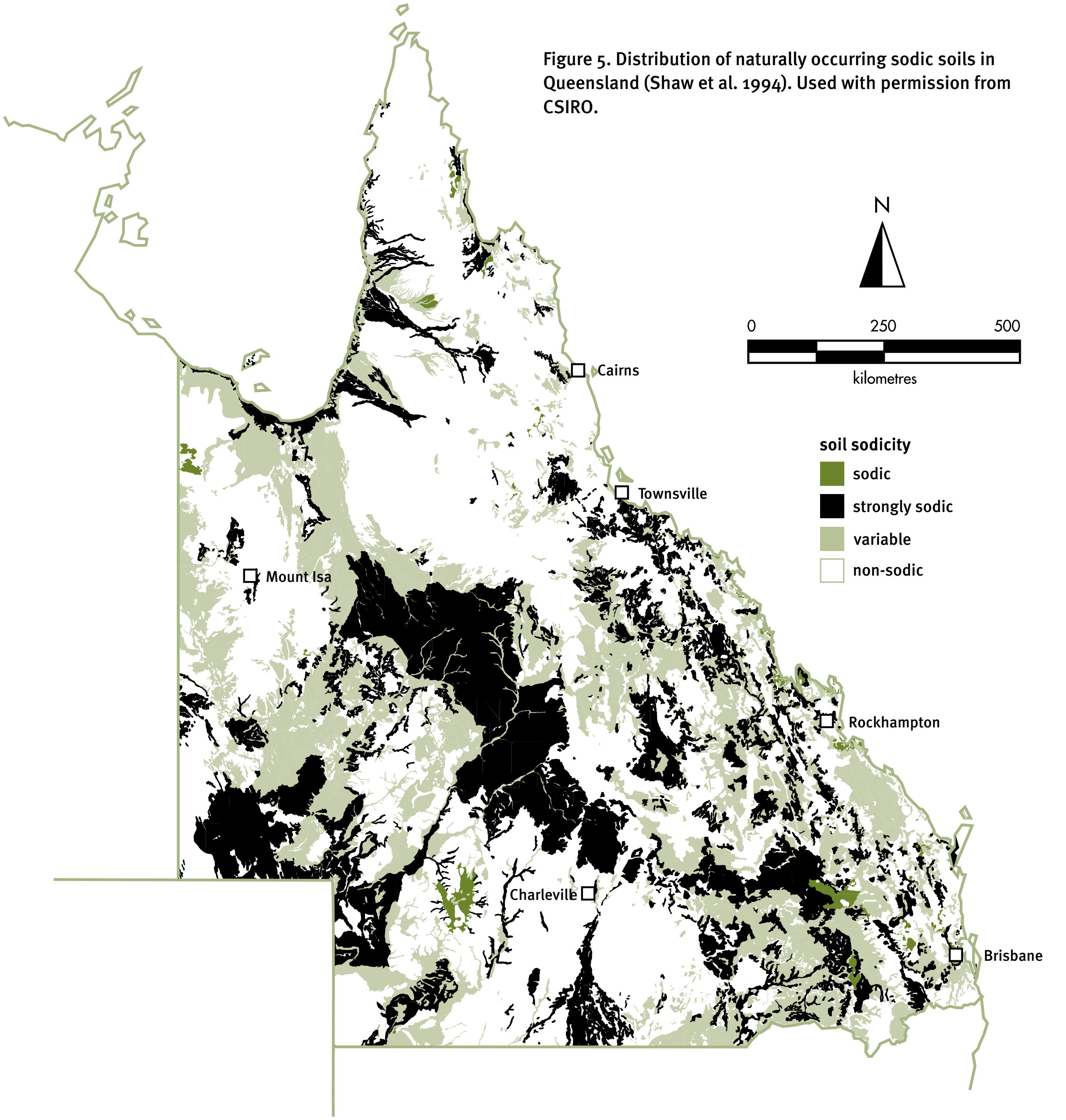


Figure 4. Natural groundwater discharge of the Great Artesian Basin associated with geological faulting which has formed mound springs in the South Australian section of the basin.

Figure 5. Distribution of naturally occurring sodic soils in Queensland (Shaw et al. 1994). Used with permission from CSIRO.



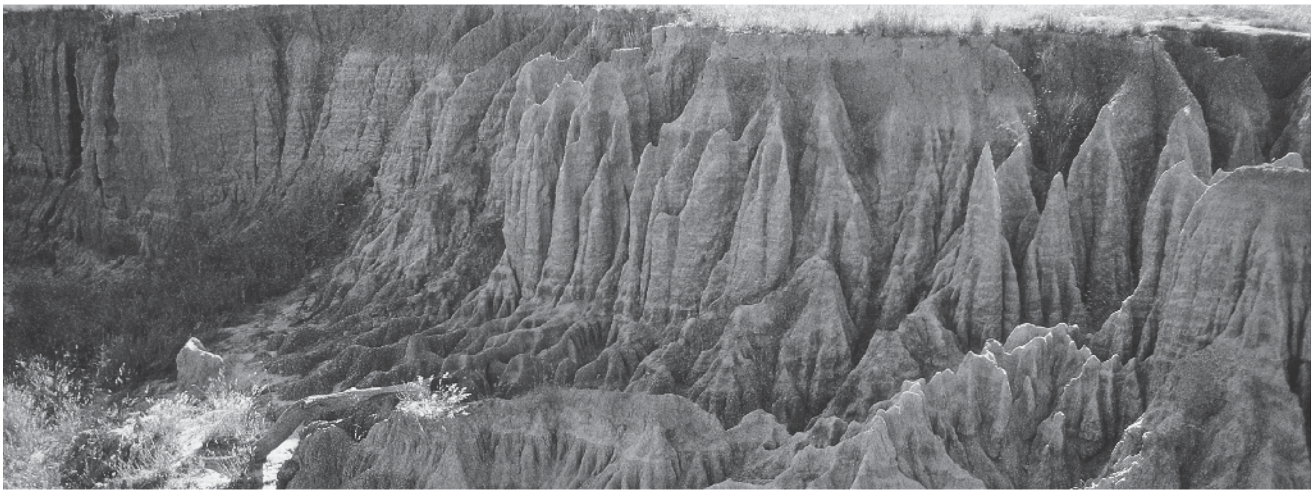


Figure 6. Naturally occurring sodic subsoils.

Watertable salting

Appearance

Salting associated with a rising or shallow watertable can become apparent in the following ways:

- The ground surface may become permanently or seasonally damp or waterlogged, or remain damp for extended periods after rain. Previously ephemeral gullies and streamlines may begin to flow continuously or for longer periods.
- Vegetation in low-lying areas may fail to germinate or grow, or may die off over a period of time.
- Pasture composition and diversity may change over time so that couch grass or other salt-tolerant species dominate.
- In residential areas, buildings may suffer from rising damp.
- Groundwater quality may deteriorate.

An area severely affected by watertable salting typically consists of a bare area, perhaps with a salt-encrusted soil surface, fringed by salt-tolerant vegetation, with groundwater underlying or seeping through the soil surface. In a seepage area, the ground will appear wet or shiny. If the salting is not severe, the seepage area itself may be lightly vegetated with salt- and water-tolerant species but the surrounding area may be bare. In some situations, the groundwater does not rise near the soil surface because a deep creek or gully in the vicinity intersects the watertable and acts as a drain. The base flow in such a drain may be poor quality, saline water.

Process

Watertable salting (discussed in detail in **Hydrologic controls on salinity** page 14) occurs when the watertable exists close to the soil surface. Capillary action draws water from the watertable upwards through the soil. This water evaporates or is used by vegetation. Salts which were dissolved in the water accumulate at the soil surface or in the root zone when the water is removed. Salt concentration can increase to a level at which vegetation can no longer survive.

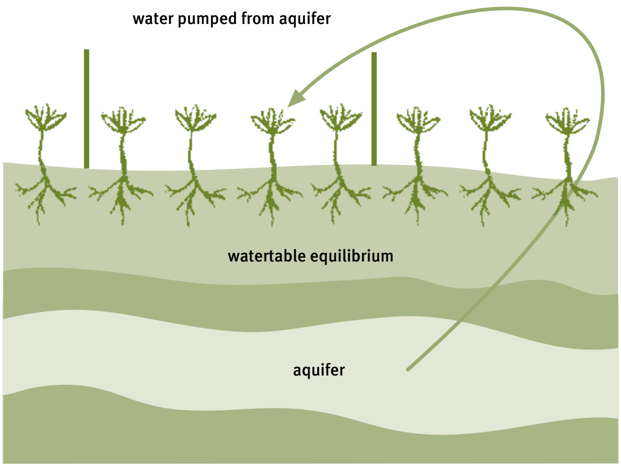
Seepage salting, a form of watertable salting, occurs when the watertable is at the soil surface, permanently or seasonally, and groundwater seeps through the soil surface. A seepage can reduce salt accumulation in the soil by moving salt to the soil surface and flushing it away. However, salt can accumulate in the area surrounding a seepage as a result of capillary action from the shallow watertable.

Where watertable salting occurs, the groundwater itself is often, but not necessarily, saline.

Watertable salting can occur in irrigated areas as well as dryland areas. When groundwaters are used for irrigation, watertable rise is rarely a problem because there is no net increase in the amount of water entering the catchment; excess water draining below the root zone is effectively cycled from the groundwater to the irrigation water and back to the groundwater (Figure 7). Watertable rise is more likely to occur when surface waters are used for irrigation because this increases the water inputs to the system—amounting to a 200 to 600 mm/yr effective increase in rainfall, doubling rainfall input in some irrigation areas.

In dryland areas, watertable salting usually occurs after vegetation clearing and subsequent development reduces water use and thus the ability of the system to maintain the watertable at an adequate depth below the soil surface.

Figure 7. Groundwater irrigation cycles water within the system, but irrigation with surface water increases water inputs to the system, increasing the likelihood of watertable rise.



Occurrence in Queensland

In 1990, the Department of Primary Industries conducted a survey of available information on lands affected by and susceptible to secondary watertable salting (Gordon 1991). Reports of salt-affected land were concentrated in the south-east, south and central Queensland regions, and were commonly associated with basalt areas that receive an average of 500 to 1 200 mm of rainfall each year. Watertable salting was found to seriously affect 10 000 ha of land in Queensland; at least a further 73 000 ha was identified as being susceptible to salting. Areas of known salinity in 1990 are indicated on Figure 8. New outbreaks have occurred since that time.

Figure 8. Known areas of land severely affected by salinity in Queensland in 1990 (Gordon 1991).

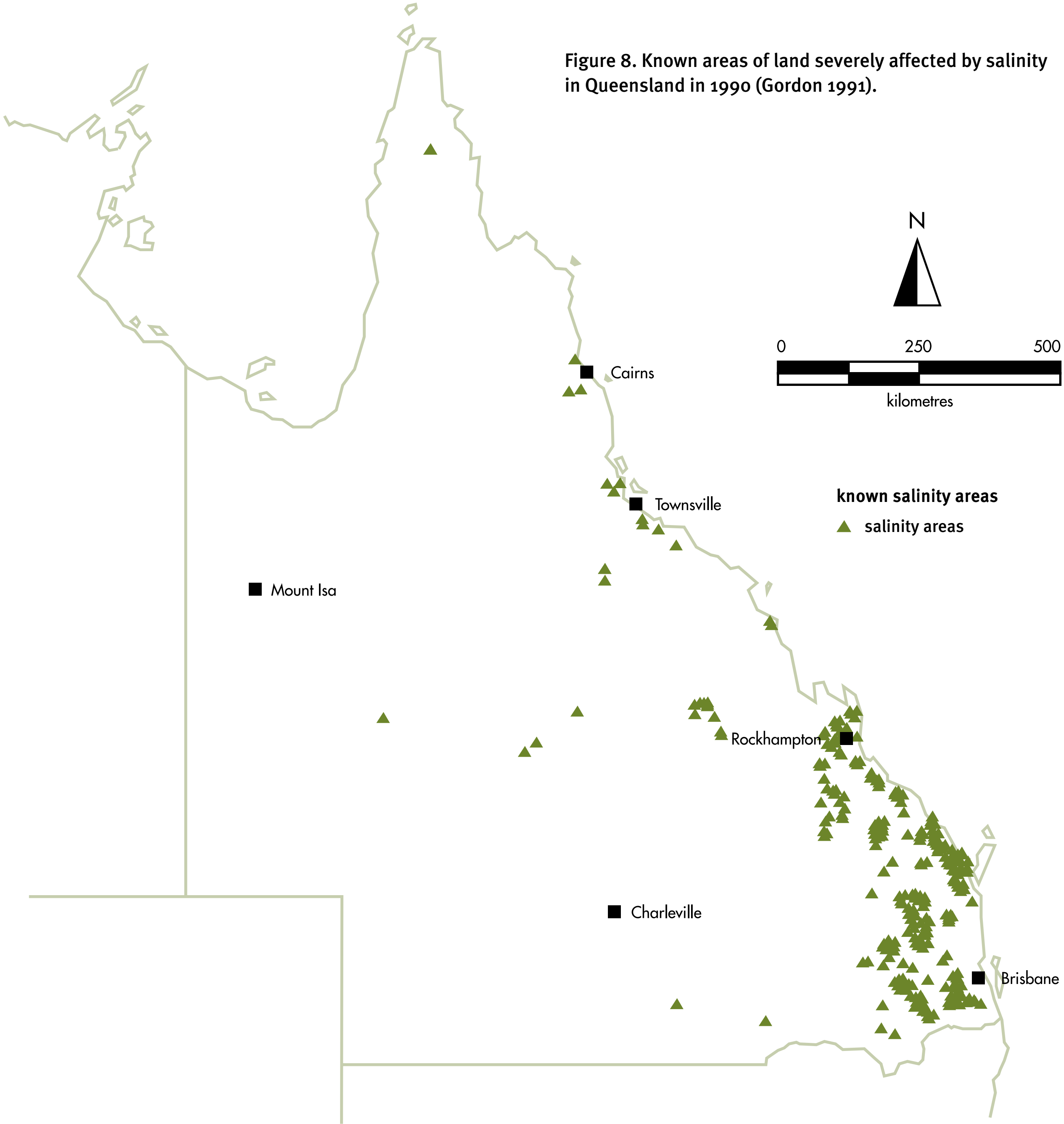


Figure 9. Soil salinity effects on irrigated cotton due to evaporation from shallow groundwater in the Emerald Irrigation Area, Queensland. The problem was reclaimed with the installation of shallow drainage.

The affected area was greater than that reported in an earlier study (Hughes 1979, updated in 1982), which described 7 900 ha of salt-affected land. The overall trend is for an increase in the number of salt-affected areas in Queensland. The extent of affected areas fluctuates seasonally, and sharp increases in area often occur following very wet years.

The area under irrigation affected by rising watertables in Queensland is small. Watertable salting has been recorded in the Emerald, Maryborough, Mareeba–Dimbulah, Bundaberg, and Burdekin irrigation areas where approximately 400 ha of land is seriously affected (Gordon 1991). An increasing problem in the Emerald Irrigation Area has been controlled by subsurface drainage. One reason for the low incidence of watertable salting in Queensland irrigation areas compared with irrigation areas in southern States is that a greater proportion of Queensland irrigation is based on groundwater supplies.

Irrigation water salting

Appearance

In irrigated areas, the effect of irrigation water quality on soil behaviour and plant growth may be apparent as:

- Crop yields may decline progressively over a number of years or be significantly reduced in dry years.
- In severely affected areas, soils may appear 'fluffy' and light (characteristic of saline soils). The soil surface may be dispersible, water infiltration limited, the seedbed poor, and germination poor or unsuccessful (characteristic of sodic soils).
- Crops may appear water-stressed even though adequate amounts of water have been applied.

Process

Irrigation water salting and sodicity occur when salts (including sodium) from irrigation waters accumulate in soils. This is caused by the two interacting processes of salt accumulation and insufficient leaching:

- All natural waters contain salt. Salt from irrigation waters accumulates in irrigated soils as the water is removed by evaporation and transpiration. Poor quality irrigation waters contribute comparatively greater amounts of salt.
- Leaching moves salt below the root zone. Under certain soil conditions or water management practices, and where sodicity is a problem, leaching rates may not be sufficient to maintain salt in the root zone below a concentration at which plant productivity is affected.

Under irrigation, salts leached from the root zone tend to move downwards into the groundwater. In groundwater irrigation schemes, the salt concentration of the groundwater supply may increase, contributing greater amounts of salt to the soil over long time periods (decades).

Irrigation water salting can be partly controlled by growing salt-tolerant crops and by fine-tuning irrigation management. Where irrigation is used only to supplement rainfall, salinity is of less concern than sodicity; the soil salt concentration can be reduced dramatically by wet season rainfall but the proportion of sodium ions in the soil will remain high or increase slightly.

Occurrence in Queensland

It is difficult to assess the area of soils that are affected by salt from the use of marginal quality irrigation waters. The system tends to be self-regulating: growers match crops to water and soil characteristics; when it is no longer possible to grow certain irrigated crops productively, irrigation is stopped or other crops are grown.

In Queensland, 36% of the irrigation water used is groundwater (Australian Bureau of Statistics 1993). Groundwaters in most major groundwater-based irrigation areas in Queensland are suitable for irrigating a wide range of salt-sensitive and mildly salt-sensitive plants, except in the Lockyer Valley and Dee River where 34% and 64% of waters respectively are suitable only for irrigating plants with higher salt tolerances. In Table 1, waters in a number of Queensland groundwater irrigation areas are classified according to the salinity hazard that the groundwater poses for plants.

Table 1. Relative salinity hazard of groundwaters from some groundwater irrigation areas in Queensland (adapted from Shaw et al. 1987; plant salt tolerance groupings based on the criteria of Maas & Hoffman 1977).

Region	% of waters in each region falling within the plant salt tolerance grouping				
	low	medium	high	very high	extreme
Lockyer Valley	10	56	21	13	>1
Bundaberg Irrigation Area	58	40	2	0	0
Callide Valley	42	36	14	6	2
Dee River	2	32	42	22	2
Burdekin Delta	100	0	0	0	0
Queensland*	34	27	17	10	12

Note: *The data for Queensland are an average of the analyses of samples during the period 1988–93 (R. de Hayr, pers. comm.). The samples included irrigation waters suspected of causing problems as well as waters from new bores.

Erosion scalding

Appearance

Areas affected by erosion in conjunction with high salinity or sodicity may appear as follows:

- Midslope and flat areas may become bare of vegetation or support only stunted vegetation growth.
- The soil surface in some areas may be hard and compacted when dry or eroded.
- Pasture composition may change and diversity decrease over time.

In general, the ground in a scald will be bare or may be partially covered by drought- or salt-tolerant species or stunted vegetation. Usually, the soil surface will appear hard and compacted. If stones are present in the subsoil, the eroded surface may have a stone-packed appearance. If the subsoils are strongly saline, salt crystals may be apparent on the soil surface. High subsoil sodicity is a dominant features of scalds.

Areas surrounding scalds can also be affected by the process contributing to the scalding—that is, erosion and deposition of eroded material.

Process

The process of scalding usually begins when vegetation is removed—whether by clearing or overgrazing or by drought or fire. Without vegetation to bind the soil and provide a protective cover, wind and water erosion remove the topsoil, exposing the subsoil. A dispersed surface (crust) forms on the surface of the subsoil.

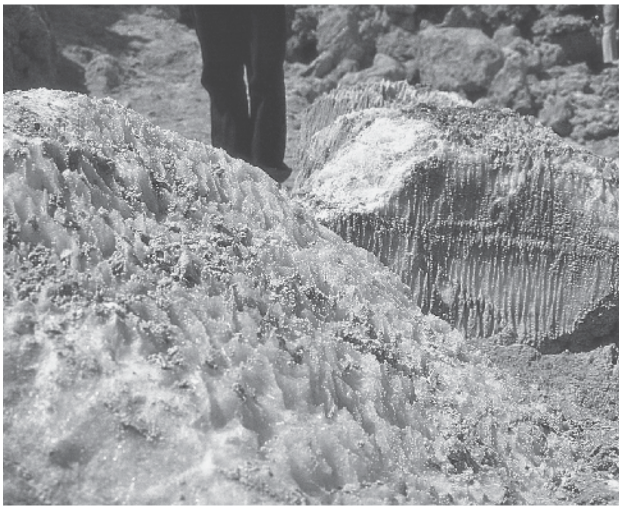
This crust inhibits vegetation growth, increases runoff and contributes to poor soil structure. The dispersed surface is made up of (mostly fine) sand, silt and enough sodic clay to cement it together when dry and seal the surface. The crust disperses when wet.

Occurrence in Queensland

Approximately 590 000 ha of land in Queensland are affected to some degree by erosion scalding (Working Party on Dryland Salinity 1982). Scalding is most common in Queensland on heavily grazed, fragile soils in the arid and semiarid regions in the west of the State (rainfall less than 500 mm per annum).

Figure 10. Erosion occurring on an extensive scalded area of exposed sodic subsoil in south-west Queensland.

Figure 11. Historic salt deposits in an area adjacent to the Dead Sea, Israel.



Sources of salt

The dominant sources of salt are rainfall and rock weathering. Rain is a dilute source of salt, but over time, salt deposited by rain can accumulate in the landscape. Rainfall contributes salt to the landscape at about two to three times the 'average' rate that weathering contributes salt, based on some broad estimates (Shaw et al. 1987). However, weathering can be a dominant source of salt in some landscapes, particularly in Queensland. The dominant source of salts in a particular area will depend on the rock types and the extent of weathering.

Rainfall patterns and soil properties determine the extent to which weathering products remain in the soil profile. In areas with high rainfall and good drainage (such as the wet tropical and subtropical coast of Queensland), most of the salt produced by weathering is flushed out of the landscape. The converse is true, and particularly so, in more arid areas where rainfall is insufficient to leach salt and where drainage out of the region is restricted, such as in Lake Eyre.

Where rainfall is the dominant source of salt, sodium chloride is the most common salt. Where weathering dominates, bicarbonate salts are more common.

Rainfall

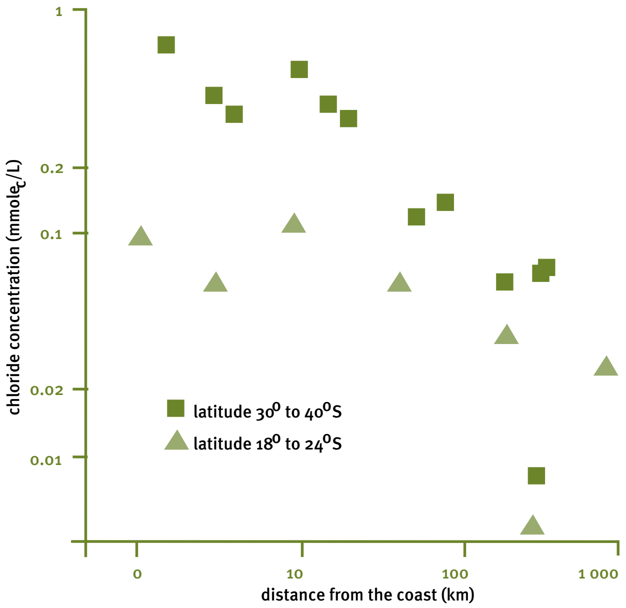
The concentration of salt in rainfall is greatest near the coast, and decreases inland as distance from the coast increases. Salt accessions from rainfall are greater in southern latitudes than in northern latitudes (Figure 12). For instance, the salt concentration of rainfall near the coast north of 24°S (say, Gladstone) is about one-tenth of the concentration of salt in rainfall near the coast in latitudes south of 30°S (say, Grafton).

Differences in sea surface salinity combined with wind patterns and intensities may explain this latitude effect. Variations in sea surface salinities, which depend on relative precipitation and evaporation rates, are minor in Australian oceanic regions (less than 2 000 mg/L) (Shaw et al. 1994).

Weathering

All weathered rock types contribute salts to the landscape to differing extents. For instance, marine sediments contain greater amounts of salt than freshwater sediments, and contribute more salt on weathering. The texture of sediments influences the extent to which salt is retained during weathering. The salts derived from marine sediments are mainly sodium and magnesium chlorides.

Figure 12. Chloride concentration in rainfall with distance from the coast for two latitude ranges (plotted from the data of Isbell et al. 1983 from Shaw et al. 1994). Used with permission from CSIRO.



Queensland has a low incidence of marine sediments compared with other Australian States. Extensive marine inundation occurred in Victoria during the late Mesozoic to early Cainozoic (approximately 135 to 50 million years ago). These marine sediments, in areas such as the Murray Basin, are a primary source of salt (Macumber 1978; Evans et al. 1990). In contrast, Queensland has had little marine inundation since the Mesozoic and none since the early Cainozoic (approximately 65 million years ago) (Beckmann 1983).

Igneous rocks generally have low chloride contents. The relative distribution of volcanic areas in Queensland is similar to other eastern states, but the Queensland occurrences are of a greater age. Volcanic areas in Queensland are intensively used for agriculture and have a lower incidence of sodic soils than other parts of the state. This is due to the dominance of calcium and magnesium over sodium in the parent rock material.

The chemical composition of salts in aquifers can be used to determine the types of rocks contributing salts to the groundwater and to trace the movement of water through the landscape. The aquifers contributing water to salted areas in Queensland tend to be considerably less saline than in other states. Whereas the salts in most southern states are dominantly sodium chloride (NaCl), in Queensland magnesium (Mg) can be the dominant or co-dominant cation, particularly in basalt (igneous) areas. Bicarbonate (HCO_3^-) levels are often much higher in Queensland than in southern states; in some areas it is the dominant anion, indicating active rock weathering rather than a particular geology. However, the relative concentrations of salts in aquifers will change over long time periods under the influence of local chemical processes (see ***Water chemistry and salt sources identification*** page 73.)

Aeolian deposits

Wind-transported (aeolian) materials from soil or lake surfaces are another source of salt. (This process has been described by Bowler 1990.) However, airborne redistribution is a comparatively small source of salt in Queensland because of the general absence of saline soils, except in the south-west corner, and lack of current or historic saline lakes or soils in this State compared with Victoria and Western Australia.

Environmental features contributing to salinity risk

The interaction of processes contributing salt (rainfall and weathering), combined with the influence of other climatic and landscape features and the effects of human activities, determine where salt is likely to accumulate in the landscape.

The factors contributing to salting in Queensland differ to a degree from those occurring in other Australian States. These differences should be taken into account if information on salinity processes and management options is to be applied in other areas and climates.

Climate and rainfall patterns

Seasonal rainfall/evaporation patterns

In general, the most severe watertable salting occurs in areas where most seasonal rain falls in winter (Figure 13). Substantial areas of salting occur in south-west Western Australia and Victoria, both of which experience marked winter rainfall. In Queensland, the greatest incidence of watertable salting occurs in coastal areas to the south, where rainfall is less summer-dominant than in the north (Figure 13). The degree of summer rainfall dominance decreases from the north-east to the south-west of the State (Australian Water Resources Council 1976).

Areas receiving winter-dominant rainfall experience greater recharge to groundwater (and likelihood of watertable rise) than areas receiving summer-dominant rainfall (Yaalon 1983). Winter rainfall occurs during a period of low evaporative demand, so there is an excess of rainfall over evaporation. In addition, the rainfall is usually of relatively low intensity, compatible with soil infiltration rates. These factors result in a net water surplus so that water moves below the root zone to the watertable. (This process is discussed further in ***Hydrologic controls on salinity*** page 14). This also results in greater leaching of salts into the groundwater (Yaalon 1983).

In contrast, summer-dominant rainfall occurs during the active growth period when plant demand and evaporation rates are both high. Summer rainfall is usually of higher intensity with proportionally greater runoff. As a result, a much smaller proportion of water moves below the root zone as deep drainage than in winter-rainfall areas, reducing the likelihood of watertable rise. In some areas in subtropical and tropical coastal Queensland, rainfall exceeds evapotranspiration due to the volume of rainfall during the wet season.

Water balance modelling for winter- and summer-dominant rainfall regimes indicates that recharge is an annual event in winter rainfall climates (Williams et al. 1997). In contrast, recharge tends to be episodic in summer-rainfall climates, and the effect on salinity depends on the time distribution of rainfall events (see next section).

In Queensland, **average annual rainfall** is a useful indicator of salinity risk. Annual rainfall ranges from more than 4 000 mm/yr in the coastal tropics to less than 200 mm/yr in the south-west near Birdsville. In general, areas receiving on average more than 700 mm/yr and less than 1 100 mm/yr are at the highest risk of watertable salting. Areas receiving less than 600 mm/yr are not usually at risk of salinity because insufficient rain falls to satisfy plant demand and recharge the ground-water. Similarly, areas receiving more than 1 500 mm/yr are also considered to be low risk because the higher rainfall leaches salt through the soil profile. In the intermediate rainfall ranges (600 to 700, 1 000 to 1 500), salinity risk is moderate. (Refer also to ***Average annual rainfall characteristics*** page 55.)

Long-term rainfall trends

Areas affected by watertable salting can fluctuate in size and severity in response to long-term rainfall trends.

When annual rainfalls are consistently above average for a number of years, this has a cumulative effect on groundwater recharge and the likelihood of watertable rise increases. During these periods, areas affected by recurrent waterlogging will usually be at maximum size and severity. In such areas, a series of dry years can lower watertables, greatly reducing the rate of salt accumulation that results from evaporative concentration.

Figure 13. The incidence of watertable salting in Australia correlates with seasonal rainfall patterns.

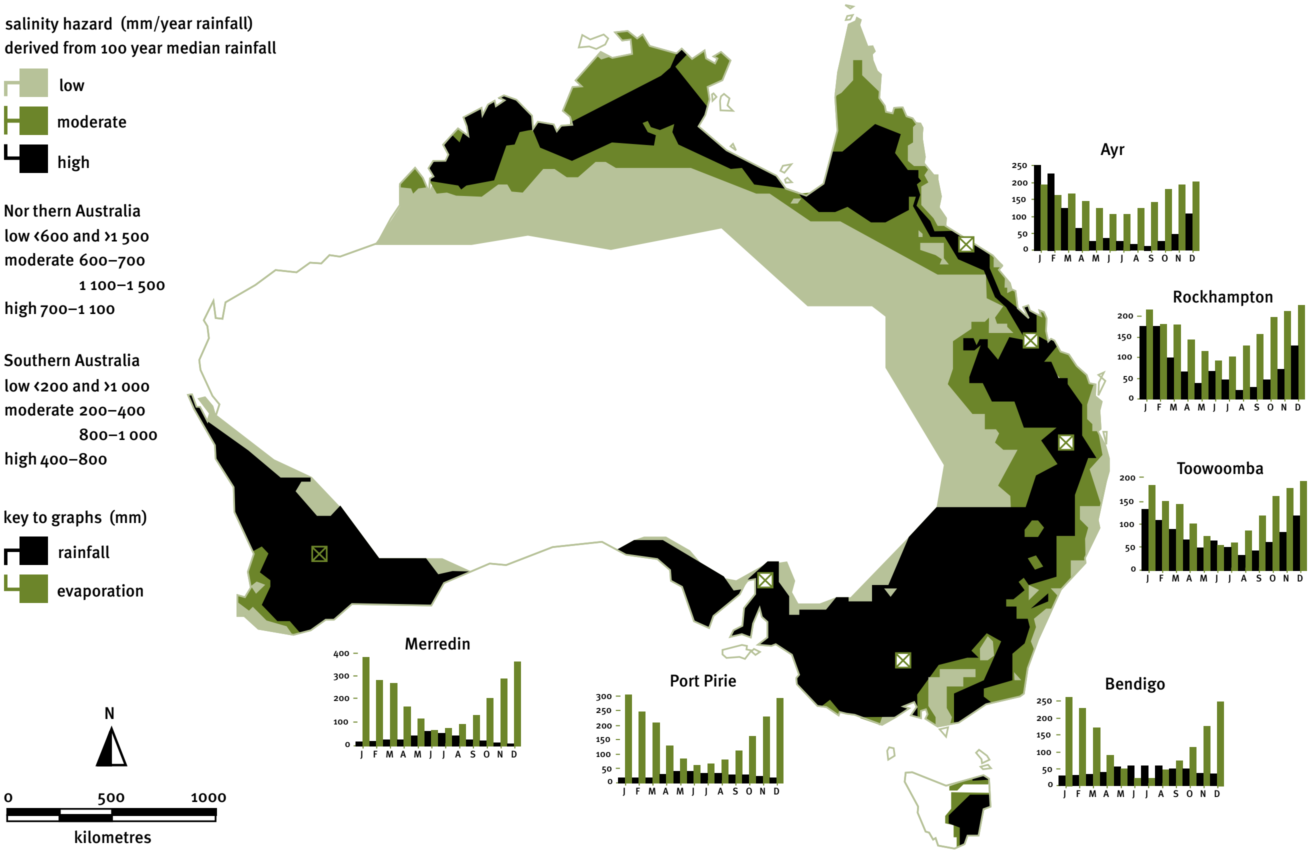
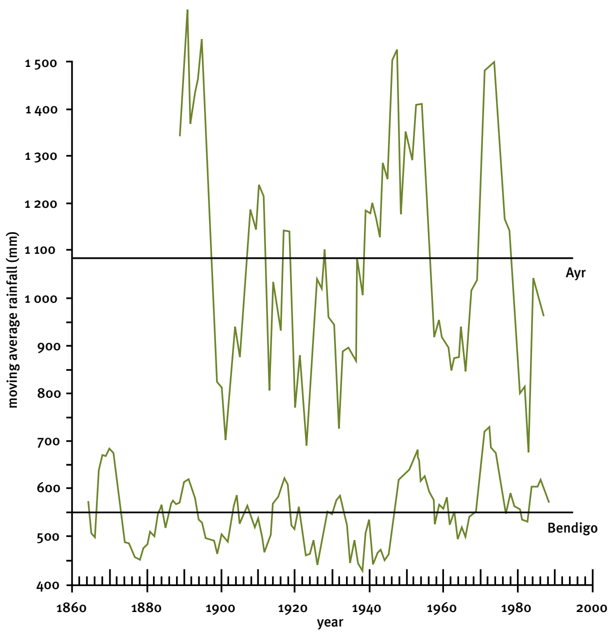


Figure 14. Five-year moving average rainfall patterns for Ayr, north Queensland, and Bendigo in Victoria, illustrating range and variability. The mean annual rainfall for each location is also shown.



In areas of Queensland where rainfall variability is high, there is opportunity for salted areas to partly or totally reclaim under natural cycles. For example, Ayr, in north Queensland, has relatively large cyclical variations in rainfall (Figure 14). The extent of watertable salting around Ayr has varied considerably from year to year, and even disappeared between 1982 and 1990. Surveys and air photos showed that salting only became evident when the moving average rainfall was above 1 100 mm for a few years. (This is discussed in detail in ***Moving average rainfall pattern*** page 56.)

Many salinity outbreaks are first noted after periods of above average rainfall. For instance, salinity outbreaks on the Darling Downs were noted in the early 1950s following an extended wet period. With normal climatic fluctuations between drought and wet periods, salting may become apparent in susceptible areas 20 to 50 years after clearing. In irrigation areas, salting can develop in much less time because of the greater input of water.

Landscape characteristics

Landform features

Watertable salting commonly occurs upslope of landscape features that restrict or inhibit groundwater movement or that provide preferential flow paths to the ground surface.

For instance:

- Geological features, such as faults or dykes, create barriers to water flow so that groundwater accumulates upslope of these barriers.
- Heavy soils at the base of slopes or clays deposited at the confluence of streams slow the movement of water through the soil or sediments, resulting in watertable rises.
- When water flowing through relatively permeable rock types or sediments encounters less permeable underlying materials, the water flows along the line of the stratum rather than through it.
- Where rock bars or other barriers constrict the throat of a catchment, the rate of groundwater flow is reduced and water pools upslope of this point. Human-constructed barriers to water flow, such as roads or dams, have a similar effect.

(Landform features commonly associated with watertable salting are described in detail in ***Landform feature identification*** page 39.)

Historic salt loads

During the period of landscape and soil formation, salinity processes caused salt to accumulate in areas where drainage was poor or where watertables were close to the soil surface. As more recent climates have been drier than past climates and watertables deeper, these historic salt loads are now generally at some depth in undisturbed landscapes.

When the hydrologic balance of a landscape is changed through natural processes or human activities so that a new and wetter hydrologic equilibrium is established, rising watertables can move salt from these historic salt loads closer to the soil surface.

Most occurrences of watertable salting in Queensland can be attributed to the mobilisation of historic salt loads following land development. Vegetation patterns and soil morphological properties, such as inclusions of calcium carbonate, silcrete, ironstone, or manganese–ironstone nodules formed during extended periods of wetness in the past, are often evident in these areas.

Human activities

In areas sensitive to hydrologic change, watertable salting can occur when human activities disturb the hydrologic balance by increasing water inputs to the catchment or by introducing barriers to water movement within the catchment.

There is a marked association between land clearing and outbreaks of watertable salting in hydrologically restricted catchments, although there can be long time intervals between clearing and salting. This delay depends on the degree of hydrologic change (due to clearing, irrigation, climatic variation) and the storage and outflow capacities of the catchment. Finely balanced catchments with low storage and subsurface outflow capacities will experience salting in perhaps a few years compared with a number of years in catchments with greater capacities.

When native vegetation is cleared and an area is developed for agriculture, grazing pressure and cropping practices can reduce the vegetative cover at times such that the vegetation cannot adequately use the available water provided by rainfall. Also, most crop and pasture species are more shallow-rooted than native species. During these periods, extra water moves below the root zone to the groundwater, increasing the likelihood of watertable rise. Clearing in the Lockyer Valley in the early 1900s first resulted in salinity about 30 years later, which increased markedly in the 1950s before establishing an apparent equilibrium in the 1960s. Similarly, salinity developed on cleared areas in the Bundaberg Irrigation Area approximately 35 years after initial clearing (Kingston 1985).

The use of reticulated water supplies in unsewered rural residential areas can, in effect, increase the rainfall to a landscape, disturbing the hydrology to such an extent that extensive waterlogged or saline areas develop. Landscapes under unsewered rural residential developments can receive an equivalent increase in rainfall of about 100 mm/yr (based on residential water supply design guidelines). Surface water irrigation can contribute water inputs equivalent to an increase in annual rainfall of some 200 to 600 mm/yr. Depending on their position and construction, roads and dams can act as barriers to water movement. Shallow watertables and seepage areas can develop upslope of some roads and dams.