Report

Report on the Condition of Agricultural Land in South Australia

Report No 1

December 2004

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R. A. Payne

The Department of Water, Land and Biodiversity Conservation

Soil Conservation Council South Australia

Government of South Australia

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Foreword

Soil and land resources underpin the economic and environmental performance of South Australia's regional landscapes.

Our ancient and delicate landscapes have been subjected to periods of extreme degradation. Most visible of these were the huge wind and water erosion events, particularly during the first half of the 20th century.

On a personal note, during 2002 and 2003, I watched as South Australia experienced a number of significant dust storms, partly due to the ongoing drought conditions. Areas such as the Murraylands, Mid North and Eyre Peninsula suffered most when tens of thousands of tonnes of valuable topsoil were stripped from paddocks.

There are also less dramatic forms of land degradation that are still damaging to our critical soil resources. Perhaps the most significant of these are dryland salinity, soil acidity and the loss of perennial vegetation cover, with its associated native biodiversity.

We are aware of these problems in the landscape and know that some are improving, while some are getting worse. But what are the trends? Are we improving our performance quickly enough? To answer these questions requires a dedicated, long term monitoring and evaluation effort.

This first report on the condition of the State's agricultural land resources essentially represents a baseline for the long term monitoring of South Australia's soil and land resources. It also points to a number of key management practices that could significantly reduce future damage to our soil resources.

This work will be a valuable resource for landholders and for our new Natural Resources Management Council and Regional Boards as they undertake integrated actions to improve our natural resources.

I would hope and expect that future land condition monitoring reports will show a reversal of soil degradation trends, as well as improvements in land management practices that enhance the environmental and productive values of the State's rural landscapes.

Minister for Environment and Conservation

April 2005

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Executive Summary

There are 10.2 million hectares of land used for farming in South Australia. This land has been cleared of its native vegetation and almost all of it has suffered some form of degradation as a result of farming systems that are inadequately aligned with sustainability requirements of its natural resources. Loss of productive capacity of agricultural soils results in adverse environmental, economic and social impacts, many of which are effectively irreversible.

This is a report on a range of indicators of the condition and management of agricultural land in South Australia. The report is based on data collected and collated by the Land Condition Monitoring Program (LCM) of the Department of Water, Land and Biodiversity Conservation. Data sources include field surveys, the Australian Bureau of Statistics, Bureau of Meteorology and surveys of land manager practices, knowledge and attitudes. The LCM Program has been collecting original data for only 4 years, so for some issues where changes occur over very long time periods, this report presents only a baseline assessment.

WATER EROSION

About 781,000 hectares of South Australian agricultural land have a moderate to high inherent susceptibility to water erosion by virtue of soil type and land slope. Conventional farming practices are not adequate for preventing unsustainable levels of soil loss on this land. The greatest proportion of this highly susceptible land is in the Northern and Yorke Region and the Mt Lofty Ranges. A further 2.4 million hectares of land is inherently susceptible to significant water erosion if inappropriate land management practices are used.

Soil Erosion Indicators	Current Range (Whole State)	Desirable Short term	Desirable Long term
Water Erosion Risk Index	55–86 days	< 35 days	< 15 days
Wind Erosion Risk Index	72–171 days	< 35 days	< 15 days

The LCM Program does not measure or estimate actual quantities of soil lost during any given period, because such direct measurement over the whole State would be technically difficult and require large resources. Instead it uses a risk assessment approach. The method is based on a combination of inherent susceptibility (slope and soil type) and key management practices (mainly tillage and surface cover) in major cropping districts of the State. It is assumed that, in the longer term, any change in erosion risk would be reflected as proportionate change in actual soil loss.

The primary indicator developed in the LCM Program for monitoring water erosion risk is the **Water Erosion Risk Index (Water ERI)**. It is effectively an estimate of the average period for which cropped land is exposed to water erosion risk during the year. Over the 4 years of monitoring to date, the annual state-wide Water ERI has ranged from 55 to 86 days. In the Northern and Yorke Region, with the largest area of susceptible land, the annual index has ranged from 52 to 99 days.

As yet, the period of data collection is too short to determine meaningful trends. Land that is managed with best available tillage and stubble management practice should have a Water ERI of less than 15 days, so there is scope to reduce water erosion risk significantly in most areas.

The main opportunities for improvement are in the elimination of all pre-sowing cultivations through large-scale adoption of direct-drill and no-till systems. Farmer surveys show that around 20% of cropping land is prepared using no-till, with a total of 30% (including no-till) of cropping land prepared by direct drill technologies.

WIND EROSION

About 2.4 million hectares of agricultural land in South Australia have a high inherent susceptibility to wind erosion, due mainly to having sandy soils. Most of this highly susceptible land occurs in Eyre Peninsula, Murraylands and South East Regions. A further 3.5 million hectares have a lower inherent susceptibility, but can lose significant amounts of soil if the surface is left in a fine, loose state due to inappropriate tillage or grazing practices.

The methodology developed in the LCM Program to monitor wind erosion uses a similar risk assessment process to that used for water erosion. The process is based on assessing a combination of inherent susceptibility (soil type) and key management practices (mainly tillage and surface cover) in the main cropping districts of the State. It is similarly assumed that, in the longer term, levels of change in actual soil loss should be reflected by proportionate changes in erosion risk.

The primary indicator developed in the LCM Program for monitoring wind erosion risk is the **Wind Erosion Risk Index (Wind ERI)**. It is effectively an estimate of the average period for which cropping land is exposed to wind erosion risk during the year. Over the 4 years of monitoring to date, the annual state-wide Wind ERI has ranged from 72 to 171 days. The greatest overall period of risk occurred on Eyre Peninsula with 212 days in 1999-2000 when drought severely affected western parts of the region, and was 203 days in Murraylands region in 2002-2003.

The state-wide drought in 2002 was most severe in Murraylands and, because many crops and pastures failed to establish, significant areas were exposed to erosion through the following summer and autumn. The period of data collection to date is insufficient for determining trends in wind erosion risk, but there is clearly scope for a very large reduction.

The main opportunities for improvement are in the management of soil surface cover for both cropping and grazing on sandy soils. Direct drill and no-till methods are important technologies for maintaining surface cover in cropping systems. Surveys show that around 21% of farmers still use cultivated long fallow in their cropping systems. The figure is as high as 50% of farmers in the highest risk, low rainfall areas. One of the keys to reducing the period of erosion risk is to minimise the cultivation and exposure of land to erosion before sowing. However, in highly susceptible areas, as many as 62% of farmers currently prefer to start their cultivation program by March, resulting in extended exposure of the land. With best cropping and grazing practices, the annual Wind ERI should be less than 15 days.

SOIL ACIDITY

Most agricultural systems accelerate the rate of soil acidification. As soil pH falls below about pH_{CaCl} 5, productivity and water use by crops and pastures declines markedly. At least 1.9 million hectares of agricultural land in South Australia is either already in a degraded state due to acidity, or is on the brink of damage due to acidification. The only practical and effective method for managing soil acidification is through the application of lime.

The primary indicator of soil acidification used in the LCM Program is the balance between estimated acidification rates for agricultural land, and the amount of lime used.

Lime use increased by more than 100% during the 1990's, but at current levels of about 200,000 tonnes per annum, it is still only about 85% of the theoretical amount required just to balance annual acidification on high-risk soils. An estimated 879,000 ha of agricultural soils are already so acidic that productivity and long-term fertility has been significantly reduced. These soils would require a further 1.2 million tonnes of lime to bring their pH up to a level that is not production limiting.

Surveys have shown that the incidence and level of acidification are generally under-estimated by farmers. In the Mt Lofty Ranges and Kangaroo Island, where soil acidity should be of universal concern, only 60% of farmers considered they had acidic soils on their property and only 51% of them were able to identify correctly the critical pH below which production is likely to decline. In the surveys, while 92% of Mt Lofty Ranges and Kangaroo Island farmers with acid soils knew that lime application was the main treatment for soil acidity, only 64% had applied lime in the previous 3 years.

In practical terms, an increase in lime use on susceptible soils to about 350,000 tonnes per annum would be required to be confident that South Australian agricultural soils have a net positive trend with respect to acidification.

Acidification Indicators	Current	Desirable
Estimated application to:		
– Balance Acidification	200,000 tonnes/yr	230,000 tonnes/yr
– Raise pH of Low pH soils (10 yrs)	–	120,000 tonnes/yr

DRYLAND SALINITY

The area of land directly affected by water-table induced secondary salinity in the agricultural and remnant native vegetation areas of the state is estimated to be around 398,000 ha.

This is predicted to increase to about 593,000 ha in the next 20-50 years, with most of the increase on the coastal plain of the Mid and Upper South East.

Monitoring has shown the watertable rising up to 10 cm annually in places in this region (Barnett 2001) depending on seasonal rainfall. The Upper South East Dryland Salinity and Flood Management Plan, incorporating extensive drain construction, has been implemented to address the situation.

To date, the Land Condition Monitoring Program has not implemented a routine system to collect data on the areal extent and spread of dryland salinity. However, many of the other soil degradation issues addressed in this report contribute to accelerated groundwater recharge rates as a result of reduced productivity and water use by crops and pastures. There are opportunities for significantly increasing the water use of these annual plants and for a much wider use of perennial plants in the landscape.

PHYSICAL CONDITION – COMPACTION, STRUCTURE DECLINE, SEALING, CRUSTING

Almost 1.7 million hectares of agricultural land in South Australia have soils with physical properties that make them inherently susceptible to soil surface structure breakdown. More than half of the susceptible soils occur in the Northern and Yorke Region. These soils readily form surface crusts and seals under raindrop impact, which in turn reduces water infiltration rates, increases runoff and risk of water erosion. Almost all agricultural soils suffer some level of compaction and pan development below the depth of cultivation. Depending somewhat on soil type, the impact of compaction can range from relatively minor to severe loss of productivity.

The main opportunities for reducing adverse soil physical conditions are to significantly reduce tillage and maintain surface cover. Surveys indicate that South Australian farmers currently average 2.3 tillage passes, including sowing, to prepare land for crop. Anecdotally, this represents a large reduction in tillage, even in the last decade or so, but is still substantially more than the ultimate goal of only a single pass at sowing. The surveys also show that an average of 12% of farmers usually burn residues and another 49% occasionally do so.

Soil physical Condition Indicators	Current	Desirable
Average tillage passes for crop preparation	2.3 passes	1 pass
Proportion of managers usually burning stubble	12%	0

This practice not only leaves the soil surface open to degradation by erosion, but also reduces the organic matter available for soil biological activity. There is still considerable scope for reduced cultivation and burning as a means of improving soil physical condition across the cropping districts of South Australia.

SOIL NUTRIENT DECLINE

Agricultural crops and pastures take up large quantities of nutrients from the soil, and considerable amounts are exported in produce. Nutrient decline is not itself a permanent degradation state, as it can generally be remedied with some form of fertiliser application. However, low or unbalanced soil nutrition can cause very large reductions in productivity and water use and consequent increased risk of erosion and salinity.

The majority of South Australian soils have very low natural phosphorus levels, and often have trace element deficiencies. Without very large inputs of key nutrients, agricultural productivity would be very low. Around 30% of soil samples submitted to the South Australian Soil and Plant Analysis Service over the last decade were low in soil available P. This might suggest either poor nutrition management, or that cropping is expanding onto soils of lower nutritional status.

The nutritional status of agricultural soils needs to be managed so that it does not limit production and thereby increase the risk of other degradation. An important part of achieving this is the use of better technology to support nutrition decision-making by land managers. Surveys have shown that soil testing is used regularly by 71% of farmers across the State, but only 54% of those in low rainfall areas do so. Farmers in low rainfall areas also tend to rely more on their own knowledge than to seek outside expertise to assist them.

WATER REPELLENT SOILS

Water repellence is a problem mainly of siliceous sandy soils, where it can cause poor establishment of sown crops and pastures, resulting in low productivity and water use. Poor plant growth and cover on sandy soils exposes them to risk of wind erosion. There are about 2.48 million hectares of agricultural land in South Australia that are moderately to severely affected by water repellence.

Clay spreading is a relatively new practice, requiring large capital investment, which has widespread application for reducing the effects of water repellence and increasing fertility and productivity of sandy soils. It has been successfully used in the upper South East, where surveys indicate that 27% of farmers with repellent soils on their property have undertaken some clay spreading. The practice is increasingly being taken up in other regions, but is in the relatively early stages of adoption and the results have been mixed. While there are some tillage management practices that can improve performance of sown crops and pastures on water repellent soils, their adoption is relatively low.

The land manager surveys show that an average of only 44% of farmers with water repellent soils on their properties have tried one or more of the available management options, including clay spreading. There is still considerable scope for improved production and water use on very large areas of sandy agricultural soils.

WATER USE EFFICIENCY

The Land Condition Monitoring Program uses changes and trends in crop water use efficiency (as measured by the proportion of wheat and barley potential yield achieved) as a general, integrative indicator of the productive capacity and health of SA cropping lands. Of primary concern would be any declining trend in WUE, since this would suggest some form of degradation of the natural resources upon which agriculture is dependent.

Water use efficiency for wheat and barley, the major cereal crops grown in South Australia, rose from 34% to 52% of their combined potential yield, between the decades of 1965-1974 to 1991-2000. While this is a significant improvement there remains considerable scope to increase water use efficiency in annual cropping and grazing systems in most districts.

Soil Fertility Indicators	Current	Desirable
Proportion of soil samples Available phosphorus < 20 mg/kg (SASPAS)	30%	< 10%
Proportion of managers using soil testing	71%	> 90%

Water Repellence Indicator	Current	Desirable
On Water Repellent properties: – Proportion where clay spreading used	27%	> 60%

Water Use Efficiency Indicators	Current	Desirable
Wheat and barley grain yield: Proportion of potential yield achieved	52%	> 75%

REVEGETATION

Revegetation, particularly with native perennial plants, can provide a range of environmental, economic and amenity services. Initial surveys of NHT planting records indicated an annual rate of revegetation, by tubestock and direct seeding, of 6,000 ha in 1997 and 1998. Over a subsequent 4-year survey period, the rate of planting of native indigenous species for non-commercial purposes was consistently around 4,000 ha per annum, with a further 400-1000 ha of Australian native plants that are not local species.

Commercial planting of Eucalypts for the pulp and paper industry varied from 3,000 ha to 21,000 ha per annum. Overall, an estimated 74,000 ha of revegetation (including hardwood plantations but not including commercial pine forest plantings) were undertaken between 1999 and 2002, with most in the South East and Mt Lofty/Kangaroo Island regions.

It will take many decades of revegetation at this rate to have a significant impact on major NRM issues like dryland salinity, soil erosion or native habitat restoration.

Revegetation Indicators	Current (Ha/yr)	Desirable (Ha/yr)
Plantings of:		
– Native species	5 – 6,000 ha/yr	20,000 – 50,000 ha/yr

Introduction

Land Condition Monitoring

Considerable damage has been done to the soil and land resources of South Australia since the advent of agriculture.

The evidence of severe wind and water erosion can still be seen in some areas, either a legacy of the past, or a demonstration of ongoing problems. However, there is also a range of less visible soil degradation processes that threaten the long-term sustainability of agriculture.

So, how well are we going? Are we on top of land degradation or is it getting out of control? Are our efforts effective, or do they need to change? To answer these questions, we need to monitor changes in our landscape and the way the land is managed.

Most land degradation issues are difficult and expensive to measure directly. Year to year changes in land condition are often slight and can be confounded by seasonal climate variation. A consistent long term monitoring program is required in order to quantify definite changes in the land condition.

This report is the first of what is expected to be a regular series, attempting to quantify changes in land condition in South Australia's agricultural areas. In most cases surrogate, indirect measures have been used to assess land condition because of the difficulties of direct measurement.

Data from field surveys, Australian Bureau of Statistics, Bureau of Meteorology, the South Australian Soil and Plant Analysis Service and land manager telephone surveys have been used to develop the indicators. Data from the soil and landscape description database (Soil and Land Information, 2002b) developed by the Soil and Land Information group of Department of Water, Land and Biodiversity Conservation, has been extensively used to show the distribution and calculate the area of susceptible land for each degradation issue.

This large gully began in thunderstorms in the summer of 1941, near Callington, South Australia. (Photo A. McCord, DWLBC)

Land Resources

The Australian continent has been relatively free of major tectonic activity for many millions of years and there has been little geologically recent land uplift or volcanic activity to provide fresh substrate for new soil development. Unlike most other continents, Australia was not significantly exposed to the soil renewal processes associated with more geologically recent glaciation events. The topography of Australia is generally low lying, and most of the soils have been formed on re-worked sedimentary rocks. As a consequence, the soils are generally of low natural fertility.

Fluctuating sea levels in the past have also left a significant legacy on the soils and landscapes of South Australia. Large areas of low lying land were periodically inundated by high sea levels, leaving them covered with calcareous marine deposits, extensive stranded coastal dune systems and a high salt load in many of the rocks and soils.

MANAGEMENT

Australia is characterised by ancient landscapes and soils. The soil, vegetation and water systems had evolved over time into relatively stable systems, considerably shaped by climate, and modified over thousands of years of more recent history by land management practices of indigenous Australians. The advent of agriculture onto ancient landscapes brought about the removal of much of the natural vegetation, and cultivation of the relatively infertile soils. There was a change from a relatively balanced suite of native ecosystems to managed agricultural ecosystems for food and fibre production.

Managed agricultural ecosystems are characterised by high levels of material, energy and human inputs, much of which are non-renewable and do not flow in closed eco-cycles. These ecosystems `leak' non-renewable resources, and are inherently unstable. Without these high input levels, managed agricultural ecosystems would eventually revert to a completely different suite of semi-stable ecosystems, which would neither resemble the native ecosystems, nor would they deliver the food and fibre outputs demanded by our current society.

SOILS

The characteristics of a soil are determined by the inter-action of climate and biological activity on parent materials over time.

Most of South Australia's agricultural soils are formed on sedimentary or metamorphic basement rocks, their weathering products, ancient unconsolidated clays and sands, calcareous marine deposits or windblown deposits derived from them. Due to either the high degree of weathering which they have undergone, or their sandy or calcareous nature, the parent materials on which modern soils are formed are nutritionally poor.

A long weathering history, arid climate and past marine incursions have resulted in significant quantities of sodium and other soluble salts in soil profiles in most parts of the State. In lower rainfall districts, alkalinity, sodicity and salinity commonly affect subsoils, while those soils not affected are likely to be deep, low fertility sands prone to water repellence and wind erosion

In higher rainfall districts, texture contrast (duplex) soils are common. Subsoils are often nutritionally deficient or toxic, have high strength and bulk density, with low water conductivity and consequent poor root growth and function. Topsoils of the hilly districts, and areas where aeolian deposits have been stripped, often contain more clay and tend to be poorly structured soils of sandy loam surface texture. These soil surfaces are commonly susceptible to hard setting and surface sealing. Low infiltration rates, surface ponding, excessive runoff and erosion, patchy seedling emergence and poor workability are characteristic problems.

Across all districts, it is common for root zone depth to be limited by adverse physical and/or chemical subsoil characteristics. Sandy soils in the higher rainfall areas can suffer the additional problems of leaching and acidification. As a result of a relatively arid climate, low inherent soil fertility and biological activity, the rate of soil formation is low.

Organic matter and most of the nutrients critical for plant growth are usually concentrated in the upper 10 cm or so of soil. With slow-forming, shallow topsoils that can also be structurally unstable, and subsoils that are infertile and often hostile to root growth, any loss of soil by erosion or other degradation processes can cause large and very long-term losses of productive capacity.

Calcrete plain in Southern Murraylands region, South Australia (Photo A. McCord, DWLBC)

Major Agro-Ecological Regions of South Australia

SOUTH EAST

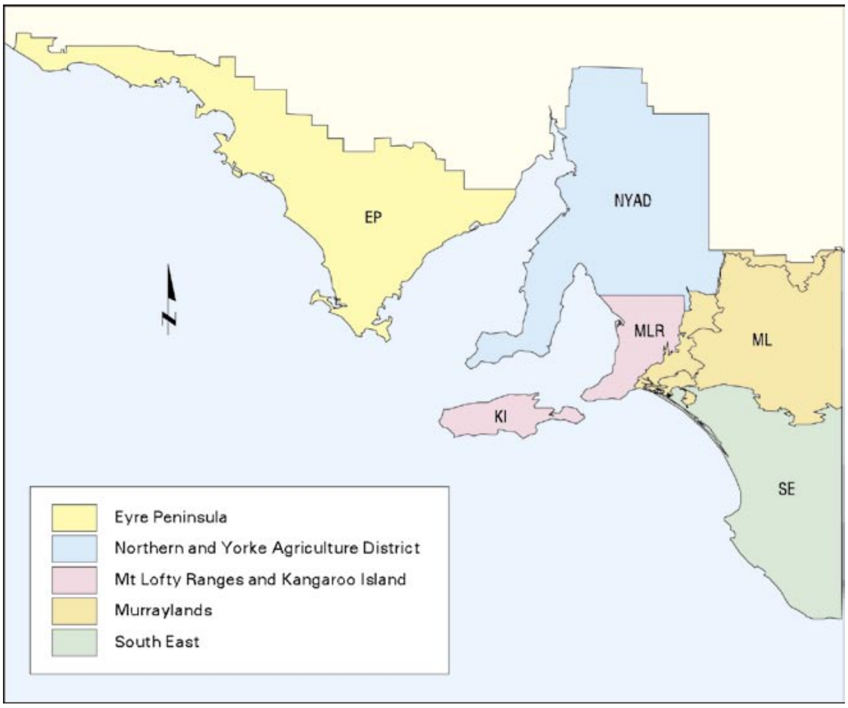
The South East is a region of generally low relief (0-240m above sea level), with large areas below 50m. Annual rainfall is reliable and varies from 400mm in the north to over 700mm in the south.

Broad-hectare agricultural production is primarily livestock grazing of perennial and annual pastures, although crop production is increasing. More intensive dryland cropping and irrigated seed and pasture production is common in the Upper South East and horticultural industries are developed on volcanic soils around Mt Gambier and better drained soils at Coonawarra, Padthaway and Mt Benson.

The region has 3 distinct landscapes. The western part of the region is a plain comprising a series of ancient calcareous coastal dunes parallel to the current coastline, and associated inter-dunal flats. The north-eastern area around Bordertown is an elevated clayey plain. To the south surrounding Mt Gambier is a marine limestone plain with dark loamy soils and small areas of more fertile soils overlying volcanic basalt. Siliceous dunes, sand spreads and dunefields commonly overlie all these landscapes.

Dryland salinity is a major problem in the Mid and Upper South East in the inter-dunal flats, while soil acidity, waterlogging and contamination of groundwaters are major issues in the higher rainfall lower South East. Wind erosion and water repellence are of concern on the sandy soils of the region.

Major agro-ecological regions of South Australia



Dune-swale complex in Murraylands region, South Australia (Photo D. Heinjus)

Hillslope surfaces in the Mt Lofty Ranges, South Australia (Photo D. Maschmedt, DWLBC)

MURRAYLANDS

The Murraylands is a region of low relief (40-120m above sea level) although some dune systems reach 150m or more. Annual rainfall ranges from an unreliable 220mm at Morgan in the north to 400mm south of Lameroo. Broad-hectare agricultural production is largely mixed cereal and livestock grazing, although pulse and oilseed crops are increasing as cropping intensifies, particularly in the more reliable southern areas.

On eastern outwash slopes of the Mt Lofty Ranges, along the western boundary of the region, the sandy loam soils can be susceptible to both wind and water erosion. The northern, eastern and southern areas of Murraylands are essentially dune-swale plains, while the western half is largely a flat to rolling dissected calcrete plain formed from ancient calcareous aeolian material with siliceous dunes superimposed over the main landscape. The main land degradation issues are wind erosion and water repellence on the sandy soils. Apart from the deep sands, many of the soils have alkaline, calcareous, sodic and salty subsoils that restrict root depth and water use efficiency of crops and pastures. Accelerated recharge to ground water-tables following clearing of this region is expected to eventually contribute significant amounts of extra salt to the River Murray.

MT LOFTY RANGES AND KANGAROO ISLAND

The topography of this region varies from coastal plains to the hilly Mt Lofty Ranges (1m-800m above sea level). Annual rainfall is relatively reliable, ranging from 400mm to the north of Adelaide to around 1200mm at Mt Lofty. Broad-hectare agricultural production is largely livestock grazing on perennial and annual pastures in the higher rainfall hilly districts and Kangaroo Island. Horticulture and viticulture is locally significant in the central Ranges, McLaren Vale and Northern Adelaide Plains. Mixed farming with cereal, pulse and oilseed crops and livestock grazing on annual pastures, occurs on the western coastal plain and the lower rainfall eastern slopes adjacent to Murraylands.

Flat to gently undulating plateau surfaces are characterised by low fertility ironstone soils over deeply weathered rock. Ironstone soils and acidic sandy loam to loamy soils over rock are common over much of Kangaroo Island. Soil acidity and waterlogging are major issues and poor water use efficiency can result in mobilisation of salt causing salinisation of lower lying land. On gently sloping to steep hillslope surfaces with sandy loam to clay loam soils over clay subsoils, the main degradation issues are acidification, stream-bank and gully erosion in watercourses and sheet and rill erosion. Sporadic saline seeps and landslips occur in some areas.

A series of ancient glacial valleys filled with unconsolidated sediments occur on Fleurieu Peninsula. The typically sandy soils are prone to both wind and water erosion, as well as water repellence and acidification, while clayey soils are prone to landslip and gullying. The sandy to loamy surface soils overlying mottled clay subsoils, that are common in valleys, are susceptible to water and stream-bank erosion, waterlogging, salinity and acidification. Erosion and leaching also contribute to stream pollution and this not only can affect land along the stream course but also marine coastal habitats. Shallow soils over calcrete, and calcareous and siliceous dunes occur on the coastal areas of southern Kangaroo Island.

NORTHERN AND YORKE REGION

This region includes Yorke Peninsula and the coastal plain north of Adelaide, but mainly comprises an undulating to hilly landscape that is a northward continuation of the Mt Lofty Ranges, and the southern parts of the Flinders Ranges. Most of the land is over 300m but relief varies from 1m above sea level on the coastal plain to several peaks exceeding 700m. Annual rainfall ranges from around 300mm on the western (Pt Pirie) and eastern (Terowie) edges to over 600mm around Clare and becomes more reliable as it increases.

Broad-hectare primary production is mixed farming with cereals and livestock grazing on annual pastures in the driest areas and more intensive cereal, pulse and oilseed cropping where rainfall exceeds 325mm.

On the coastal plain, shallow calcrete and calcareous loams overlying highly calcareous unconsolidated deposits, as well as dune-swale and sand spread complexes occur. Wind erosion is a major issue on these plains, as well as the broad occurrence of saline surface soils. Subsoils are commonly moderately saline, sodic and alkaline which restricts plant root depth and causes poor water use efficiency.

Yorke Peninsula is a gently undulating plain with central rises and low hills. Soils are largely loam over clay, shallow calcrete or calcareous loams with some areas of dunefields and saline land. Wind and water erosion, soil fertility and salinity are the main degradation issues. Subsoil salinity, sodicity and alkalinity similarly restrict root depth.

In the hill and valley landscapes of the Northern Mount Lofty Ranges, the neutral loamy soils over red clay subsoils are highly susceptible to water erosion. There are also numerous small areas of dryland salinity across the region, reflecting shallow local watertables. The rates of soil acidification are high in areas of high productivity and intensive cropping. Many of the valley flats, particularly those with a history of lucerne, require regular lime application to prevent loss of productivity and permanent soil damage. Subsoil salinity, alkalinity, sodicity and boron are widespread and all restrict root growth and water use efficiency.

Hills & slopes in the Northern Agricultural Districts, South Australia
(Photo G. Gale, DWLBC)

EYRE PENINSULA

The agricultural area of Eyre Peninsula is a gently undulating plain of generally low relief from coastal areas (20m above sea level) to the Koppio Hills (320m). Annual rainfall ranges from a reliable 600mm at Pt Lincoln to a highly variable 270mm west of Penong. Broad-hectare agricultural production is largely mixed cereal and livestock grazing on annual pastures, although pulse and oilseed crops are increasing as cropping intensifies in the more reliable rainfall areas (>325mm).

Eyre Peninsula is largely a flat to rolling plain with extensive shallow calcrete and calcareous loams overlying highly calcareous unconsolidated deposits with areas of dune-swale and sand plain complexes. Wind erosion is the major land degradation issue, while water repellent sands are a significant management problem limiting water-use efficiency of crops and pastures. A broad occurrence of subsoil salinity, alkalinity, sodicity and boron restricts root depth, water use efficiency and productivity of crops and pastures.

Extensive areas of dry saline land occur, where erosion of shallow topsoil leaves a surface very hostile to plant establishment and growth. Water erosion is a significant land degradation issue on sloping land of the Koppio and Cleve Hills. There are also significant areas of poorly buffered (sandy) acid soils under more intensive cropping in the more reliable higher rainfall areas where rates of acidification are relatively high. Throughout the region there are scattered saline soaks where shallow local watertables intercept the soil surface.

Calcereous plain of western Eyre Peninsula, South Australia (Photo B. Hughes, PIRSA)

Land Management Issues

Soil Erosion

BACKGROUND

Soil erosion is the process by which soil particles are detached from one site, transported by wind or water flow and deposited at a different site. It results from a complex interaction of soil type, topography, climatic conditions and land management practices. Large erosion events occur when extreme rainfall or wind events act on loose soils that are inadequately protected by vegetative cover. Natural rates of soil erosion are usually relatively low, and less than rates of soil formation except, for example, on very steep slopes or in natural dune fields.

When natural vegetation is cleared and the soil cultivated for agricultural production, the rate of soil loss usually accelerates to many times natural levels. When topsoil is lost at a rate greater than new soil is formed, the productive capacity of the land is almost always reduced.

Very large areas of South Australia's agricultural lands have suffered high levels of wind or water erosion, particularly in the first half of the 20th century. The average rates of soil loss to wind and water erosion have markedly reduced in the last 50 years, but they still exceed rates of soil formation and therefore remain unsustainable.

The inherent susceptibility of soil to water erosion is determined by land slope, soil type and climatic conditions such as recurrence interval and intensities of rainfall runoff events. The steeper the land, the more energy a water flow has for detachment and transport of soil particles. The more frequently runoff events occur, the more likely they are to coincide with soil being in an exposed state.

Soil particles with low cohesion are more easily detached from the soil mass, and smaller soil particles require less energy for transport than larger particles. In general terms, soils with higher clay content, on flatter slopes, are far less susceptible to erosion than those containing less clay, on steeper slopes.

The quantity and nature of vegetative cover of a soil also considerably affects it susceptibility to water erosion. A highly erodible soil on a steep slope might still have low soil loss if it is completely covered by standing vegetation.

Water Erosion occurring in the Northern and Yorke Region, South Australia
(Photo M-A. Young, PIRSA)

Wind erosion in the 2002 drought at Loxton, South Australia (G. Forward, PIRSA)

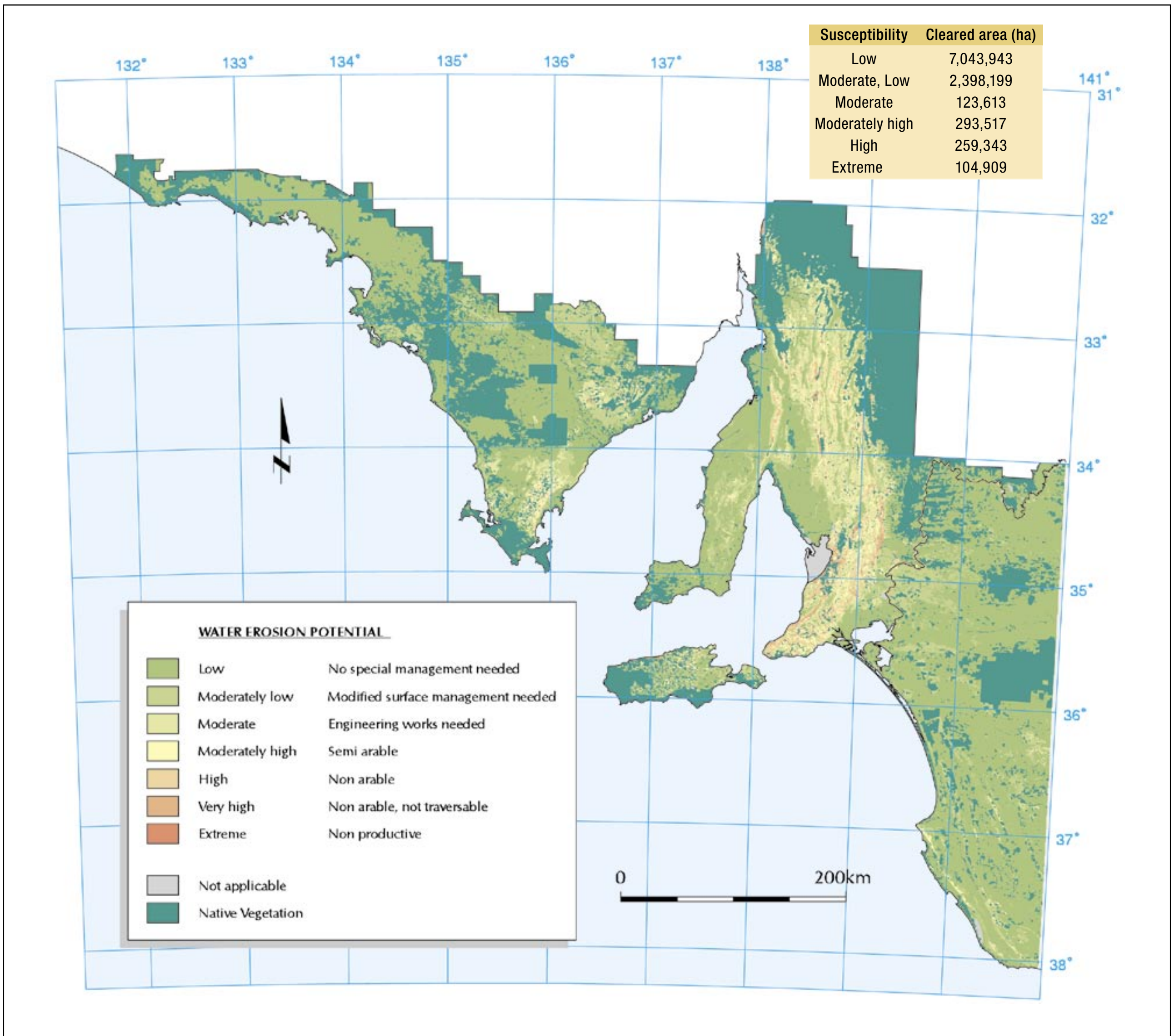


Figure 1. Distribution of cleared land susceptible to water erosion in South Australia

Figure 1 is a map of South Australian agricultural land showing inherent water erosion risk classes (Soil and Land Information, 2001b).

Disregarding non-arable land such as conservation parks and other reserves, lakes and areas of native vegetation, there are approximately 781,000 ha of arable agricultural land in the State with an inherent risk of water erosion that require special management measures to avoid unacceptable soil loss. Another 2.4 million ha of arable agricultural land have soils with a moderately low susceptibility, but which can be at risk during extreme rainfall events if subject to excessive cultivation or grazing practices.

The area of inherently susceptible land is shown by region in Table 1. The key factors that predispose this land to erosion are slope and soil type.

Similar principles apply to inherent susceptibility for wind erosion.

The key risk factors are soil type, surface disturbance and surface cover.

It is the coincidence of loose, dry, bare soils and strong winds that leads to the greatest loss of soil by wind erosion.

Table 1: Area of cleared land with soils susceptible to water erosion in regions of South Australia

Region	Moderate to highly Susceptible Area '000 ha	Moderately Low Susceptible Area '000 ha
Eyre Peninsula	119	579
Northern and Yorke	265	997
Mt Lofty Ranges	307	159
Murraylands	29	299
Kangaroo Island	42	79
South East	18	286
TOTAL	**780**	**2,399**

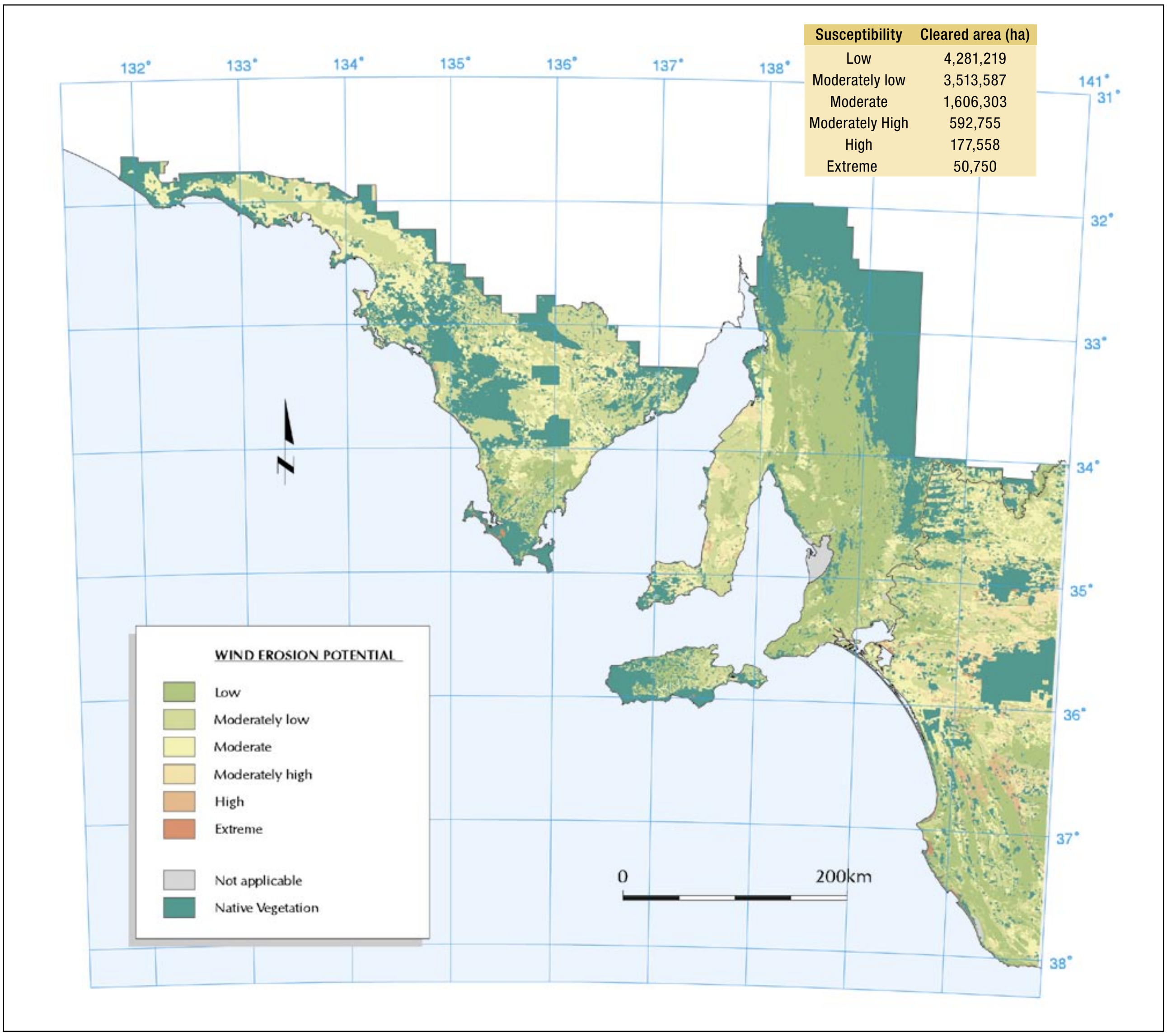


Figure 2. Distribution of cleared land susceptible to wind erosion in South Australia

Figure 2 is a map of South Australian agricultural land showing inherent wind erosion risk classes (Soil and Land Information, 2002b). There are around 2.43 million ha of arable agricultural land in the state with a level of wind erosion risk that requires special management measures. Another 3.51 million ha of land have soils of higher clay content that can also be at risk following excessive tillage or grazing practices. The regional areas of inherently susceptible land are shown in Table 2.

Table 2: Area of cleared land with soils susceptible to wind erosion in regions of South Australia

Region	Moderate to highly Susceptible Area '000 ha	Moderately Low Susceptible Area '000 ha
Eyre Peninsula	841	1,681
Northern and Yorke	227	563
Mt Lofty Ranges	18	50
Murraylands	713	552
Kangaroo Island	16	80
South East	612	587
TOTAL	**2,427**	**3,513**

MONITORING WIND AND WATER EROSION

The occurrence of large soil loss events is highly variable both temporally and spatially. They usually result from a concurrence of an extreme wind or rainfall event on an area of land left susceptible by a set of inappropriate or poorly timed management practices. This can mean that a given piece of land might not suffer significant soil loss for several decades, but then lose a great deal of soil in only a few hours.

Monitoring soil loss by direct measurement is therefore technically impractical. More indirect, or surrogate, indicators of soil loss are required.

Monitoring Methodology and Rationale

The inherent susceptibility of a land surface to erosion is determined by soil type and topography. Surfaces are relatively resistant to erosion, provided they are left undisturbed and a high level of surface cover is maintained. However, once the surface is loosened, even low energy winds or water flows are able to detach soil particles to the full depth of the loosened soil. Management practices that loosen the soil also inevitably result in loss of surface cover. Therefore, the critical management practices that affect the risk of accelerated soil loss are:

> the occurrence, intensity and timing of tillage operations, and,

> the quantity and nature of surface cover.

The timing of tillage operations is of utmost importance because the longer a soil is in a loose state, the higher the probability of a coincident erosive wind or rainfall event. The intensity of tillage practice can also modify the risk. Cultivation practices which result in a very finely divided soil make it much more susceptible to erosion than a single, no-till operation that only loosens the soil in relatively narrow slots. Surface cover lowers water erosion risk by protecting the soil from direct raindrop impact and by reducing the velocity and energy of overland flows. In the case of wind erosion, surface vegetative cover significantly reduces wind velocity at the soil surface.

The approach of the DWLBC Land Condition Monitoring Program to monitoring erosion is to measure changes in key practices affecting risk of erosion. Risk indices are derived from simple groundcover, surface looseness and soil/landscape ratings, as well as the period of time that the land is at risk. This approach does not provide a direct estimate of the amount of soil lost in any given erosion event or period, but aims to provide a quantitative indicator of changes in risk of wind and water erosion due to management practices, over the longer-term. Any change in risk is expected to translate into a proportionate change in overall quantity of soil lost from agricultural landscapes, provided climatic conditions do not change significantly.

A field survey methodology has been developed to collect key erosion risk data. The land zone framework and transects used in the survey are shown (in red) in Figure 3. The land zones are based on the soil and land description database of the Soil and Land Information group of DWLBC.

Data collection is undertaken in land zones considered to have a significant intrinsic potential for soil erosion. These include parts of the Lower, Mid and Upper Northern and Yorke Region (nyr), Eyre Peninsula (ep), Murraylands (ml) and the Upper and Mid South East (se), representing about 8 million hectares of a total 10.2 million ha of arable farming land in South Australia.

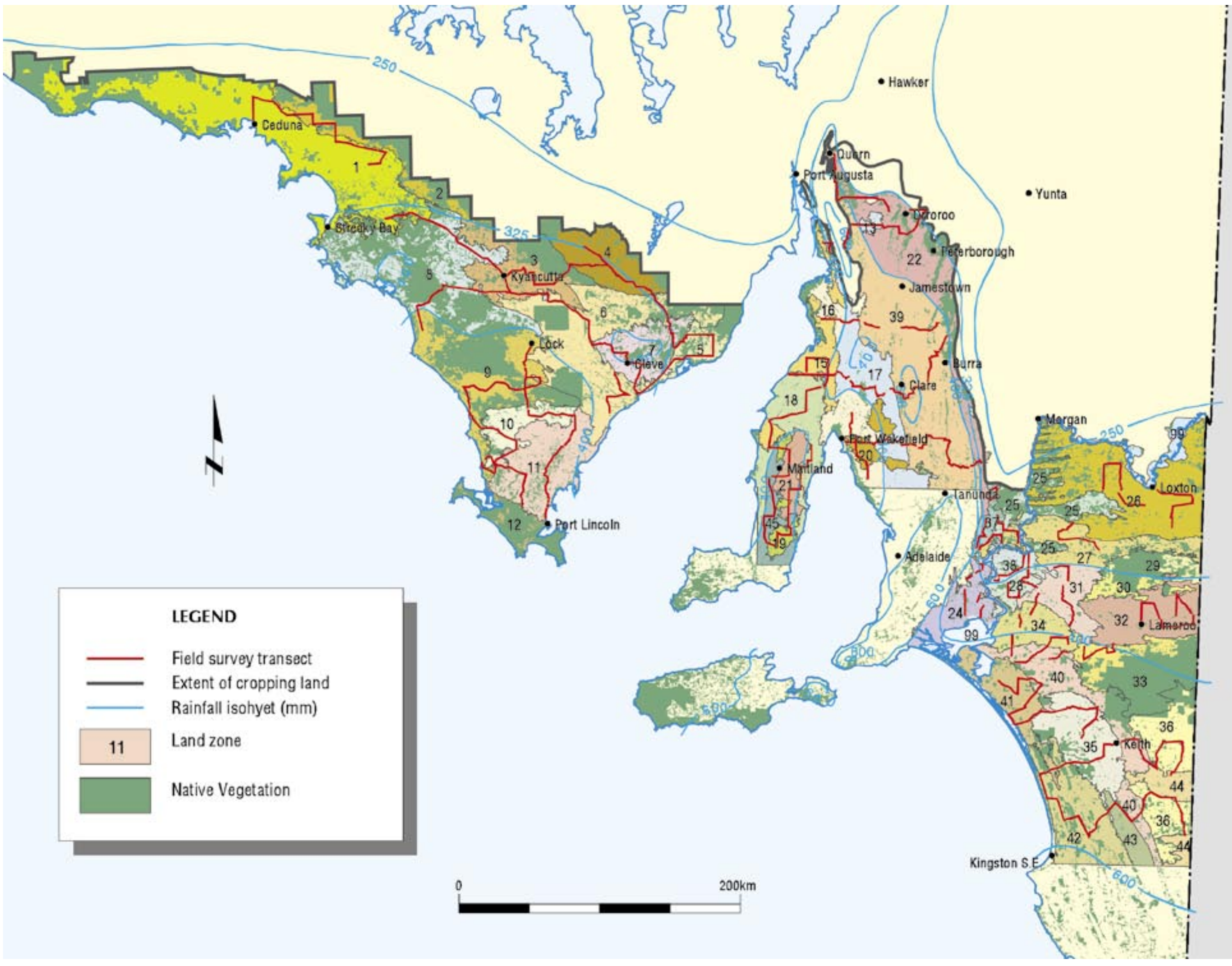


Figure 3. Land zones and field survey transect locations for assessment of land cover in South Australia

To date, erosion risk data have not been collected in Lower Yorke Peninsula, Kangaroo Island or the Lower South East, where neither wind nor water erosion are major issues, or in the Southern Mount Lofty Ranges, where some isolated instances of paddock soil erosion do occur, but they are usually on a relatively small areal scale.

Approximately 5,500 sites are surveyed four times each year, in October, March, May and at peak sowing time (usually June). This time sequence is used to derive a measure of the cumulative area of land at risk of erosion over the whole year, including land cultivated as long fallow before October. The key data recorded for all sites are ratings of vegetative cover and the level of soil disturbance. In addition, ratings of land slope are recorded for sites with a water erosion risk and ratings of soil texture for those prone to wind erosion. Indices of erosion risk have been developed using these parameters. Although the main objective is to describe the longer-term trends in erosion risk, the measurements in any particular year can be significantly influenced by seasonal conditions. Long term monitoring is essential to accommodate this variability.

Water Erosion Risk

Annual erosion risk profile

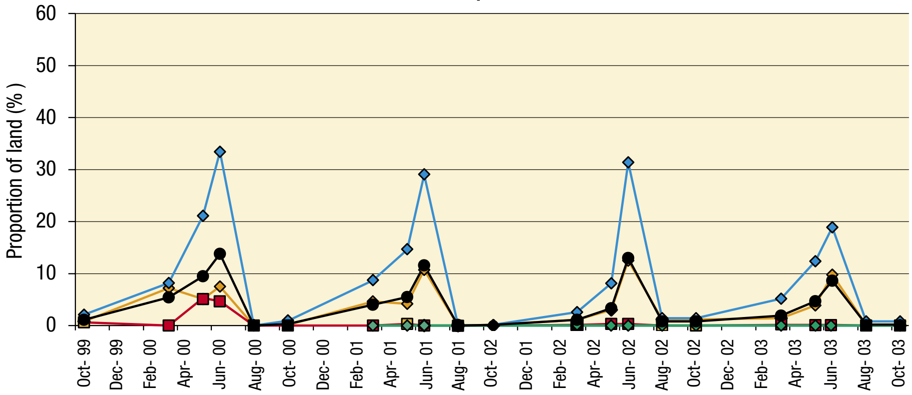
Figures 4 and 5 illustrate the temporal pattern of cyclic exposure of agricultural land to water erosion risk over the 4 years from October 1999 to October 2003. Figure 4 shows the amount of land at risk of water erosion as a proportion of all cleared land in regions of the state and Figure 5, the estimated area of land where there is risk of water erosion.

In most years the erosion risk peaks in June during the crop sowing period and declines to virtually zero by August as crops and pastures establish and cover the ground. The Northern and Yorke Region has a relatively high cropping intensity and the greatest area of land with inherent risk of water erosion (see Table 1).

This is demonstrated by the much higher peak risks in both graphs in all years.

The annual peaks in Figures 4 and 5 provide an estimate of the area of inherently susceptible land that is cropped in any year. However, there are small areas of susceptible land that are managed using no-till or zero-till technology that minimise soil disturbance and maintain cover so that erosion risk is kept low. Greater adoption of low intensity tillage systems should see the annual peak values decline over time.

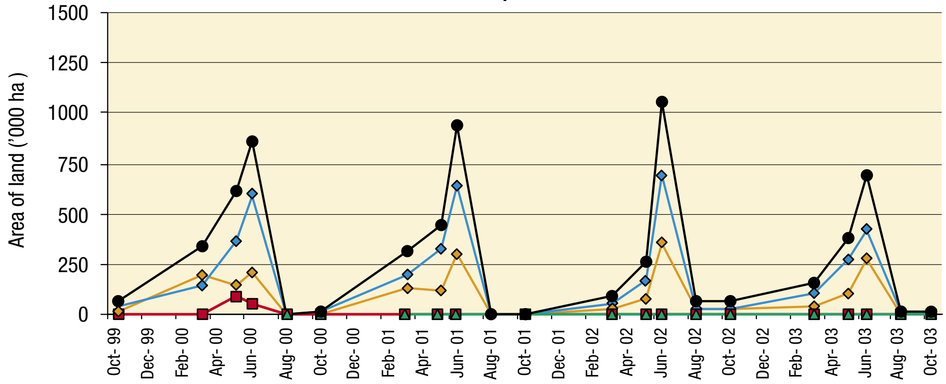
Figure 4: Proportion of cleared land (%) at risk of water erosion in Regions of South Australia for the period October 1999 – October 2003



	Oct-99	Mar-00	May-00	Jun-00	Aug-00	Oct-00	Mar-01	May-01	Jun-01	Aug-01	Oct-01	Mar-02	May-02	Jun-02	Aug-02	Oct-02	Mar-03	May-03	Jun-03	Aug-03	Oct-03
ep	0.8	7.2	5.1	7.5	0	0.1	4.6	4.2	10.7	0	0.1	1.1	3	12.5	1.2	1.2	1.4	3.9	9.8	0.1	0.1
ml	0.6	0	5.3	4.7	0	0	0	0.3	0	0	0	0.1	0.3	0.3	0	0	0.1	0.1	0.1	0	0
nyr	2.1	8.2	21.1	33.4	0	0.9	8.7	14.6	29	0	0.1	2.6	8.1	31.4	1.4	1.4	5.2	12.4	18.9	0.8	0.8
se							0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
South Australia	1.1	5.4	9.5	13.8	0	0.3	4	5.5	11.6	0	0.1	1.1	3.3	13	0.8	0.8	1.9	4.7	8.6	0.2	0.2

Month / Year

Figure 5: Area of cleared land ('000 ha) at risk of water erosion in Regions of South Australia for the period October 1999 – October 2003



	Oct-99	Mar-00	May-00	Jun-00	Aug-00	Oct-00	Mar-01	May-01	Jun-01	Aug-01	Oct-01	Mar-02	May-02	Jun-02	Aug-02	Oct-02	Mar-03	May-03	Jun-03	Aug-03	Oct-03
ep	23	203	144	212	0	3	130	119	322	0	3	31	85	353	34	34	40	110	277	3	3
ml	11	0	95	59	0	0	0	5	0.3	0	0	2	5	5	0	0	2	2	2	0	0
nyr	37	144	370	585	0	20	192	323	642	0	2	57	178	690	31	31	114	272	415	18	18
se							0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
South Australia	70	347	609	856	0	23	322	447	944	0	5	90	268	1048	65	65	156	384	694	21	21

Month / Year

While the length of monitoring time is too short to draw conclusions about the trend, the reduction in peak water erosion risk in 2003 compared with previous years suggests that the anecdotal evidence of an increase in no-till systems may be occurring. Longer term monitoring is required to confirm this.

Period of Risk

Figure 5 also shows the area of susceptible land that is exposed to water erosion in October, March and May prior to the sowing peak around June.

Land first exposed to erosion risk in October is exposed for at least 9 months, until the subsequent crop establishes and stabilises the soil surface. A large proportion of annual soil loss will occur on land cultivated prior to sowing, particularly on the long fallows and land cultivated by late summer. Over the 4 years of monitoring, an average of more than 50% of the cumulative exposure to water erosion risk (area at risk x period of exposure) occurred in the period prior to the May surveys. This means that more than 50% of soil loss due to water erosion is likely to occur because of cultivation carried out before May. Since there is no significant technical barrier to reducing the early cultivation of land, the level of water erosion soil loss could be reduced to only 40% of current levels if no soil disturbance occurred prior to May, even if conventional tillage practices were used after that. It could be further reduced to less than 20% of current levels if no cultivation was carried out before sowing.

Risk Index

Figure 6 shows the main standardised annual indicator, the **Water Erosion Risk Index (Water ERI)** for the 4 years from October 1999 to July 2003. This Index is an estimate of the annual average cumulative period of water erosion risk distributed over the area of cropped land susceptible to erosion. This indicator shows the relative risk of water erosion to susceptible land in the cropping districts of South Australia.

The average Water ERI for South Australia ranged from 55 to 86 days. In the Northern Agricultural and Yorke Districts, where the highest proportion of susceptible land occurs, the Water ERI varied from 52 to 99 days during the 4 years of monitoring. The nominal value for the index under direct drill with full cultivation is around 15 days, assuming an average 30 days after sowing crops to fully stabilise the soil surface.

In key zones where water erosion is an issue, the period ranged from 47 to 134 days (Table 3). For other zones the risk was either less or water erosion was not an issue.

With an average Water ERI for both Eyre Peninsula and the Northern and Yorke Agricultural Districts in excess of 50 days, there is considerable scope for reducing water erosion risk by starting cultivation later. This can be achieved by the adoption of Direct Drilling, and in particular No-till, management systems for crop sowing.

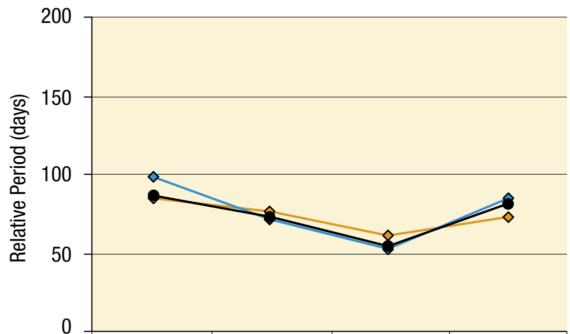
A longer period of monitoring is necessary before realistic trends or comparisons in the erosion risk can be determined.

Wind Erosion Risk

Annual erosion risk profile

Figures 7 and 8 illustrate a cyclic pattern of exposure of agricultural land similar to water erosion risk. The annual pattern of wind erosion risk has so far been more variable than for water erosion risk during the 4 year monitoring period from October 1999 to July 2003. This is to be expected because an extended dry period can have a number of contrasting effects. In 2002, for example, the dry summer and autumn significantly reduced 'early' tillage in most districts across South Australia and this effectively reduced the area and time that land was exposed to wind erosion risk up to sowing. On the other hand, the continuing drought conditions meant that large areas of exposed land remained at risk right through the year.

Figure 6 The annual Water Erosion Risk Index (cf. susceptible crop area) in Regions of South Australia for the period October 1999 – July 2003



	99/00	00/01	01/02	02/03
ep	85.4	76.0	60.5	73.1
nyr	99.2	70.8	51.8	85.4
South Australia	85.7	72.8	55.0	81.5

Year

Table 3 Average Water Erosion Risk Index (days) relative to susceptible cropped land area in key zones of South Australia between October 1999 and July 2003

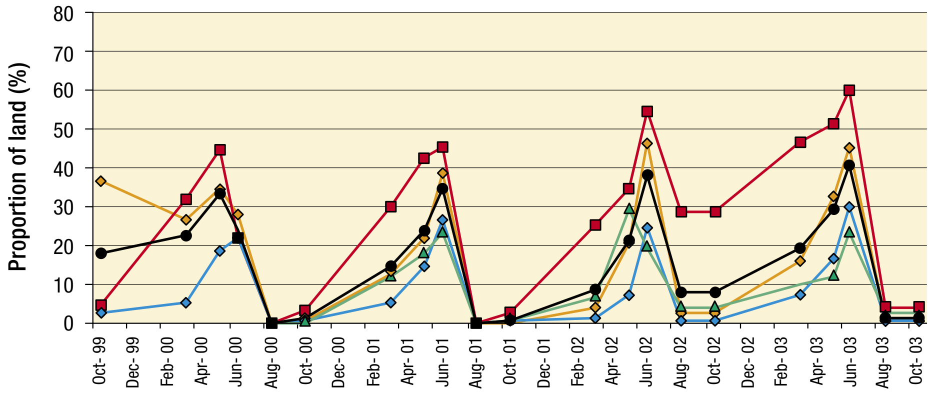
Region	Key Zone	Range (Ave)
EP	4	50–52 (51)
	7	61–87 (70)
	11	47–80 (66)
NYR	17	56–95 (74)
	19	48–68 (56)
	21	54–64 (57)
	22	52–134 (102)
	39	50–68 (61)
	45	51–62 (57)

While cultivation practice for cropping contributes most of the risk, grazing can also contribute. As livestock reduce cover they are more likely to loosen the surface of sandy soils and make them more erosion prone. The risk profiles reflect a combination of cropping and grazing effects.

Figure 7 shows the amount of land at risk of wind erosion as a proportion of all cleared land in regions of the state and Figure 8, the estimated area of land where there is risk of wind erosion. The June erosion risk peaks, occurring during the crop sowing period, usually decline to zero by August as crops and pastures establish and cover the ground. Eyre Peninsula and Murraylands regions have the greatest area of land with inherent risk of wind erosion (see Table 2) as indicated by the much higher peak risks in both graphs in all years.

Similar to the water erosion situation, the peaks largely reflect the area of inherently susceptible land that is cropped in any year, although some susceptible land can be exposed to erosion by heavy grazing. Greater adoption of minimum tillage systems, such as no-till or zero-till technology, offers the greatest potential to reduce the peak erosion risk in the future. To date, the anecdotal evidence of increasing use of these systems, does not appear to have significantly affected the wind erosion risk. However, the length of monitoring time is too short to draw conclusions about the trend.

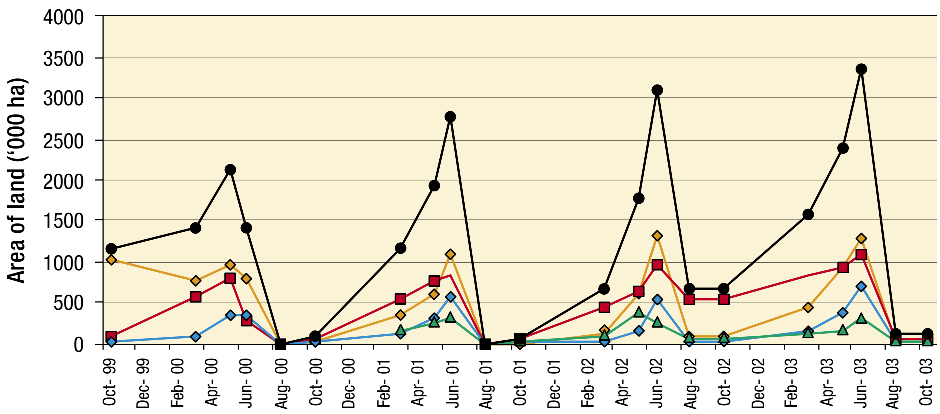
Figure 7: Proportion of cleared land (%) at risk of wind erosion in Regions of South Australia for the period October 1999 – October 2003



	Oct-99	Mar-00	May-00	Jun-00	Aug-00	Oct-00	Mar-01	May-01	Jun-01	Aug-01	Oct-01	Mar-02	May-02	Jun-02	Aug-02	Oct-02	Mar-03	May-03	Jun-03	Aug-03	Oct-03
ep	36.7	26.7	34.6	28	0	0.8	12.5	21.8	38.8	0	0.2	4.2	21	46.8	2.7	2.7	16.2	32.5	45.1	0.3	0.3
ml	4.5	31.9	44.9	21.7	0	3.2	30	42.7	45.6	0	2.7	25	34.7	54.5	28.7	28.7	46.6	51.5	59.8	4	4
nyr	2.3	5.4	18.4	21.7	0	0.6	5.2	14.5	26.4	0	0.3	1.5	7.4	24.8	0.7	0.7	7.1	16.9	30.3	0.3	0.3
se					0	0	12.2	18.2	23	0	0.8	6.3	29	19.5	3.8	3.8	10.2	11.8	23.6	2.5	2.5
South Australia	18.2	22.3	33	23.9	0	1.2	14.3	23.9	34.4	0	0.9	8.4	21.6	38.1	8.1	8.1	19.5	29.1	40.8	1.5	1.5

Month / Year

Figure 8: Area of cleared land ('000 ha) at risk of wind erosion in Regions of South Australia for the period October 1999 – October 2003



	Oct-99	Mar-00	May-00	Jun-00	Aug-00	Oct-00	Mar-01	May-01	Jun-01	Aug-01	Oct-01	Mar-02	May-02	Jun-02	Aug-02	Oct-02	Mar-03	May-03	Jun-03	Aug-03	Oct-03
ep	1037	755	978	791	0	23	353	616	1097	0	6	119	594	1323	76	76	458	919	1275	8	8
ml	81	572	806	272	0	57	538	766	818	0	48	449	623	978	524	524	836	924	1080	72	72
nyr	35	102	347	349	0	11	113	319	577	0	7	33	163	547	15	15	156	380	695	7	7
se							159	237	300	0	10	82	378	254	50	50	133	154	308	33	33
South Australia	1153	1429	2131	1413	0	91	1164	1938	2792	0	71	682	1757	3102	665	665	1583	2377	3357	120	120

Month / Year

Period of Risk

Figure 8 shows the estimated area of susceptible land that is exposed to wind erosion in October, March and May prior to the sowing peak around June.

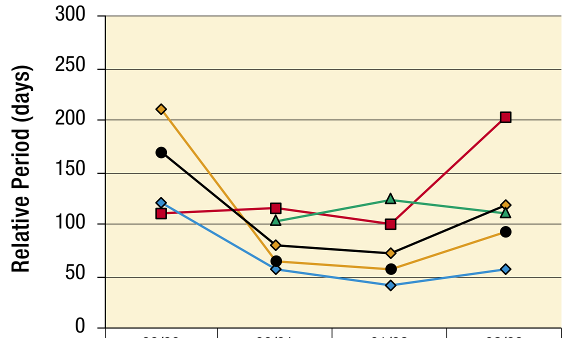
A large proportion of annual soil loss occurs on land cultivated prior to sowing, particularly on the long fallows and land cultivated by late summer. Over the 4 years of monitoring, an average of more than 70% of the cumulative exposure to wind erosion risk (area at risk x length of exposure) occurred in the period prior to the May surveys. This implies that almost 70% of soil loss due to wind erosion is currently likely to occur because of cultivation and grazing carried out before May. Based on this data, the level of soil loss from wind erosion could be reduced to little more than 30% of current levels if no soil disturbance occurred prior to May, even where conventional tillage practices are subsequently used. It could be further reduced to less than 15% of current levels if no cultivation was carried out before sowing.

Risk Index

Figure 9 shows the main standardised annual indicator, the ***Wind Erosion Risk Index (Wind ERI)***. This Index is an estimate of the annual average cumulative period of wind erosion risk for the area of cropped land that is susceptible to erosion in zones/regions/state. As with water erosion, this indicator highlights the current risk of wind erosion to susceptible land in the cropping districts of South Australia.

The average Wind ERI for South Australia ranged from 72 to 171 days. In the Northern and Yorke Region, where the lowest proportion of susceptible land occurs, the Wind ERI varied from 42 to 121 days during the 4 years of monitoring. The Index varied from 58 to 212 days on Eyre Peninsula, 100 to 203 days in Murraylands and 103 to 124 days in the South East where the highest proportion of susceptible land occurs. As for water erosion, the nominal value for the index under direct drill with full cultivation at sowing is around 15 days. The data emphasise there is a very large scope for reduction in wind erosion risk in all areas of the State by starting cultivation later.

Figure 9: The annual Wind Erosion Risk Index (cf. susceptible crop area) in Regions of South Australia for the period October 1999 – July 2003



	99/00	00/01	01/02	02/03
ep	211.1	65.5	58.1	93.2
ml	109.7	115.6	100.1	203.3
nyr	121.4	56.1	42.3	58.3
se		103.3	123.8	109.8
South Australia	170.9	80.0	72.2	117.8

Year

Table 4 Average Wind Erosion Risk Index (days) relative to susceptible cropped land area in key zones of South Australia between October 1999 and July 2003

Region	Key Zone	Range (Ave)
EP	1	64–445 (172)
	6	51–207 (103)
	8	47–226 (100)
ML	26	115–256 (163)
	31	85–333 (150)
	32	81–164 (115)
NYR	15	38–85 (66)
	20	36–81 (60)
SE	35	95–196 (125)
	36	121–122 (122)
	44	46–92 (71)

In key, high risk zones, the Wind ERI ranged from 36 to 445 days (Table 4) and for most other zones risk was within this range as well.

Examples of considerable regional variation have occurred during the 4 years of monitoring. The very high numbers are caused by severe drought leading to land exposure for abnormally extended periods due to crop and pasture failure in western Eyre Peninsula in 1999 and across the State in 2002. In both situations widespread bare soil remained through the following summer and until after the winter of 2000 and 2003, respectively. While the Index is derived using the area of cropped land, in some seasons large areas of grazing land can be exposed and contribute to its value.

The strategies for significantly reducing the area of land exposed to wind erosion risk parallel those of water erosion. The widespread adoption of tillage systems such as Direct Drill and No-till, that reduce the erosion risk before and after sowing in cropping districts, is paramount. Grazing management that maintains surface cover is also important where livestock are part of the farming system. Maintenance of surface cover is arguably more critical for management of wind erosion risk than water erosion, since sandy soils are usually highly erodible once cover is removed, even with only limited disturbance.

Land Management Indicators for Erosion Risk

Private landholders manage approximately 80% of South Australia's land resources and there are a number of land management practices that are accepted as either increasing or minimising the risk of degradation. A survey of farmers (PIRSA 2000 and 2002) was undertaken twice in the last 4 years to begin to monitor the knowledge, attitudes and key management practices used. The surveys were carried out in Eyre Peninsula (EP), South East (SE), Murraylands (ML), Northern and Yotke (NYR) and the combined Mt Lofty Ranges and Kangaroo Island (MLR/KI) Regions of the State. They also covered high (>600 mm), medium (325 – 600 mm) and low (<325 mm) rainfall zones). The data collected to date provide useful baseline measures, but a much longer monitoring period is required to determine reliable trends. The following data relate to wind and water erosion management.

Recognition of erosion as an issue

Both wind and water erosion were particularly severe in many parts of the State during the first half of the 20th century. The incidence and severity of erosion has declined markedly as improved practices have been developed and adopted.

The survey data show that an average of 22% of land managers recognised water erosion as a serious land management issue (Figure 10)across the State. 30-37% of land managers in the Mt Lofty Ranges, Kangaroo Island and Northern and Yorke Region, where most susceptible land occurs, considered water erosion an important issue compared with 4-22% of those in other regions. These are relatively low recognition levels, particularly in the higher risk districts. This might in part result from the very long periods (commonly 20 years and more) between individual experience of severe water erosion events.

On a statewide basis, 40% of current land managers recognise that wind erosion remains a serious issue in their districts today (Figure 11).

Figure 10: Average proportion (%) of land managers considering water erosion a land management issue in their district in South Australia; LM survey 2000/2002

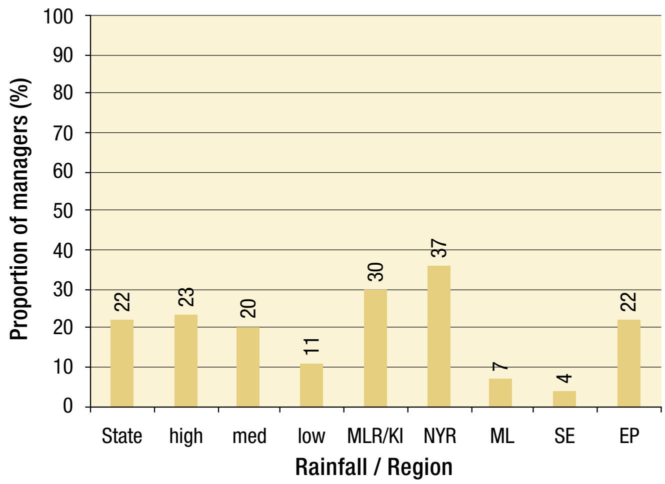
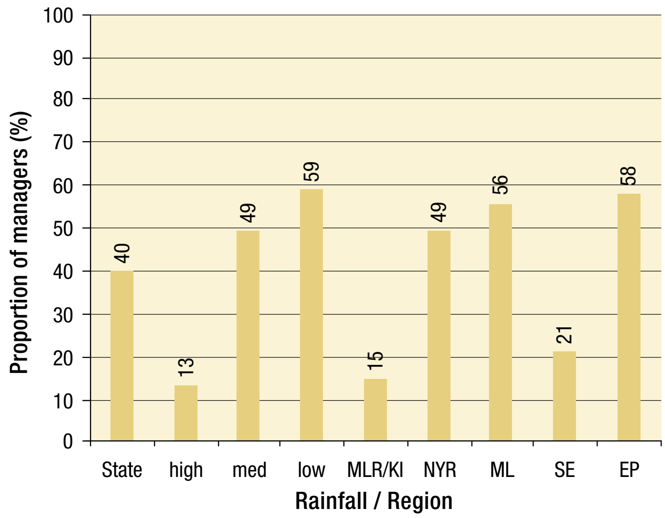


Figure 11: Average proportion (%) of land managers considering wind erosion a land management issue in their district in South Australia; LM survey 2000/2002



Recognition ranges from an average of 56% in Murraylands and Eyre Peninsula to between 15 and 21% of land managers in the higher rainfall Mt Lofty Ranges and South East, which correlates with the relative wind erosion hazard in those districts. Around 49% of land managers in the Northern and Yorke Agricultural Districts, where much of the land is of lower susceptibility (Class 2), considered wind erosion to be important.

Long fallow

Long fallow is the practice where cultivation of land is commenced in the spring or early summer (before January) prior to sowing crop. On land with medium or high inherent susceptibility to wind or water erosion, this practice puts the land at greatest risk of soil erosion. The soil is in a loose state for a large proportion of the year so that any strong wind or water runoff event will inevitably result in soil loss.

Long fallow at Freeling, South Australia
(Photo A. McCord, DWLBC)

The fact that an average 25% of farmers in low rainfall areas still usually use long fallows for preparing some of their crop land and a further 27% use it occasionally, is cause for concern (Figure 12). Most of the benefits of long fallow can be achieved by other means that should also be more profitable. These alternatives generally require a higher level of knowledge, skill and investment, but from a soil conservation point of view alone, cultivated long fallows should be eliminated from farm rotations.

Timing of first tillage operation

For most soils the risk of soil loss rises by at least an order of magnitude once the first tillage operation is carried out. This is especially the case for water erosion prone soils. Typically, these soils in South Australia have a sandy loam texture, which generally has enough clay to bind particles together and resist detachment while undisturbed. However, once their fragile structure is disturbed by tillage, fine particles of soil are easily dislodged by raindrop splash and surface water flows. On sandy soils subject to wind erosion, there is the additional management dilemma of excessive animal traffic loosening the surface soil, exposing it to easy detachment, even in moderate winds.

The longer a soil is in a loosened state, the greater the risk of soil loss. The timing of the first tillage operation is therefore critical. There are no reliable technologies currently available to sow and produce productive grain crops without some form of tillage disturbance. From a soil conservation viewpoint, the later the first cultivation occurs the safer is the tillage system. The preferred timing of first disturbance is at sowing. Even then, loose soil is still at risk until the new crop is sufficiently advanced to stabilise and protect the surface, usually 4 to 6 weeks following sowing.

For many farmers the actual timing of the first cultivation is dictated by the occurrence and quantity of rainfall in the months prior to sowing. The survey indicates that a relatively large proportion of farmers (16%) in low rainfall areas preferred to get their first working in before the end of the previous year and up to 61% would prefer to have started by March (Figure 13). Such extensive early cultivation poses a huge erosion risk in wind erosion prone districts during the normally dry summer and autumn period.

The same applies in water erosion prone areas where land can be damaged by isolated storms at any time of the year.

Figure 12: Average proportion (%) of land managers using cultivated long fallows for crop land preparation; LM survey 2000/2002

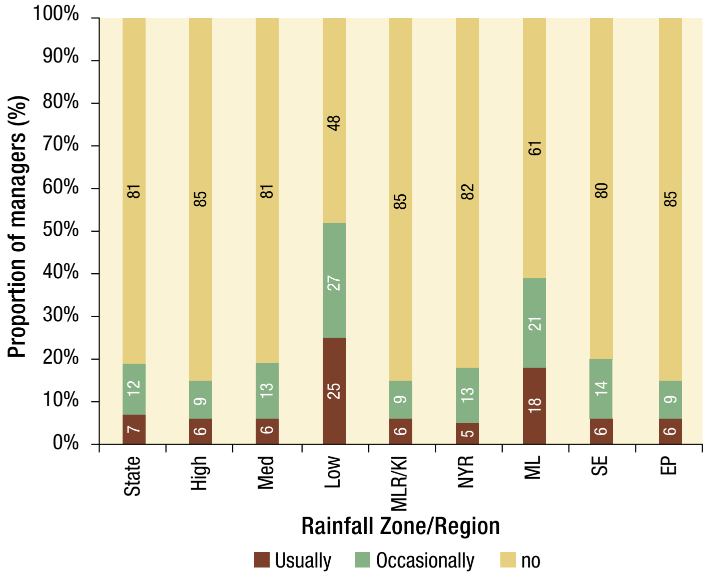
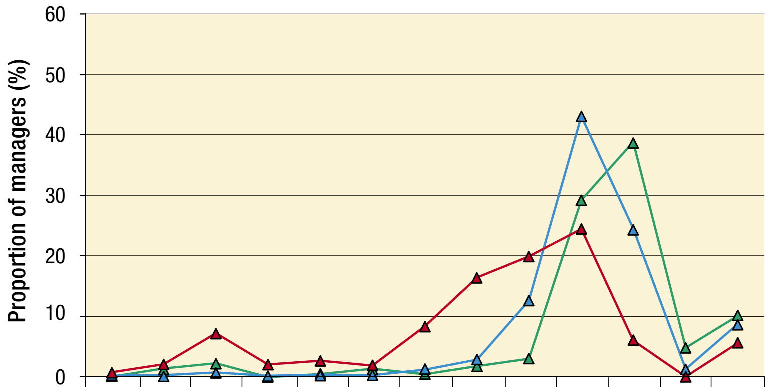


Figure 13: Average preferred month for initial cultivation in preparation for a crop in rainfall zones of South Australia; LM survey 2000/2002



	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Sow
High	0.0	1.3	2.2	0.0	0.4	1.3	0.4	1.7	3.1	29.2	38.8	4.8	10.1
Med	0.3	0.2	0.7	0.1	0.2	0.2	1.2	2.8	12.6	43.1	24.4	1.3	8.7
Low	0.7	2.0	7.2	2.0	2.6	1.8	8.3	16.4	19.9	24.5	6.1	0.0	5.7

Month

Cultivated land remains susceptible to erosion until safely covered in winter by growing crop. However, in a drought the risk can continue if the crop either cannot be sown or does not successfully establish due to lack of rain.

In high rainfall districts a much smaller proportion (10%) of land managers prefer to undertake their first tillage operation by March. However, since there are around 39% who usually like to start their cultivation by the end of April, this still represents a significantly greater risk than the ideal of first tillage at sowing.

Direct drill sowing

Direct drill sowing systems are those in which the one and only tillage operation is undertaken at sowing. By definition, direct drilling minimises the period of exposure of loose soil and thereby significantly reduces erosion risk. The direct drilling operation might entail a full cultivation (full soil loosening to sowing depth), which still leaves the soil vulnerable until the new crop is sufficiently advanced to stabilise and protect it. Direct drilling usually leaves more protective cover on the soil surface than after multiple cultivations. Overall soil erosion losses would be reduced several-fold if all cropping was undertaken using direct drill systems. In the 2000 and 2002 surveys, an average of 53% of farmers who sowed crop indicated they use direct drilling (including No-till) for sowing at least a proportion of their crop (Figure 14). In low rainfall areas 34% of land managers used the technology compared with around 55% in the medium and high rainfall districts in 2002. This correlates fairly closely with the difference in preference for timing of first cultivation.

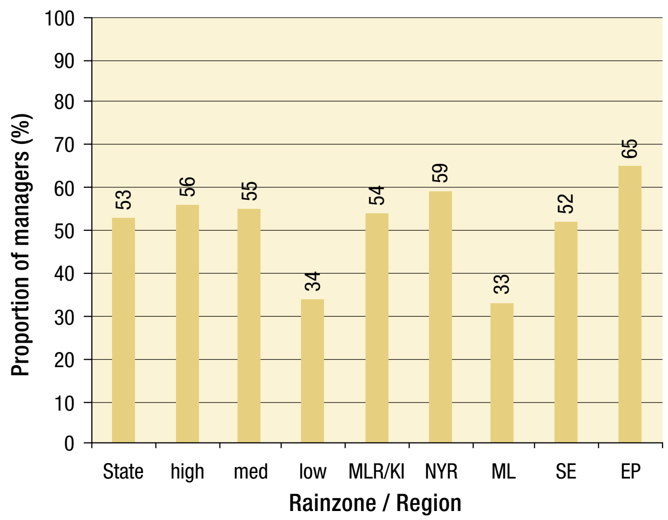
Direct drilling in the Northern and Yorke Region, South Australia (Photo A. McCord, DWLBC)

Averaged over the two surveys, 31% of total crop area was sown using direct drill. The area ranged from 60% of crop in the higher rainfall districts to 18% in the low rainfall districts. A little over 33% of land managers sowing crop in Murraylands region, where wind erosion was widespread in the drought of 2002, indicated they used direct drilling to sow around 16% of their total crop area. On Eyre Peninsula 65% of land managers reported that they sowed around 31% of their total crop area using direct drill.

Field experience suggests these might be over-estimates, which future surveys should clarify.

Only 35% of the farmers in the surveys expected to increase the use of direct drilling on their land in the foreseeable future and this data indicates that adoption of this technology by land managers is lower than desirable. An increase in the amount of crop sown by direct drill practices would significantly reduce soil erosion.

Figure 14: On cropped properties – Average proportion (%) of land managers who use direct drilling for sowing crop in South Australia; LM survey 2000/2002

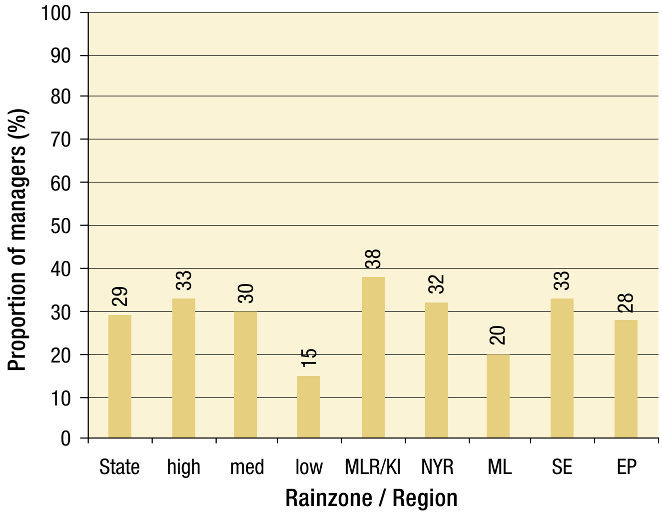


No-till sowing.

No-till and zero-till systems are advanced direct drill techniques that reduce the degree of loosening of the surface soil. Seed and fertiliser are placed in a narrow slot in the soil in a single pass with a specially designed tyne or disc implement. This technology is also usually associated with high levels of stubble retention that further reduces the risk of soil erosion.

Around 29% of farmers who sowed crop in South Australia reported that they have used no-till practices to some extent on their properties, with use varying from up to 33% of land managers in high and medium rainfall districts to only 15% of those in low rainfall areas (Figure 15). They indicated that they sowed around 20% of their crop area using no-till. Based on the field cover monitoring surveys these estimates seem high. However, increasing these practices will significantly reduce the risk of wind and water erosion.

Figure 15: On cropped properties – Average proportion (%) of land managers who use no-till for sowing crop in South Australia; LM survey 2000/2002



Wheat sown with No-till farming near Booleroo, South Australia (Photo A. McCord, DWLBC)

Stubble retention

Maintenance of surface cover is a critical factor in the management of soil erosion, particularly if the soil surface is also loosened by cultivation or heavy animal traffic. Residues were traditionally removed by burning or heavy grazing prior to initial cultivation of crop land, because implements were not designed to pass through them. The more cultivation is used, the more stubble or other plant residue is buried or broken down into smaller pieces that are less protective of the soil surface

In the land manager surveys, an average of 87% of land managers who sow crop in South Australia reported that retaining all stubble and pasture residue was important on their farms (Figure 16). The average proportion of land managers was 91% in the medium rainfall areas, 73% in the higher rainfall areas and 89% in low rainfall areas. Although current adoption is not at a correspondingly high rate, this is clear evidence that most land managers do recognise the need for residue retention.

Figure 16: On cropped properties – Average proportion (%) of land managers considering stubble retention important for sowing crop in South Australia; LM survey 2000/2002

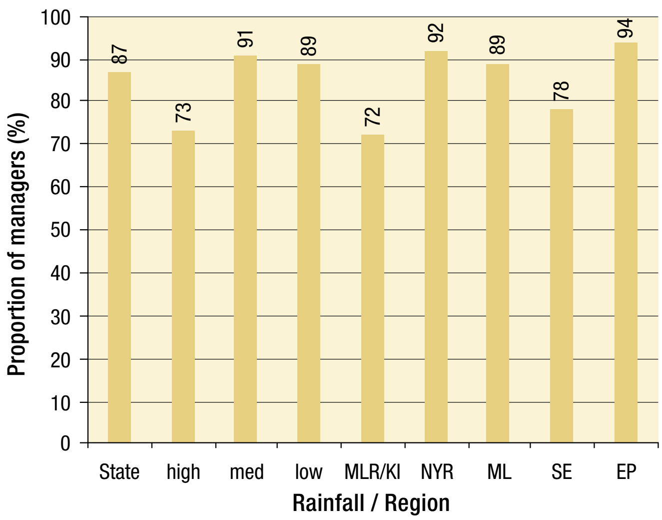
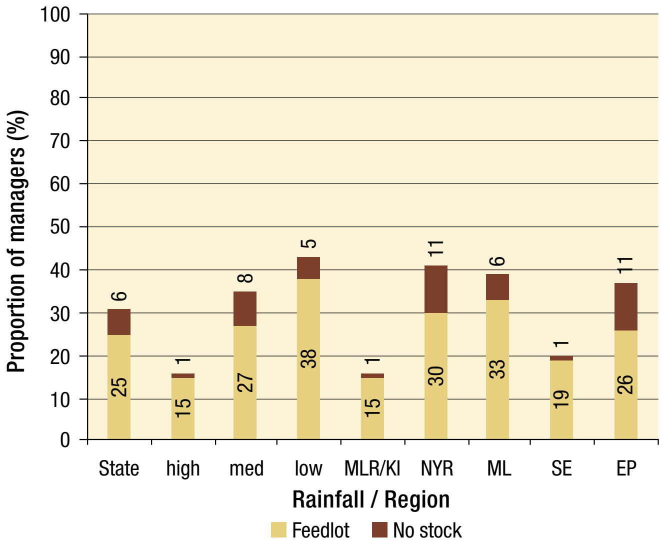


Figure 17: Average proportion (%) of land managers who feedlot stock in autumn to manage paddock residues in South Australia; LM survey 2000/2002



Feedlotting stock

A feedlot is an important option for managing paddock surface cover, particularly in late summer and autumn when feed availability and ground cover in the paddock is declining. The practice allows the removal of stock from paddocks before surface cover declines below critical protective levels. It is most valuable in the management of wind erosion on sandy soils since heavy grazing by stock can loosen the surface of these soils making them more susceptible to erosion.

In the land manager surveys only 25% of all farmers used feedlots as a means of managing erosion risk and another 6% had no livestock on their property (Figure 17). The lowest use (15%) was in the higher rainfall areas, where autumn feed shortage is usually not as critical an issue, whereas up to 38% of land managers in low rainfall areas used the practice. Some of the variation in usage may in part reflect the fact that some intensive cropping farmers no longer run livestock.

The long-term objective is to have a greater proportion of farmers, with livestock, using feedlots to conserve protective paddock residues, particularly in the wind erosion prone districts.

EROSION EVENTS RECORDED IN THE 1999 TO 2003 PERIOD

Field survey methodology has been used successfully to assess the extent of wind erosion in the Victorian Mallee (Anderson et al.,1992). The South Australian land condition monitoring methodology was not specifically designed to measure the incidence and distribution of actual erosion events. That would require a very much larger number and frequency of observations, or targeted surveys following specific erosion events. However, visual evidence of erosion is recorded during the field surveys.

Water Erosion

During the 4-year monitoring period from 1999 to 2003 only isolated observations of water erosion were recorded. The most notable were across lower Eyre Peninsula in March 2000, localised occurrences in the Booleroo/Melrose area in the Northern and Yorke Region in April/May 2000, and in the Cummins and Koppio Hills areas on Lower Eyre Peninsula in March 2001.

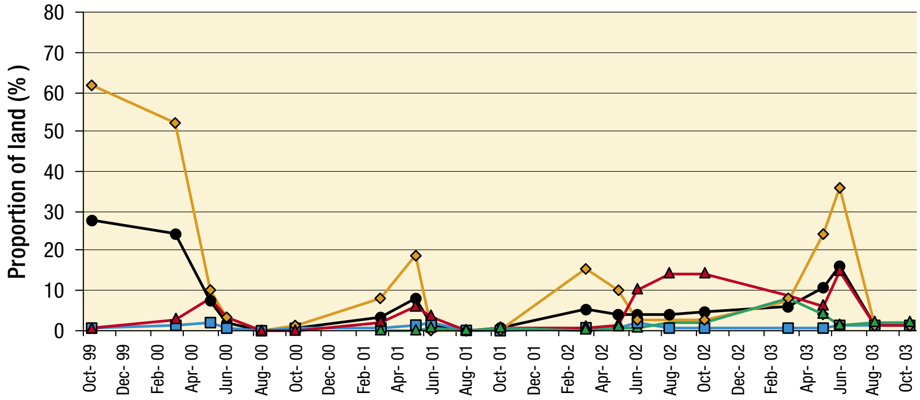
Wind Erosion

Wind erosion has been much more extensively reported during the monitoring period. Western Eyre Peninsula suffered a drought in 1999 that resulted in widespread wind erosion through winter, spring and into summer of 2000. During field surveys, active erosion was observed on over 60% of sites on Eyre Peninsula in October 1999, although most was only small areas of surface sweep, rather than mass movement. The erosion was still evident on more than 50% of the sites in March but declined rapidly from then to sowing. Significant incidence of wind erosion (up to 19% of sites) has been recorded in the region in subsequent autumn surveys, and on around 36% of sites at sowing in 2003 following the drought conditions of 2002.

In Murraylands region, strong winds from June to October 2002 caused erosion on almost 10% of all survey sites at sowing. By October 2002 as crops failed to establish or paddocks were left unsown this increased to 14% of all sites, and up to 33% of the worst affected land zone 26 (see Figure 3) in the Northern Mallee. With widespread failure of crops and poor pasture growth, wind erosion damage continued through the summer of 2003. In the Northern and Yorke Region less than 2% of sites overall suffered damage but in the dune-swale zone 20, in the Avon-Balaklava area, up to 27% of sites recorded some active wind erosion. Damage in autumn and winter was rare in the South East, although wind erosion was recorded on 2% of sites in October 2002.

Following the 2002 drought, autumn and winter of 2003 were very windy, causing further damage. Across South Australia, wind erosion was recorded on around 4% of sites in March, including 7% of Eyre Peninsula and 9% of Murraylands sites. This rose to 16% of sites state-wide at sowing, with 35% of Eyre Peninsula and 15% of Murraylands sites. Even in the reliable South East region, failed crops or heavily grazed pastures can result in damage in the occasional adverse season, and wind erosion was recorded on 8% of sites there in March 2003.

Figure 18: Proportion of cleared land (%) where wind erosion occurred in Regions of South Australia for the period October 1999 – October 2003



	Oct-99	Mar-00	May-00	Jun-00	Aug-00	Oct-00	Mar-01	May-01	Jun-01	Aug-01	Oct-01	Mar-02	May-02	Jun-02	Aug-02	Oct-02	Mar-03	May-03	Jun-03	Aug-03	Oct-03
South Australia	27.4	24.2	7.3	2.2	0.0	0.6	3.3	8.1	1.2	0.0	0.2	5.5	3.8	3.6	4.1	4.3	5.7	10.4	16.1	1.2	1.2
ep	61.5	52.4	10.3	3.2	0.0	1.2	8.0	18.8	0.1	0.0	0.0	15.3	9.7	2.7	2.4	2.4	7.0	24.3	35.6	0.9	0.9
nyr	0.1	0.9	1.5	0.2	0.0	0.2	0.4	0.9	1.5	0.0	0.1	0.3	0.4	1.8	0.3	0.3	0.3	0.2	1.0	1.0	1.0
ml	0.3	2.7	8.3	3.5	0.0	0.1	1.9	6.2	2.9	0.0	0.5	0.4	1.3	9.7	14.2	14.2	8.9	5.7	14.9	1.4	1.4
se							0.0	0.0	0.5	0.0	0.3	0.0	0.3	0.3	1.7	1.7	7.8	4.0	1.1	1.6	1.6

Month

EROSION SUMMARY

Most of the information presented above is based on only 4 years of data. More years of consistent monitoring are required to confidently identify and quantify any trends in erosion risk or its management. However, even this baseline information demonstrates that there are very large areas of agricultural land in South Australia that are exposed to wind and water erosion risk each year. When severe wind and rainfall events occur, there will continue to be unacceptably high levels of soil loss. The immediate result will be some production loss, but more significantly, a long-term loss of productive capacity. There are farming systems available that would significantly reduce wind and water erosion if more widely adopted.

Soil Acidity

BACKGROUND

Many soils are naturally acidic, particularly those of higher rainfall areas where soil formation processes over long periods of time have removed clay minerals, reduced cation exchange capacity and depleted base cation levels (eg. calcium, magnesium and potassium).

When a soil reaction drops below about pH_{CaCl}5, a number of degradation effects are likely to occur:

> Many plants and soil organisms are intolerant of low pH and productivity is likely to decline. For example, nitrogen fixing Rhizobium bacteria associated with legumes do not thrive in very acid soils.

> Plant growth can be reduced as a result of increased levels of toxic aluminium or manganese in the soil solution. Solubility of aluminium and manganese increases as the soil becomes more acidic.

> Highly acidic soils are likely to have nutrient deficiencies and/or imbalances that adversely affect plant growth (eg. molybdenum, calcium, magnesium and potassium).

> Clay minerals can be decomposed in strongly acid conditions, resulting in permanent loss of soil fertility.

> Poor plant growth can result in greater accessions to water tables, and resultant salinity.

> Increased nutrient loads in groundwater and streams due to leaching from soil.

While soil acidification does occur naturally, it can be significantly accelerated by agricultural practices. Some of the main causes of accelerated acidification of agricultural soils are:

> Use of acidifying forms of nitrogen fertilisers. Fertilisers which contain nitrogen in the reduced form (eg. urea or ammonium based) will cause net acidification of the soil

> Removal of agricultural products. All plant and animal products contain some base cations removed from the soil. When products are exported from a paddock there is a net loss of base cations and a net acidification of soil. The higher the production, the higher the rate of acidification. Hay production has a particularly high acidifying impact.

> Nitrogen fixation by legumes has a net acidifying affect on soils.

> Leaching of nitrate. This results in a net acidification of soils, and possible degradation of water resources. Most excess nitrate leached from soils comes from decomposition of animal wastes, plant residues and soil organic matter, although excess nitrogen fertiliser is sometimes the cause, particularly on horticultural crops.

Figure 19 shows the areas of agricultural land in South Australia with significant risk of acidifying (Soil Land Information, 2002b). This is predominantly land with soils that are already neutral or acidic, have low clay content, low buffering capacity, no free lime and relatively higher rainfall and production levels. A total of around 1.9 million ha of cleared land is moderately to highly susceptible. By regions, the area ranges from 90,000 ha of susceptible soils in Murraylands to 684,000 ha in the South East (Table 5).

Most of these soils are already acidic, some to the extent that they are suffering significant production losses.

If topsoil acidity is not treated, subsoils might progressively acidify. Significant production losses are likely when subsoils become acidic and their amelioration is difficult and expensive. Approximately 640,000 ha of cleared agricultural land in South Australia, mostly deep sandy soils, are at immediate risk of subsoil acidification.

Accelerated soil acidification is an inevitable consequence of most agricultural systems. The rate at which soils acidify can be moderated to some extent by management practices. However, in most cases it would involve significantly reducing production levels and changing enterprises, for example, from intensive cropping to extensive grazing.

Estimated rates of acidification for a range of broad-hectare agricultural land uses are shown in Table 6. The rates are given as the equivalent amount of calcium carbonate (agricultural lime) needed to neutralise annual acidification. This is a useful way of presenting acidification rates because the application of liming materials is the only practical way of increasing the pH of acidic soils and balancing the acidification cause by agricultural production systems.

Table 5: Summary of acidification risk in cleared areas of regions in South Australia

	Susceptible Area ('000 ha)
Eyre Peninsula	191
Northern and Yorke	343
Murraylands	90
Mount Lofty Ranges	406
Kangaroo Island	185
South East	684
Total	**1,900**

Table 6: Summary of annual acidification rates in broad farming systems

Cropping/Pasture system	Range and Average ( ) Annual Acidification rate (kgs lime/ha/year)
Continuous grain cropping	180–320 (232)
Crop – pasture rotations	40–230 (99)
Low production grazing	20–60 (35)
High production grazing	60–145 (112)

Source: *Southern Farming Systems*, from Merry, R. unpublished data
Sites originally sampled 1967 to 1973 and re-sampled 1993

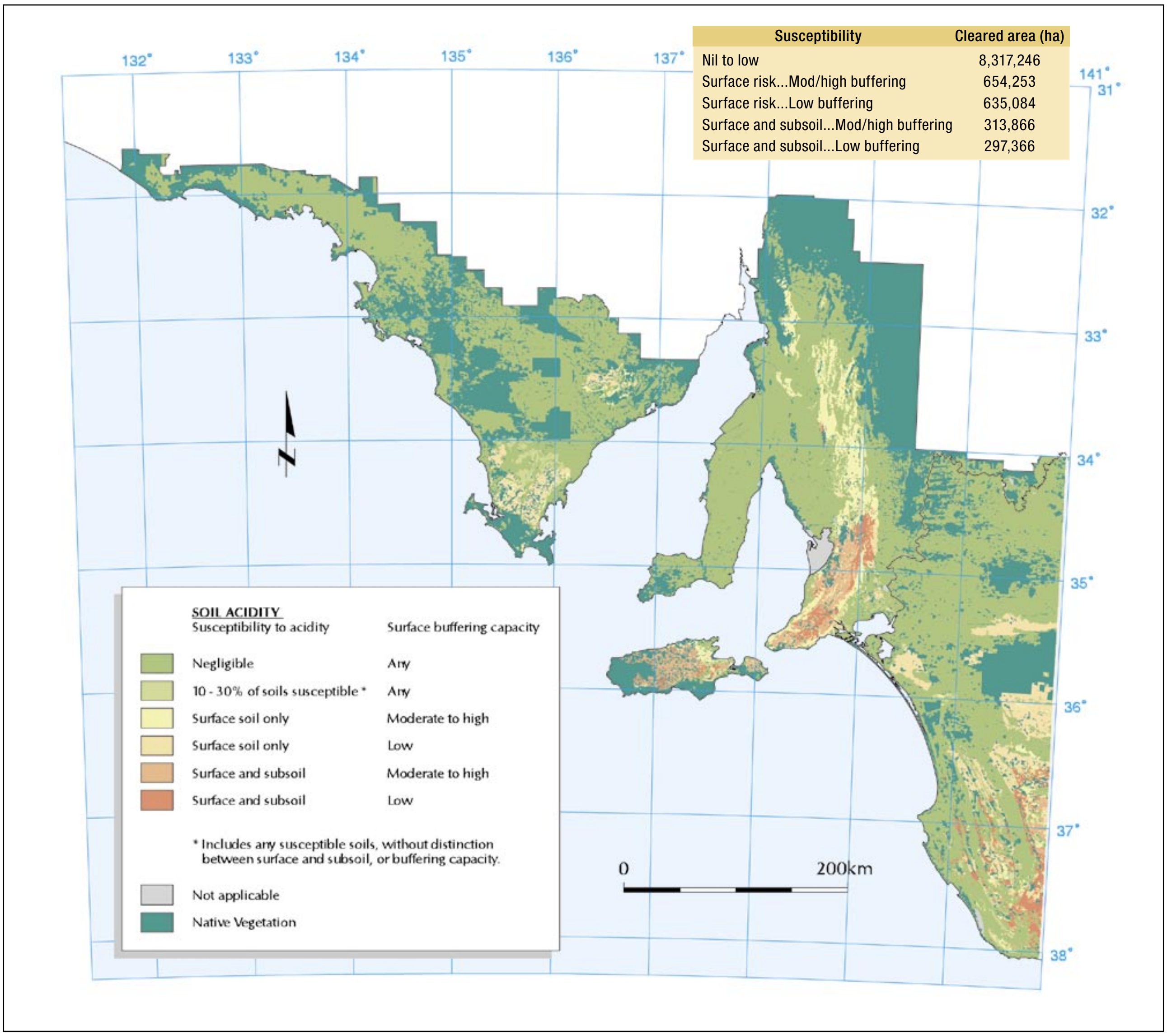


Figure 19: Distribution of cleared land with soils susceptible to induced acidification in South Australia

Liming materials are alkaline compounds that both neutralise the acid reaction in the soil and provide base cations to replace the hydrogen ions produced by the acidification process.

The most common liming materials are calcium and magnesium carbonates derived from limestone. There are a number of other materials used in South Australia for neutralising soil acidification, including lime sands, lime lake sediments, alkaline clays and industrial by-products. Alkaline irrigation water and alkaline forms of nitrogen fertiliser are also used in horticulture.

When estimating the lime requirement of a soil, there are two main components to be considered:

1. the amount of lime required to raise the pH of very acid soils to a level at which production is no longer reduced by acidity, usually taken as about $pH_{CaCl} = 5$
2. the amount of lime required to neutralise the annual rates of acidification, and so maintain a stable soil pH

MONITORING CHANGES IN SOIL ACIDITY

Soil Sampling

A very large and expensive sampling and soil testing program would be required to directly monitor changes in soil pH in a systematic way.

However, some soil testing data is available from commercial soil testing services. Figure 20 shows the proportion of soil samples with pH_{CaCl} of 5 or less, tested by the South Australian Soil and Plant Analysis Service (SASPAS) in Hundreds of South Australia between 1990 and 1999.

A significant proportion of the topsoil samples sent for analysis by farmers from Lower Eyre Peninsula through to the South East were acidic. The highest proportion of acidic samples (commonly >50%) came from the Mount Lofty Ranges and Kangaroo Island followed by the Lower South East and Lower Eyre peninsula (commonly 21% to >50%). This information can be taken as a semi-quantitative indicator only, as there is no control over selection or sampling of soils. They are simply the accumulated data from soil samples submitted by farmers and any sampling errors or biases are unknown. However, they confirm that topsoil acidification is most likely in the higher rainfall districts of the Mt Lofty Ranges and Kangaroo Island, the South East, parts of the Northern and Yorke Region and Lower Eyre Peninsula.

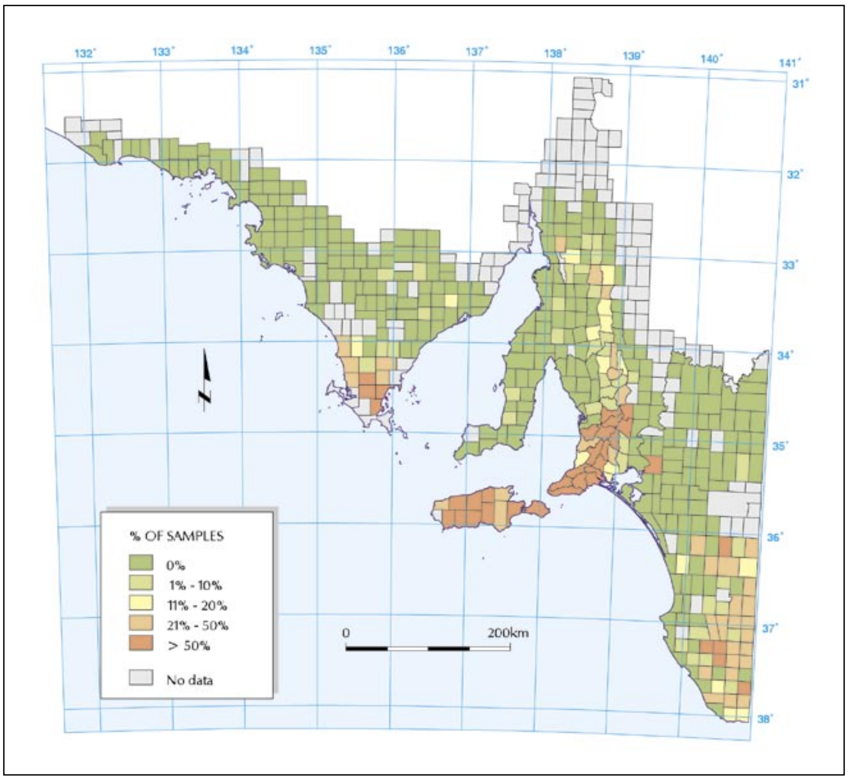


Figure 20: The proporation of low pH (pH_{CaCl}≤5) soil samples analysed by the SASPAS in Hundreds of South Australia for the period (1990 – 1999)

Table 7: Estimates of lime required to raise low topsoil reaction of all cleared land to pH_{CaCl}=5 in regions of South Australia

Region	Area of land with topsoil pH_{CaCl}<5.0 (‘000 ha)	CaCO3 required to raise topsoil pH_{CaCl} =5 (‘000 tonnes)
Eyre Peninsula	125	168
Northern and Yorke	72	77
Mount Lofty Ranges	286	415
Kangaroo Island	120	144
Murraylands	16	24
South East	260	410
TOTAL	**879**	**1,238**

Lime Use

Estimating lime required to manage acid soils

Monitoring agricultural lime use provides an indication of the extent to which farmers have recognised the need to ameliorate soil acidification and a means of estimating the average rate at which acidification is being neutralised. The pH distributions derived from the SASPAS soil testing service acidity data in Figure 20 are used to estimate the area of land with low topsoil pH from the area of cleared land in each region. Table 7 shows estimates of the amount of lime required to raise the pH of very acid topsoils to pH_{CaCl}5.0 in regions of South Australia.

An estimated 879,000 ha of land in the State has a very low topsoil pH_{CaCl}. It would require around 1.2 million tonnes of lime just to raise the reaction of these soils to pH 5. Most of the need for lime on these very acid soils is in the South East (410,000 tonnes) and Mount Lofty Ranges (415,000 tonnes). This estimate does not include any lime required to lift pH of very acid subsoils, which would be a much greater amount again.

The second component of lime requirement is that required to neutralise annual acidification.

Table 8 summarises the estimated acidification rates by region. The acidification rates were calculated by firstly estimating the area of each farming system within each region (see Table 5), multiplying this by the estimated annual acidification rate (see Table 6) and summing the values for each region. An estimated 200,000 tonnes of lime are required in South Australia just to balance the annual acidification rate of agricultural soils.

Table 8: Estimate of lime required to neutralise acidification of cleared land in regions of South Australia

Region	Area of land with acid soils ('000 ha)	CaCO3 required to balance annual acidification rate ('000 tonnes)
Eyre Peninsula	191	32
Northern and Yorke	343	60
Mount Lofty Ranges	406	32
Kangaroo Island	185	15
Murraylands	90	8
South East	684	53
TOTAL	**1,900**	**200**

Table 9 is a summary of lime requirements by region and the actual amounts of lime applied in the 3 years 1998/99 to 2000/2001. The estimates of lime used are derived from direct survey of commercial lime suppliers.

The estimates in Tables 6 and 7 also assume that the lime use is strategically distributed to exactly manage acidic and acidifying soils.

While the South East and Mount Lofty Ranges appear to be applying enough lime to balance the ongoing acidification rate, it is certainly not the case that all acidifying land is being managed at a stable pH. It is likely that a proportion of landholders are liming diligently and raising the pH of their acidic soils above pH 5. Furthermore, over recent years, large amounts of lime have been used in horticulture on relatively small areas of land, particularly during vineyard establishment.

While the lime use data probably mean that acidification on some of the land in the South East and Mount Lofty Ranges regions is being well managed, there still remain large areas where the pH is declining. In practical terms, an increase in lime use on susceptible soils to about 350,000 tonnes per annum would be required to be confident that South Australian agricultural soils have a net positive trend with respect to acidification.

Approximately 50,000 ha of acidic soils have been spread with neutral to alkaline clays to reduce water repellence in the last 20 years (Hughes and Francis 2002). A secondary benefit has been a reduction in the acidity of these soils. Around 7,000 ha of acidic soils in the South East are irrigated with alkaline water. Also, more expensive alkaline forms of nitrogen fertiliser are being used to some extent in horticulture.

The overall effect of these practices is relatively small because of the proportionately small area on which they are applied.

While annual lime use has more than doubled over the last 10 years, it is still far below the amount needed to sustainably manage acidification in South Australia. The current level is only 85% of the annual acidification rate and is less than 15% of that needed to raise the pH of the very acidic soils to 5. While improvements have been made, there are still large areas of very acidic land with poor productivity and water use efficiency, and the area and degree of acidification are still increasing.

Land Management Indicators for Acidification Risk

In March 1999 and 2002 baseline and follow up surveys were undertaken as part of the "Balancing Acidity in South Australia Soils" project (BASAS survey). This survey targeted 400 farmers within the areas of the State with large areas of acid soils. Similar surveys were carried out across the state as part of the "Land Condition Monitoring" project (LCM survey) in March 2000 (618 farmers) and 2002 (1003 farmers).

Table 9: Summary of lime requirement and actual lime application estimates of all cleared land in regions of South Australia

Region	Lime to raise topsoil pH_{CaCl} 5.0 ('000 tonne)	Lime for annual balance ('000 tonne)	Lime used 1998/1999 ('000 tonne)	Lime used 1999/2000 ('000 tonne)	Lime used 2000/2001 ('000 tonne)	Lime used 2001/2002 ('000 tonne)
Eyre Peninsula	168	32	5	10	13	18
Northern and Yorke	77	60	30	28	34	34
Mount Lofty Ranges	415	32	32	37	39	39
Kangaroo Island	144	25	11	18	9	13
Murraylands	24	8	2	2	2	2
South East	410	53	20	38	54	63
TOTAL	**1,238**	**200**	**100**	**133**	**151**	**169**

Recognition of Acidification as an issue

Data from the surveys indicates there is widespread confusion about the importance of soil acidification in farming areas. In 2000, 65% of farmers in the Mount Lofty Ranges and Kangaroo Island Region, where acidification should be of universal concern, reported that they had acidic soils on their properties. In 2002 only 55% did so. Only 51% of farmers with acidic soils were able to correctly identify the critical pH below which production is likely to decline (pH 4.5-6, irrespective of the analysis method and pH scale). 29% of farmers with acid soils indicated they did not know the critical level.

Lime top dressing in the Barossa Valley
(Photo B. Hughes, PIRSA)

Perceptions of causes and treatment of acidification

Knowledge about the cause and treatment of acidity was also contradictory (see Figure 21). Around 43% of farmers with acid soils erroneously cited superphosphate as a direct cause, while 53% knew that nitrogen fertiliser and product removal were major causes. While 47% of farmers wrongly believed that gypsum could be used to treat acidification, 78% correctly indicated that lime application was important before any sign of a production decline occurred.

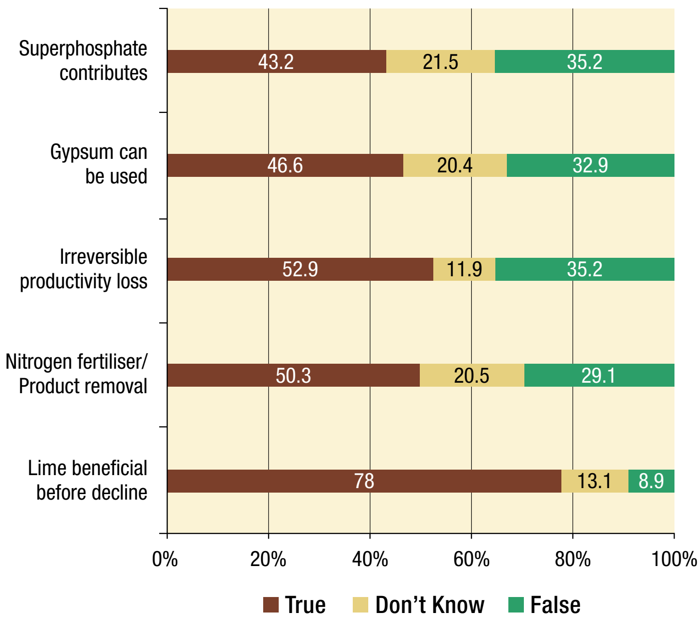
Around 45% of farmers with acid soils indicated they had spread lime or dolomite in the last 3 years. Rates used were generally adequate (1.5-2.5 t/ha) and most farmers expected to re-lime within 10 years.

The BASAS surveys also highlighted a number of other issues:

1). A significant barrier to liming is perceived to be cost. This was perceived to be particularly important on Kangaroo Island, despite having one of the cheapest lime supplies in the country.

2). On Eyre Peninsula there was concern that liming could induce trace element imbalances and deficiencies. There is a real basis for this concern and nutrition must be managed in concert with liming.

Figure 21 Perceptions of acidification causes and amelioration practices held by farmers with acidic soils in South Australia; LM survey 2002



SOIL ACIDIFICATION SUMMARY

Soil acidity is relatively widespread in South Australian agricultural land, although at a smaller scale than in most other States of Australia, because there is less susceptible land. Accelerated acidification due to agriculture has already caused productivity decline. To date, most of this has been under improved legume pastures in higher rainfall areas.

However, it is now emerging as a more widespread issue because rates of acidification have increased significantly with rises in productivity and intensity of cropping.

In susceptible areas, there are still many landholders who do not have sufficient awareness of this degradation issue, nor its management.

While agricultural lime use to ameliorate soil acidification has increased substantially during the late 1990's, the rate of application is still only 85% of the 200,000 tonnes required to simply balance soil acidification rates and maintain the current soil pH status. An additional 1.2 million tonnes of strategically placed lime is also required to increase the pH of the very acidic soils in order to improve their productive capacity and plant water use.

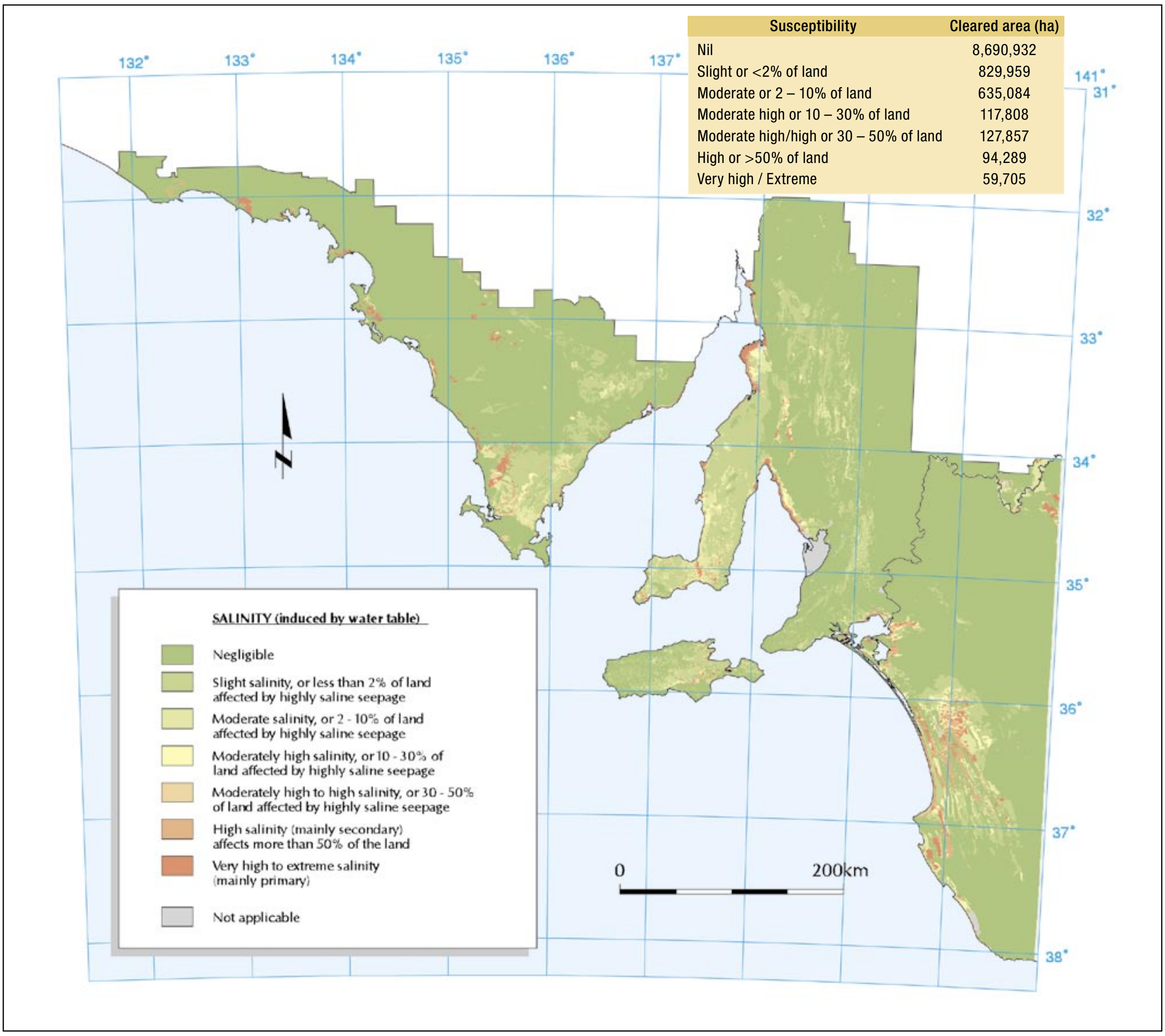
Soil Salinity

Saline inter-dunal flat at Tintinara, South Australia (Photo A. McCord, DWLBC)

BACKGROUND

Salt is a natural feature of the Australian landscape. In South Australia it is most obvious as salt land and salt lakes that existed long before European settlement. These natural expressions of salinity are termed primary salinity.

A large proportion of South Australian soils also contain relatively high levels of soluble salts within or just below the root-zone. Most of the excess salt in soil profiles is either inherited from parent materials of marine origin, or due to accumulation of air-borne salt in a semi-arid climate where rainfall has been insufficient to leach it.



Susceptibility	Cleared area (ha)
Nil	8,690,932
Slight or <2% of land	829,959
Moderate or 2 – 10% of land	635,084
Moderate high or 10 – 30% of land	117,808
Moderate high/high or 30 – 50% of land	127,857
High or >50% of land	94,289
Very high / Extreme	59,705

Figure 22. Distribution of saline land in the agricultural districts of South Australia

Since European settlement, large areas of deep-rooted perennial native vegetation has been cleared and replaced with shallow rooted annual crops and pastures, changing the water balance of the landscape. Annual crop and pasture species are much less efficient at using available rainfall than the native vegetation, allowing water to drain through the soil profile, mobilise the stored salt and cause watertables to rise. Surface expression of salinity usually begins to occur when the watertable rises to within 2m of the soil surface. Salinisation of land, due to human activity since European settlement, is termed secondary salinity. It has occurred in both rainfed (dryland salinity) and irrigated (irrigated salinity) land.

To date the Land Condition Monitoring Program has not collected data specifically for monitoring change in salinity and this report focuses only on the current extent and severity of dryland salinity. However, monitoring methods are being developed and they will be implemented in the near future.

EXTENT AND SEVERITY OF DRYLAND SALINITY

Dryland salinity occurs to some extent in all agricultural regions of South Australia. Its expression in the landscape can vary significantly from year to year and within a year due to seasonal conditions.

The current extent of dryland salinity has been assessed using two approaches:

1). In the National Land and Water Resource Audit Report by Barnett (2001), the area of secondary saline agricultural land was estimated to be around 326,000 ha largely using aerial photographic interpretation. There is an estimated 657,000 ha of saline land if all primary and secondary salinity is included (Table 10) across the agricultural districts of the State. In addition, Barnett estimated that if nothing was done to reduce secondary salinisation, the area of agricultural land affected would increase by around 60% to 521,000 ha and total saline land to over 900,000 ha, before a new balance between rainfall, water use and evaporation was reached in 2050.

2). In May 2002, the Australian Bureau of Statistics undertook a Land Management and Salinity Survey as a supplement to the 2001 Agricultural Census. The responses from land managers indicated that South Australia currently has around 350,000 ha of agricultural land showing signs of salinity. This does not include saline land in non-agricultural areas such as parks and reserves.

The present extent and severity of salinity in the agricultural districts of South Australia is shown in Figure 22 (Soil and Land Information 2002b). With an estimated additional 72,000 ha of secondary salinity in remnant vegetation areas, the total area of seconday salinity is around 398,000 ha and the total area of saline land is 729,000 ha, if all primary salinity is included as well.

Salinity risk modeling, based on geological setting, topography and current extent and severity (Hall 2003), shows that a further 292,000 ha have a high risk of becoming highly saline if water tables rise 20-30 cm across the agricultural districts.

The current 729,000 ha of saline land in this State compares with estimates of 180,000 ha in New South Wales, 670,000 ha in Victoria and 4.3 million ha in Western Australia. However, without intervention, by 2050 the area of saline land could exceed an estimated 900,000 ha in South Australia compared with around 1 million ha in New South Wales, 3 million each in Victoria and Queensland and nearly 9 million ha in Western Australia (NLWRA 2001b).

Table 10: Estimated area ('000 ha) of land affected by secondary salinity in regions of South Australia (after Barnett, 2001 and Hall, 2003)

	Total saline land ('000 ha)	Secondary saline land in cleared areas ('000 ha)	Secondary Salinity as a Proportion of total area (%)
Eyre Peninsula	138	20	1
Northern and Yorke	164	29	4
Adelaide/Mt Lofty Ranges	14	1	1
Murraylands	46	20	1
Kangaroo Island	23	6	5
South East	272	250	5
TOTAL	**657**	**326**	**3**

MONITORING SALINITY

Groundwater Depth

The Department of Water, Land and Biodiversity Conservation currently monitors groundwater depth in a few specific areas. Observation wells were drilled in 5 representative catchments in regions of South Australia in 1990/91 for salinity monitoring purposes. A network of monitoring bores was established in the Upper South East in 1975 and on the coastal plain of the Murray Basin in 1987. In the short period of groundwater monitoring for salinity, a number of trends are evident. Groundwater recharge appears strongly correlated with winter rainfall, although heavy summer falls have been rare during the monitoring period and might contribute occasionally. In the Murray-Darling Basin the regional watertable is estimated to be rising, from a relatively high rate of 7-10cm/year on parts of the coastal plain in the Upper South East, to 2-3 cm elsewhere (Barnett 2001). In contrast, in some areas of southern South Australia, a period of below average winter rainfall years has resulted in groundwater levels actually falling in recent years.

Land Management Indicators for Salinity Risk

Recognition of salinity as an issue

On average, 38% of land managers in the 2000 and 2002 surveys considered that soil salinity was an important issue in their district (Figure 23). A similar proportion (36%) reported they had saline land on their property. The proportion of properties where salinity occurred ranged from an average 41% in the medium rainfall areas to 25% in low rainfall areas. The average area of saline land reported on properties affected by salinity varied widely from 17 ha in the Mt Lofty Ranges and Kangaroo Island Region to 345 ha in the South East (Figure 24). The overall average on properties in the survey was 36ha, or around 3% of property size.

Perception of change in saline area

Most land managers (71%) thought that the extent of salinity would remain unchanged, irrespective of whether salinity currently occurred on their property or not. Around 10% of landholders were concerned that salinity was on the increase, while 14% thought that salinity would decline in the next 10 years.

Figure 23 Average proportion (%) of land managers considering salinity a land management issue in their district in South Australia; LM survey 2000/2002

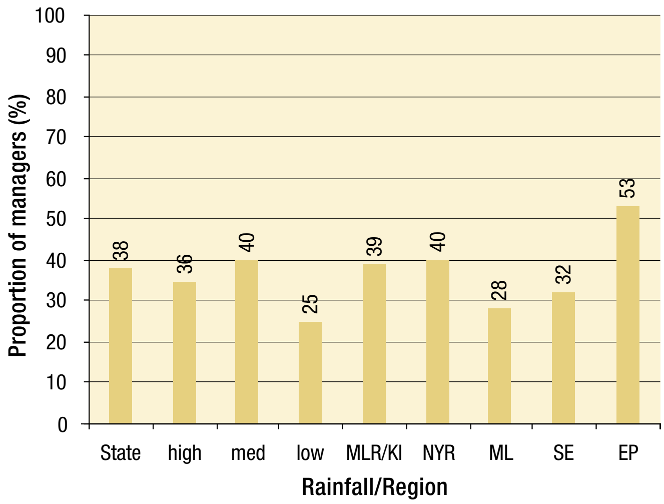
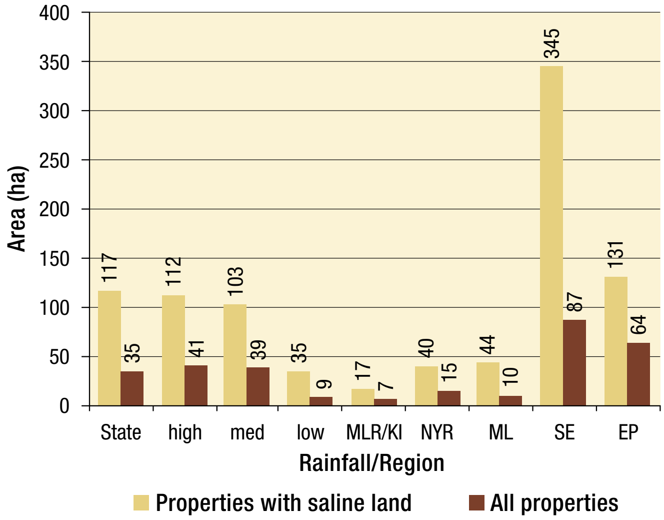


Figure 24 Average area (ha) of saline soils on all properties, and those with saline land, in regions of South Australia; LM survey 2000/2002



Implementing On-site practices

Of all the farmers who had saline land on their property, an average of 79% reported in the 2000 and 2002 surveys (Figure 25), that they were implementing some on-site management practices to minimise the affects on that land. The practices most frequently undertaken were on-site fencing to protect any cover and plant growth from grazing, planting trees, saltbush or other shrubs, as well as establishing salt tolerant pasture such as Puccinellia and Tall Wheat Grass.

Implementing Off-site practices

Within local and regional catchments where salinity occurs, all land contributes to rising groundwater. Irrespective of whether salinas currently occur on individual properties, it is essential that all land is responsibly managed. Practices that maximise rainfall use are an important factor in any salinity control program. The surveys showed (Figure 26) that an average of 31% of land managers with saltland on their properties were undertaking off-site management practices to minimise the salinity potential. Only 20% of those currently without saltland, indicated they were carrying out off-site preventative measures or salinity control measures.

Figure 25 Average proportion (%) of land managers, with salinity on their property, who undertake on-site control practices in South Australia; LM survey 2000/2002

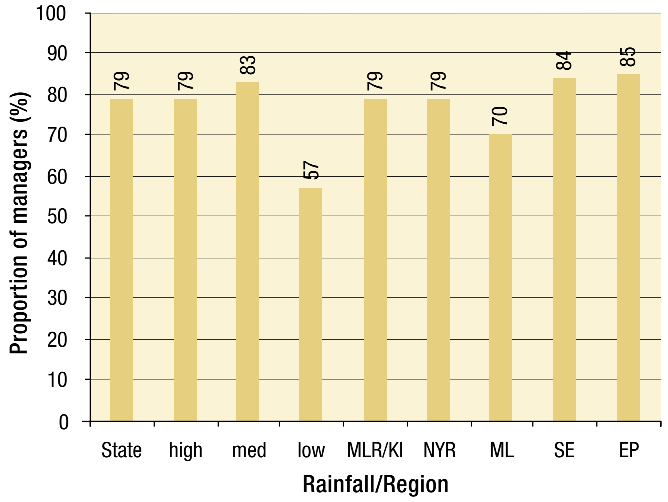
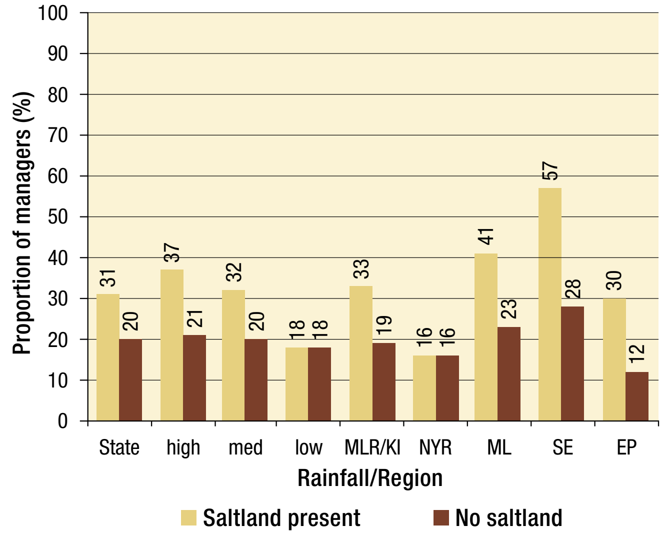


Figure 26 Average proportion (%) of land managers who carry out off-site control measures in regions of South Australia; LM survey 2000/2002



SALINITY SUMMARY

The various methods of assessing the extent of dryland salinity show a consistency in the order of magnitude of the problem. The current total area affected is in excess of 650,000 ha in South Australia and has the potential to rise to over 900,000 ha in the next 20-50 years (after Hall, 2003). Most of the high risk land occurs in the Upper and Mid South East of the State. The Upper South East Dryland Salinity and Flood Management Plan has been implemented to reduce the impact.

The distribution of current and projected highly saline land, are shown in Figure 27.

The extent of future expression of dryland salinity will depend on future rainfall patterns, including the effect of global warming, and the extent of water use balance achieved by improved farming systems and changes in land use to reduce recharge.

The replacement of annual crops and pastures with perennial plants is one of the key strategies for redressing dryland salinity. To date, the revegetation effort has not been at a large enough scale to significantly influence mitigation. The major problem is finding perennial vegetation systems that are economically feasable on the very large scale required (see Revegetation section).

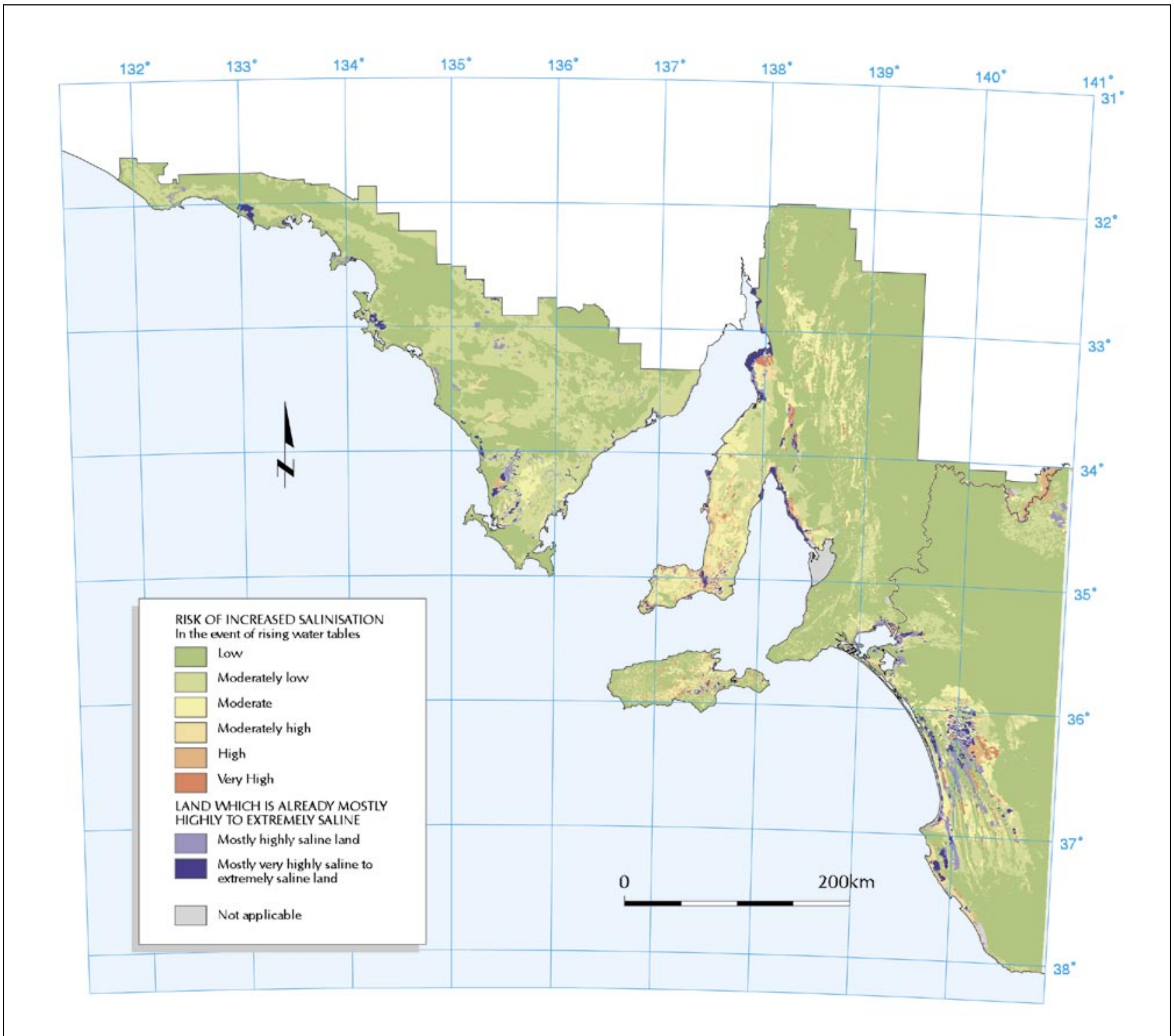


Figure 27. Distribution of current saline areas, and those at risk of salinisation* in the event of rising water tables, in the agricultural districts of South Australia (adapted from Hall 2003)

* Classes are based on an interpretation of soil landscape units and determined from existing salinity attribute ratings, position in the landscape and the salinity status of the adjacent map units.

Soil Physical Condition

BACKGROUND

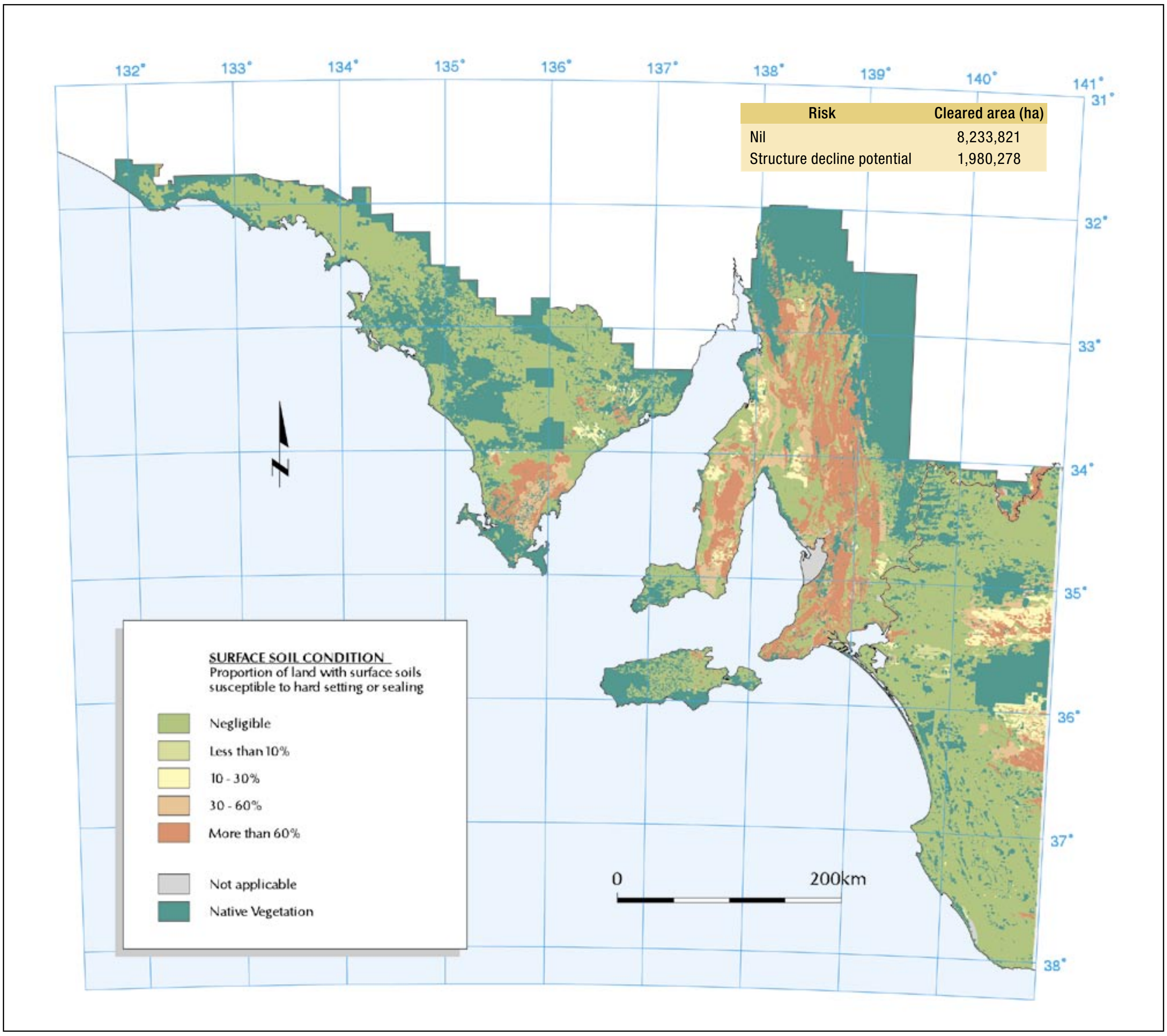
Almost all of the State's agricultural soils have some level of physical limitation, but the extent to which these contribute to reduced productive capacity is highly variable.

Surface soil structure breakdown and hardsetting

Soil structure can be described as the way in which soil particles are held together in aggregates. The inherent strength and stability of soil structure is determined largely by its texture, and in particular, by the amount and type of clay. In general, the greater the clay content of a soil, the stronger and more stable the soil aggregates, unless the clay is dispersive. A well-structured soil maintains higher water infiltration and conductivity rates and has lower soil strength, even under cultivation.

Sands are said to be structureless because they do not have enough clay to form stable aggregates. The physical properties of sands are determined by the particle size distribution of the sand grains alone. Most sands have high rates of water conductivity and low strengths, although some can become very strong and resistant to root growth when compacted. The main problem with sands as a plant growth medium, are their low water holding capacity, propensity to dry out quickly and low nutrient holding capacity.

There are large areas of agricultural land in South Australia, with mainly sandy loam textured topsoils, that have relatively unstable structures. These soils generally do not have sufficient reactive clay or organic matter to maintain larger, stable aggregates when subjected to mechanical disturbance by tillage equipment or hard hoofed animals. They typically have particle size distributions that allow relatively tight packing of particles in the absence of stable macro aggregation. In wet conditions, when larger aggregates are broken down by mechanical action, the soil particles pack tightly, resulting in very high strengths when dry (hard-setting soils) and high bulk density.



Risk	Cleared area (ha)
Nil	8,233,821
Structure decline potential	1,980,278

Figure 28. Distribution of cleared land with soils susceptble to hardsetting or sealing in the agricultural districts of South Australia

The main consequences of structure breakdown in topsoils are:

- slower infiltration and hydraulic conductivity rates, resulting in slower wetting of the soil, and more runoff
- More runoff that reduces productive potential and increases risk of water erosion
- Slower wetting and higher strength, which requires more energy and higher cost for cultivation, and seedbed preparation
- Increased risk of waterlogging

Once these soils do wet up, their strength drops and roots are generally able to grow through them fairly readily.

Figure 28 and Table 11 (Soil and Land Information, 2002b) show that almost 2 million hectares of cropping land in South Australia have physical properties that make them inherently susceptible to surface soil structure breakdown.

Surface crusting (sealing)

Surface sealing and crusting is a specific sub-set of surface structure breakdown, described above. The same loamy sand to loam textured agricultural soils are at greatest risk of surface crusting.

Surface crusts generally form as a result of raindrop impact on bare cultivated soils, where particles become detached and then re-pack in a dense surface layer. If the crust dries it increases in strength and can seriously reduce seedling emergence and crop or pasture establishment. The surface seal also results in a much reduced infiltration rate, leading to increased surface runoff, consequent loss of productive potential, and increased risk of water erosion.

Retention of stubbles and other plant residues on the soil surface to prevent direct raindrop impact is the best way of mitigating surface crusting.

Sodic surface soils

Soils with an excess of sodium attached to clay particles are termed sodic soils. When these are immersed in fresh water they disperse, or effectively go into suspension in the water. Very large areas of land in South Australia have sodic clay subsoils.

Table 11: Area of cleared land with soils suscetible to surface hardsetting and sealing in regions of South Australia

Region	Area of susceptible land ('000 ha)
Eyre Peninsula	231
Northern and Yorke	1,065
Mount Lofty Ranges	330
Murraylands	233
Kangaroo Island	8
South East	113
TOTAL	**1,980**

These subsoils typically have either a massive structure or very coarse aggregation, with high strength and resistance to root penetration, and low rates of water conductivity. They also generally have a pH_{water} of 9.2 or greater.

However, there are only very small areas of agricultural land in South Australia with sodic surface soils. Many of these result from sodic subsoils being exposed or mixed with surface soils following catastrophic loss of topsoil by erosion. These soils must be managed with great care because they are extremely susceptible to structure breakdown, crusting and water erosion. The main management options include leaving them undisturbed or applying gypsum to replace sodium on the clay particles with stabilising calcium. Maintaining surface cover is essential.

Compaction layers and hardpans

In duplex soils with a sodic subsoil there are often natural boundaries of low permeability, high strength and high resistance to root penetration between the topsoil and the subsoil.

In addition, many agricultural soils have a higher density, higher strength layer just below the depth of cultivation caused by one or all of the following:

- Compaction by implements and tractor wheels
- Compaction by hooves of grazing animals
- `Plough pan' formation resulting from soil shear and compaction caused by ground-engaging tillage implements
- Soil particle segregation at the interface of the cultivated layer and the undisturbed soil below.

When these hardpan layers are particularly severe they can have sufficient strength to resist root penetration, effectively reducing the plant rootzone and consequent productive capacity. However, even though an induced `hardpan' layer can be identified in many of the State's agricultural soils, only rarely is there good evidence of a hardpan significantly reducing root growth and production. In most cropping soils of sandy loam and heavier texture (ie. more clay) the hardpan layers seem to reduce in strength when wet and allow adequate root penetration. However, some compacted sandier textured soils, in particular, can maintain high strength and penetration resistance even when wet.

Hardpans, whether induced or natural, can contribute significantly to waterlogging and resultant production losses. If the pan reduces downward hydraulic conductivity it can act as a throttle to drainage, causing short and medium term saturation and waterlogging and even loss of productive potential, due to excess surface water runoff.

MONITORING SOIL PHYSICAL CONDITION

Change in soil organic matter level is not a useful indicator of soil condition, despite popular belief to the contrary. Soil organic matter level is most strongly influenced by clay content and mineralogy, the occurrence or otherwise of tillage, and to some extent the presence of fine lime.

It is very difficult to increase the soil organic matter level of a regularly cropped soil, even when low intensity tillage is used and all stubbles are retained. Elevated organic matter levels can sometimes be associated with low biological activity in waterlogged or highly acidic soils.

Land Management Indicators for Soil Physical Condition

Most soil physical degradation conditions are difficult to monitor directly. The main pre-disposing risk factors for structure decline are the soil's innate physio-chemical properties, mainly texture, surface and subsoil sodicity and whether or not it is calcareous. Given these soil characteristics, the main variable parameters affecting the level of soil physical degradation are the extent and nature of management practices, particularly tillage and other vehicular traffic operations, and the management of surface cover.

Recognition that soil structure decline is an issue

Land manager surveys carried out in 2000 and 2002 investigated a number of factors that affect soil structure. The surveys (Figure 29) indicated that 29% of farmers across the State were concerned about soil structure decline and that the level of concern was consistent across the state whether by rainfall district or region.

Tillage intensity

As the number of tillage passes for crop preparation and sowing increases, there are a number of key impacts on soil physical condition:

> Soil is broken into finer and finer aggregates as the number of tillage passes increase; this makes the soil more susceptible to surface crusting and hardsetting

> Increased compaction with more machinery passes

> more stubbles and other plant residues are buried and surface protection declines

Figure 30 shows the distribution of the average number of tillage passes reported in land manager surveys.

The overall average for the State in the surveys was 2.3 passes, including sowing, with 2.1 in higher rainfall districts and 2.9 in low rainfall areas, where long cultivated fallows are more common. By region, the Eyre Peninsula reported the lowest average of 2.1 passes, the Northern and Yorke, South East and Mount Lofty Ranges/ Kangaroo Island 2.2-2.3 passes, and the Murraylands 2.9 passes. The majority of soils with inherent susceptibility to physical degradation occur in the Northern and Yorke Region.

While these levels of tillage represent a huge historical reduction, there is still scope for considerable improvement. The ultimate goal is just a single tillage pass at sowing.

Residue management

Retention of stubbles is a critical management practice for maintaining protective cover on soils with unstable surface structure (see Figure 16). In addition, retaining all plant residues so that they are available to feed a dynamic soil ecosystem, is important. There is some evidence that maintaining a high level of soil biological activity, through full residue retention, can reduce the incidence of crop root pathogens. While residue retention increases soil biological activity, it does not usually result in a significant increase in soil organic matter. The practice of burning plant residues reduces surface protection and removes large amounts of 'fuel' from the ecosystem, while nutrients, particularly nitrogen and sulphur, are lost from the soil system.

Figure 29 Average proportion (%) of land managers considering soil structure a land management issue in their district in South Australia; LM survey 2000/2002

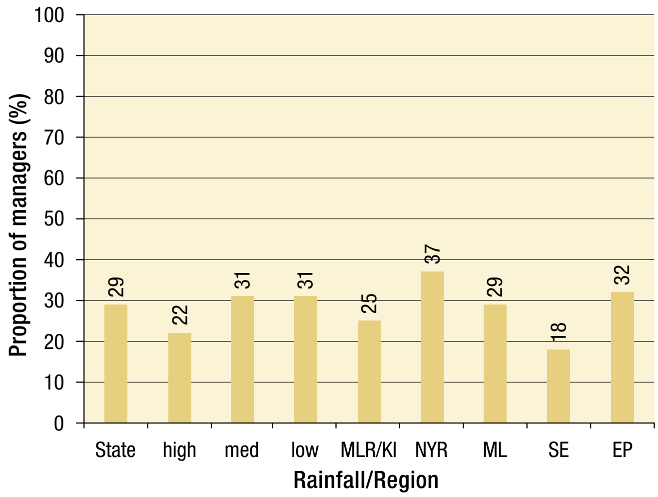
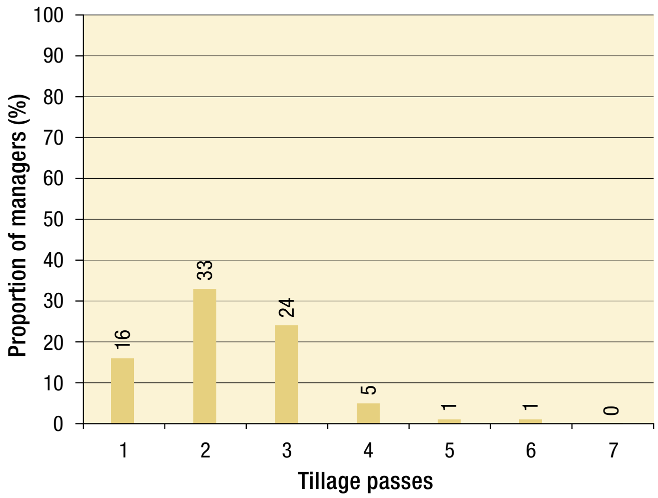


Figure 30 Average proportion (%) of land managers and number of tillage passes (including sowing) in South Australia; LM survey 2000/2002



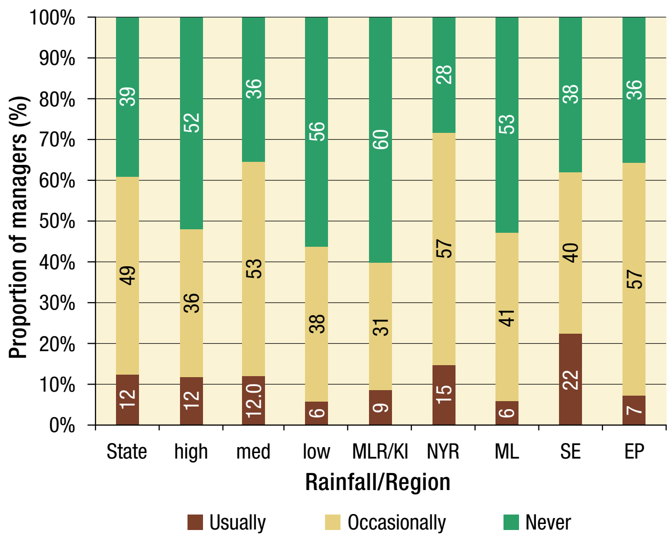
Other nutrients can also be lost if the ash is removed by wind before it is incorporated into the soil.

The 2000 and 2002 land manager surveys found that, across the State, a majority of farmers burn crop and pasture residues to some extent prior to initial cultivation of land for cropping. On average, 61% of farmers did so (Figure 31). Around 12% of managers indicated they usually burnt residues, while 49% only did so occasionally. The area of land burnt in preparation for crop can fluctuate significantly between seasons and districts. Burning was used most frequently in the Northern and Yorke Region (72%) where cropping intensity is greatest. Yorke Peninsula also has a relatively high incidence of snails as a pest in cropping, and burning is one common management strategy.

The average proportion of crop area burnt in 1999 and 2001 by region ranged from 35% in the South East to 13% in Murraylands. Note that this data represents too short a sampling period from which to draw any useful conclusions about longer-term trends, but shows that the area burnt annually is significant. Burning remains a common management strategy for snail control in some districts, and also because a lot of cropland is still prepared and sown with machinery that is incapable of handling large amounts of residues.

Burning cereal stubble in the Northern and Yorke Region, South Australia (Photo M-A. Young, PIRSA)

Figure 31 Average proportion (%) of cropping land managers who burn residues when preparing land for crop; LM survey 2000/2002



Gypsum use

Sodic soils disperse, or go into suspension, when immersed in fresh water. A sodic surface soil loses its structure when rain falls on it, resulting in sealing of the surface, reduced infiltration and increased surface ponding and runoff. All of these are detrimental to plant growth and productivity, as well as increasing the erosion risk. Gypsum, which is commonly found in natural deposits associated with ancient lakes, is used to ameliorate dispersive soils. Its key chemical component is calcium sulphate. Being relatively soluble, some of the calcium from gypsum replaces sodium attached to clay particles and this reduces the dispersive effect. At the same time the gypsum in solution has an electrolytic effect that also tends to reduce dispersion of clay particles.

While the sandy loam surface soils of many SA agricultural areas are not strictly sodic, they have weak resistance to surface structure breakdown, which seems to be ameliorated to some extent by the use of gypsum. On these soils, the beneficial effects of gypsum application usually last for 1 to 3 years only, because the benefit is probably due to the electrolytic flocculating effect of the calcium sulphate in soil solution.

Figure 32 shows the distribution of gypsum use in SA as determined from the 2001 ABS agricultural census. There is a relatively strong correlation between the use of gypsum and areas with surface soils that benefit from its use.

Some gypsum is used to supply sulphur, particularly in high production systems on sandy soils.

While gypsum can be a useful tool in the short-term management of soil physical condition, changes to tillage and stubble management are the key to longer-term improvement.

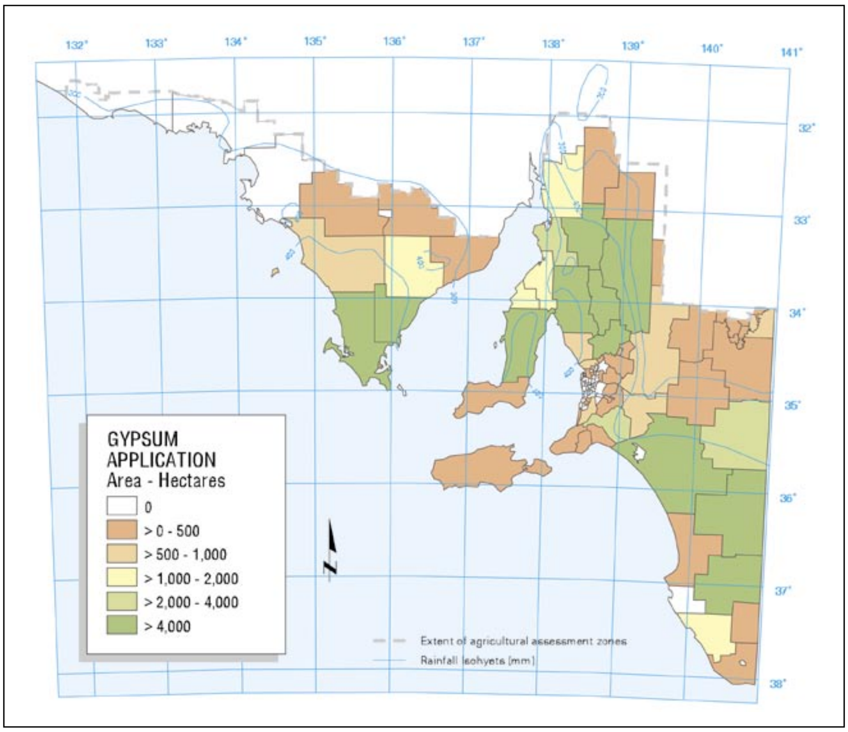


Figure 32. The distribution of the area (ha) to which gypsum was applied to ameliorite soil structure decline in Statistical Local Areas of South Australia as indicated by ABS Agricultural Census data (2001)

SOIL PHYSICAL CONDITION SUMMARY

Almost all farming operations are likely to have some impact on soil physical condition. Decline in soil physical condition can reduce root growth, water-use efficiency and productivity, and can also increase the risk of water erosion on susceptible lands. The impacts are highly variable between soil types, but the sandy-loam surface soils of the Northern and Yorke Region and parts of Eyre Peninsula are the most susceptible.

Researchers and farmers have tested mechanical ripping of compacted layers as a means of reducing soil strength and improving water infiltration and plant growth. The results have been variable and there is currently no substantive data on the benefits and extent of the use of this practice.

The most important factors in managing soil physical condition are the maintenance of surface cover and retention of plant residues so that they cycle through a dynamic soil ecosystem. A coincident reduction in the number of tillage passes and the intensity of disturbance are also key components. While these factors have generally trended in the right direction over the last decade or so, there remains plenty of scope for further improvement.

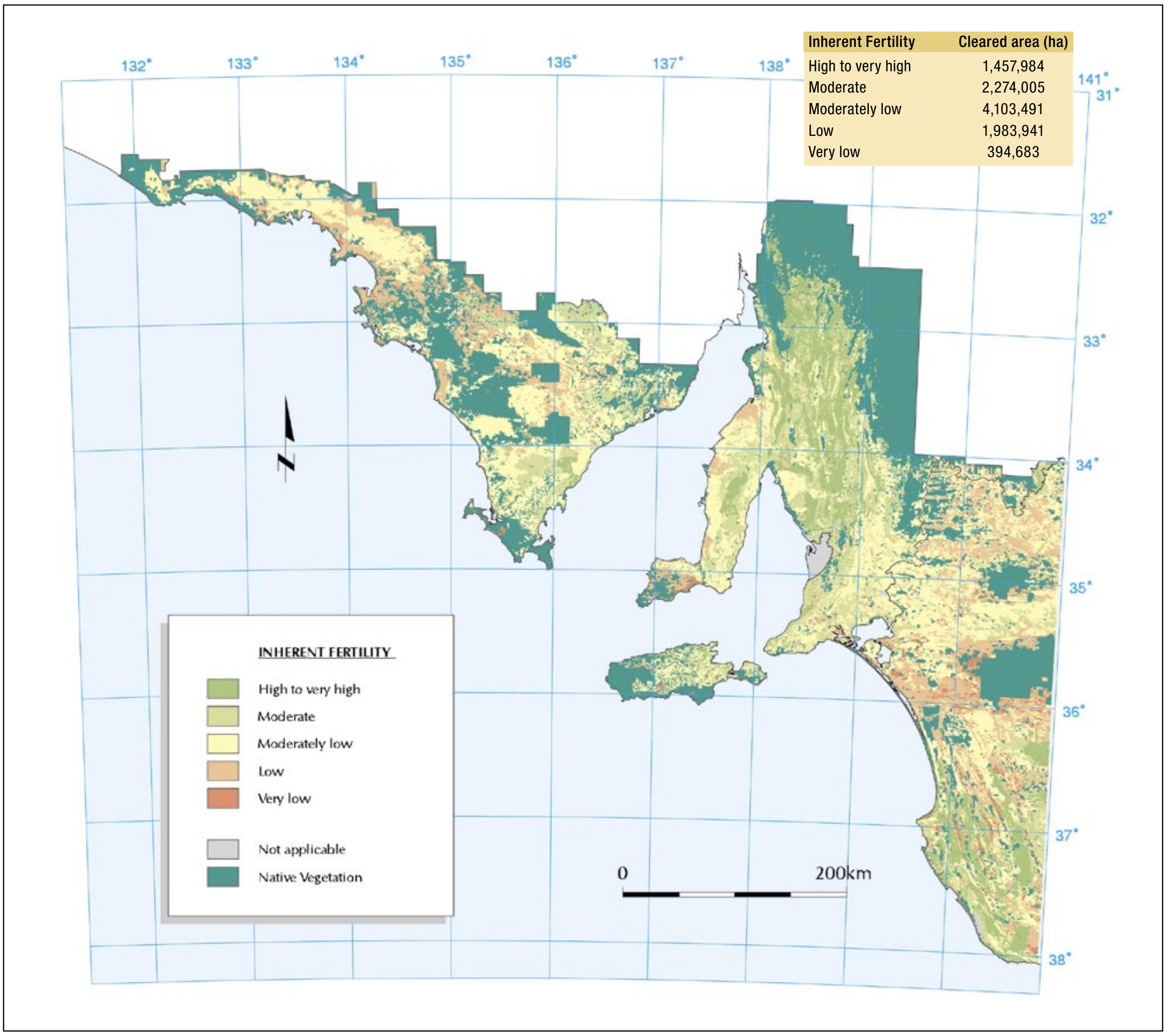
Soil Fertility

BACKGROUND

In comparison to soils of most other parts of the world, the majority of Australian soils are of generally low fertility in their natural state. Most are naturally deficient in phosphorus and many have significant trace element deficiencies. Agricultural production not only requires a higher level of nutrition than natural ecosystems, but also involves removal of nutrients at an accelerated rate. Without fertilisers in some form, to firstly build fertility and then maintain it, current levels of agricultural productivity could not be achieved.

Most soil nutrients are either contained in clay minerals and organic matter, or retained on their charged surfaces. Therefore the ability of the soil to store and supply nutrients is largely determined by clay type and content. Other soil constituents, such as carbonates and ironstone, modify this basic fertility. The distribution of inherent soil fertility is shown in Figure 33 (Soil and Land Information, 2002b). The inherent fertility ranking is assessed as a combination of the key soil properties soil texture, cation exchange capacity, leaching capacity, acidification potential and carbonate and ironstone content. Map classes are an interpretation of soil landscape units based on a proportional average of their component soils.

Inherent fertility is a concept that is useful for showing the distribution of the general fertility base, and therefore relative potential, of the agricultural soils within South Australia. Very low fertility soils are primarily deep siliceous sands, while soils with the highest inherent fertility are those with at least clay loam topsoil and a clayey subsoil, at shallow depth.



Inherent Fertility	Cleared area (ha)
High to very high	1,457,984
Moderate	2,274,005
Moderately low	4,103,491
Low	1,983,941
Very low	394,683

Figure 33. Distribution of the inherent soil fertility of cleared land in the agricultural districts of South Australia

Table 12: Area of cleared land with soils of moderate to low inherent fertility in regions of South Australia

Region	Moderately Low to Low '000 ha	Moderate '000 ha
Eyre Peninsula	2,349	453
Northern and Yorke	772	770
Mt Lofty Ranges	276	219
Murraylands	1,552	369
Kangaroo Island	130	83
South East	1,402	379
TOTAL	**6,482**	**2,273**

In South Australia there are 1.5 million ha of soils classed as high to very high inherent soil fertility. The greatest proportion of those soils is found in the Northern and Yorke Region and the Lower South East. Overall, moderate to low inherent soil fertility is an issue of significance on 8.7 million ha of land cleared for agricultural production in the state. The largest areas of low fertility soils occur on Eyre Peninsula and in Murraylands and South East regions (Table 12).

Inherent fertility shows the fertility base and highlights the potential agricultural productivity of the state soil resources. However, it is a characteristic that does not usually change except, for example, in special circumstances where clay spreading and delving significantly modify the physical and chemical nature of the soil profile. Other indicators are therefore necessary as monitoring tools.

MONITORING SOIL FERTILITY

Soil Sampling

A range of commercial soil and plant tests have been developed for routine use on farms. Data from the South Australian Soil and Plant Analysis Service (SASPAS) is readily accessible and has potential for monitoring purposes.

Soil Phosphorus

Phosphorus fertiliser has been almost universally applied in South Australian agricultural districts because the inherently low natural levels were inadequate to sustain agricultural production.

Current phosphorus status of soils is essentially a result of that fertiliser history and the ability of the soil to retain it within the profile in available form. Some phosphorus is stored in soil organic matter and is available to plants when the material is mineralised by micro-organisms. This is a particularly important source in deep sandy soils. However, phosphorus applied by fertiliser to soils can form a range of chemical compounds with varying solubility and availability to plants. Iron and calcium compounds of phosphorus are the main end products and most have only limited solubility, depending on temperature, moisture and pH conditions. Some phosphorus also ends up attached to clay surfaces.

A large response to P fertiliser in subterranean clover pasture on ironstone soils on Kangaroo Island demonstrates the production limitation posed by low P soils
(Photo N. Fleming, PIRSA/SARDI)

After many years of fertiliser application, some agricultural soils now contain a large store of phosphorus. Even though this phosphorus is generally held in low solubility compounds, they enable the soils to provide adequate phosphorus to high productivity crops and pastures, particularly when supplemented with annual applications of more readily available soluble phosphorus fertiliser.

In most districts, soil phosphorus remains a limiting nutritional factor and the levels are an important indicator of growth and production potential. Figure 34 clearly highlights the high proportion of soil samples with a low soil available P (<20 ppm Colwell P) across the agricultural areas of South Australia. The highest proportion of low P samples was in the lower rainfall areas of Eyre Peninsula, Northern and Yorke Region and Murraylands region where cost minimisation, rather than the possibility of production increase, has historically kept fertiliser application low. The area in the Mid to Lower South East with a high proportion of low P samples are associated with sandy, leaching soils used for extensive grazing. Data from the 1996 ABS Agricultural Census in Figure 35 show how P application rates are correlated with the amount and reliability of annual rainfall. Intensive grazing (eg. dairying) and horticulture contribute to some of the higher rates shown by the data in the higher rainfall districts and along the River Murray.

In the main dryland cropping districts, fertiliser has mainly been applied to cropping phases because grazing gross margins have rarely been sufficient to justify applications to pastures. This has limited potential pasture productivity.

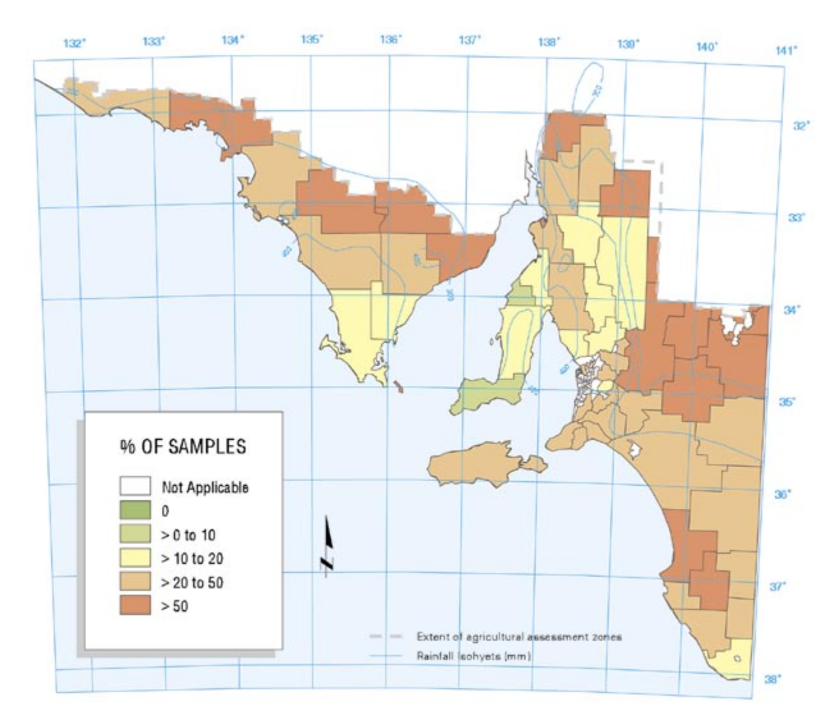


Figure 34. Proportion of low available P content (<20ppm Colwell P) soil samples analysed by SASPAS in South Australia 1990–1999

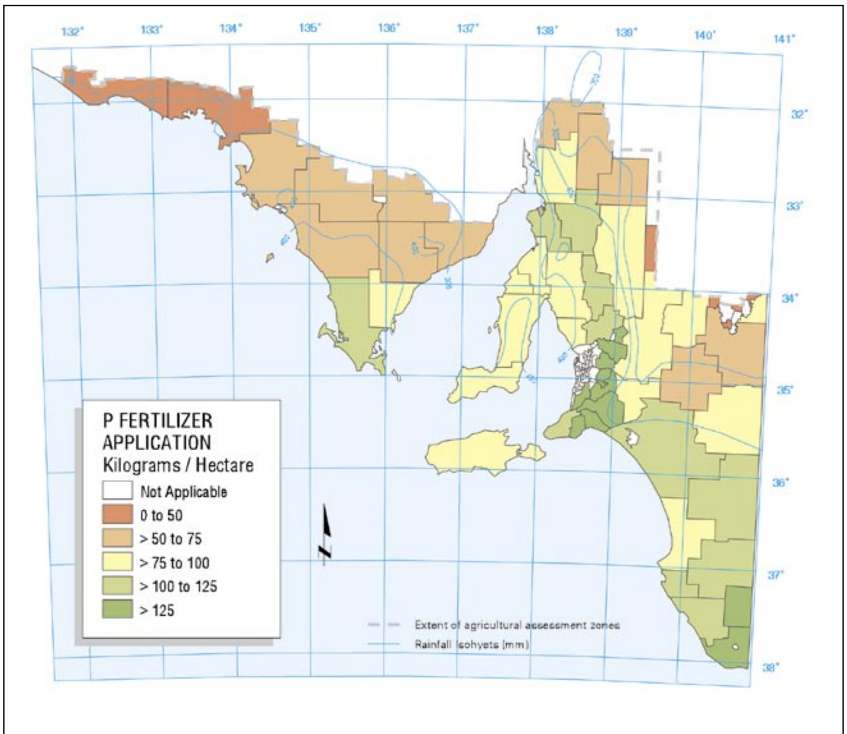


Figure 35. Annual phosphorous fertiliser application rates (kg/ha) as indicated by ABS agricultural census statistics 1996

Figure 36 shows that between the periods 1990-1994 and 1995-1999 the proportion of low P samples analysed by SASPAS increased significantly. Some of the change might be due to the expansion of cropping onto more marginal low P soils. Increased cropping generally results in increased applied fertiliser, although it also means more phosphorus is removed in farm products such as grain and hay.

Land Management Indicators for Soil Fertility

On-farm soil testing

Nutritional management is a key part of productive agriculture. There are a number of ways in which land managers can monitor their nutritional strategies, with soil and plant analysis the most significant. The land manager surveys have shown that soil testing has a solid acceptance as a management tool. Statewide, an average of 71% of land managers (Figure 37) indicated that they used soil testing on a regular basis to help them decide their fertiliser strategy. That pattern of use was relatively consistent across the state, except in low rainfall areas where, with generally lower soil nutritional status and fertiliser use, it was a much lower 54%. In the regions, soil testing ranged from the least use of 54% in Murraylands to a consistent 72-76% in the other regions.

Although the average annual (8%) or biennial (10%) use of soil testing was relatively low, 60% of farmers repeated their soil testing with a maximum of 5 years between tests (Figure 38). While this shows that soil testing is a widely used monitoring tool on farms today to help fertiliser decision making, there is still scope for a significant increase in its use.

Using off-farm advice

While the use of improved technology to increase production efficiency is important, it is almost impossible for individuals to keep abreast of all new technologies and there is an increasing use of outside advisory services. In the land manager surveys, fertiliser decision-making has been used as an example to quantify current use made of specialist consultancy advice in South Australia.

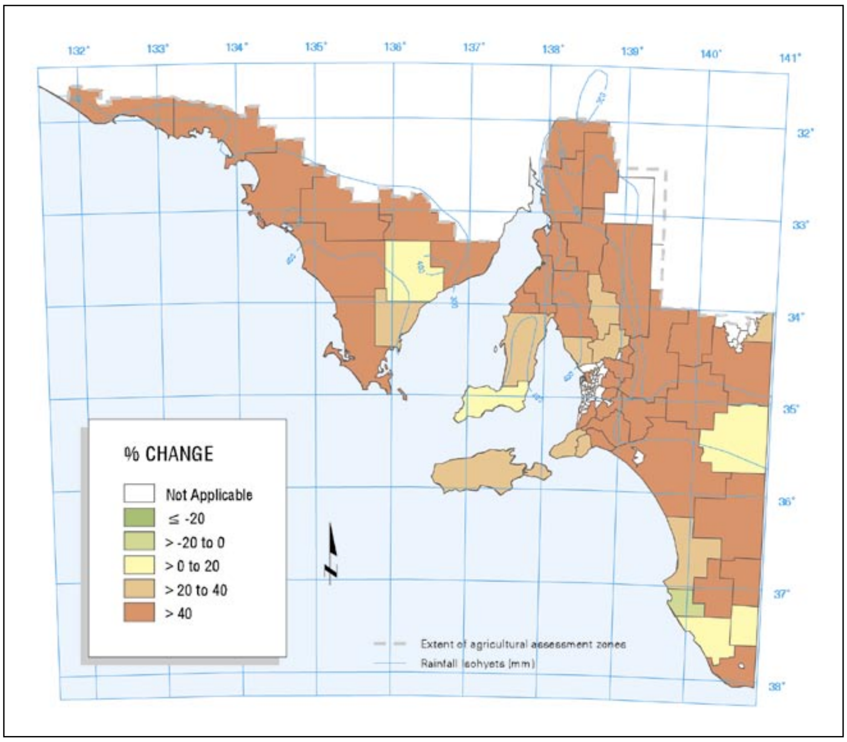
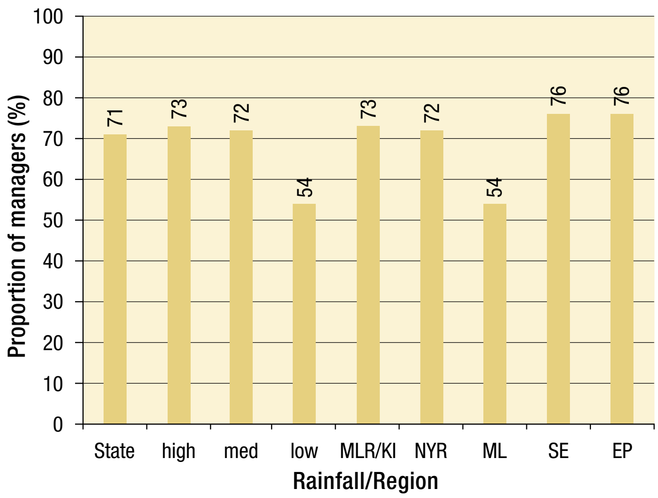


Figure 36. Change in the proportion of low available P content (<20ppm Colwell P) soil samples analysed by SASPAS in South Australia between the periods 1990–1994 and 1995–1999

Figure 37 Average proportion (%) of cropping land managers who regularly test soil fertility in South Australia; LM survey 2000/2002



The survey showed that most land managers integrated the advice of a variety of agricultural service providers (Figure 39) and that the use was widespread. The assistance sources were not mutually exclusive and land managers indicated that they sought help with their fertiliser decisions from a range of sources. In the 2000 and 2002 surveys, an average of 69% valued their own knowledge, a significant proportion (56%) also sought information from agronomists/consultants and (41%) fertiliser industry advisory services. In low rainfall districts a greater number of farmers (88%) reported their decisions relied largely on their own knowledge and significantly less indicated that they took the advice of agronomist/consultants (44%) and fertiliser agents (30%) into account.

SOIL FERTILITY SUMMARY

Commercial soil testing data indicate that as cropping area has increased, crops have more frequently been sown on lower fertility soils. Whether the fertility of these soils will rise as a consequence of greater cropping is yet to be seen.

While there is a moderate level of use by land managers of outside expertise to assist them in their nutritional decision-making, this might increase as farming technologies become more complex and farmers more sophisticated in their business responses.

The major natural resource management implications from declining soil fertility are reduced plant growth and productivity, exposing the land more often to a risk of erosion, and reduced water use, increasing the potential for salinisation.

Figure 38 Average interval (yrs) between on-farm soil testing in South Australia; LM survey 2000/2002

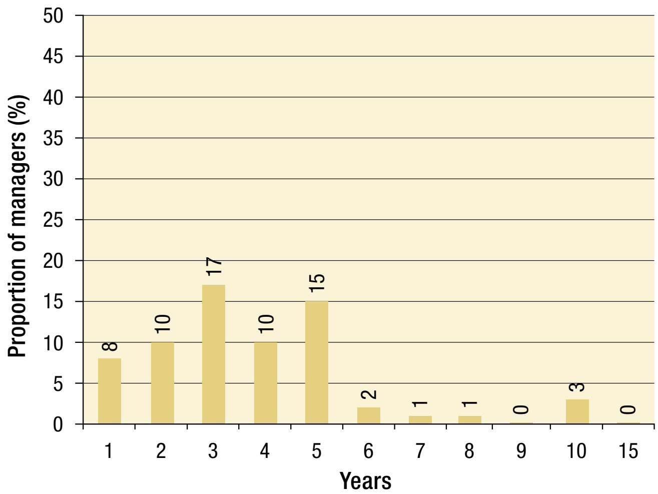
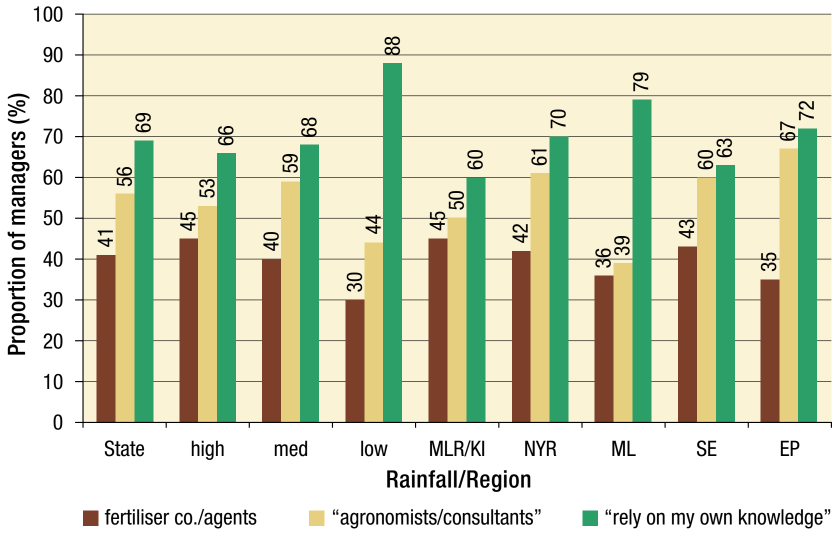


Figure 39 Average proportion (%) of land managers using information sources for fertiliser decision making in South Australia; LM survey 2000/2002



Water Repellent Soils

BACKGROUND

Water repellence is a naturally occurring soil condition in which waxy (hydrophobic) organic materials coat the surface of soil particles, resulting in uneven wetting of surface soil. These hydrophobic materials can occur in all soils, but have the greatest impact in siliceous sands.

Uneven wetting of the surface soil causes patchy crop and pasture establishment and results in a significant production loss. The problem is exacerbated in lower rainfall areas where an already limited water supply is unevenly distributed. Water repellence can be highly variable between years and is usually less of a problem in wetter years.

Water repellence is not strictly a degradation problem. It is predominantly a soil management issue since its impacts are exacerbated by annual crop and pasture management practices.

However, because it results in poor plant growth and cover on sandy soils, it can contribute significantly to increased wind erosion risk, particularly in dry conditions. Moreover, under annual crops and pastures, the water use efficiency can be so poor that it results in an increased groundwater recharge and dryland salinity risk.

The distribution of water repellent soils in South Australia is shown in Figure 40 (Soil and Land Information, 2002b) and the areas are quantified in Table 13. These are essentially land areas with a significant proportion of siliceous sand topsoil.

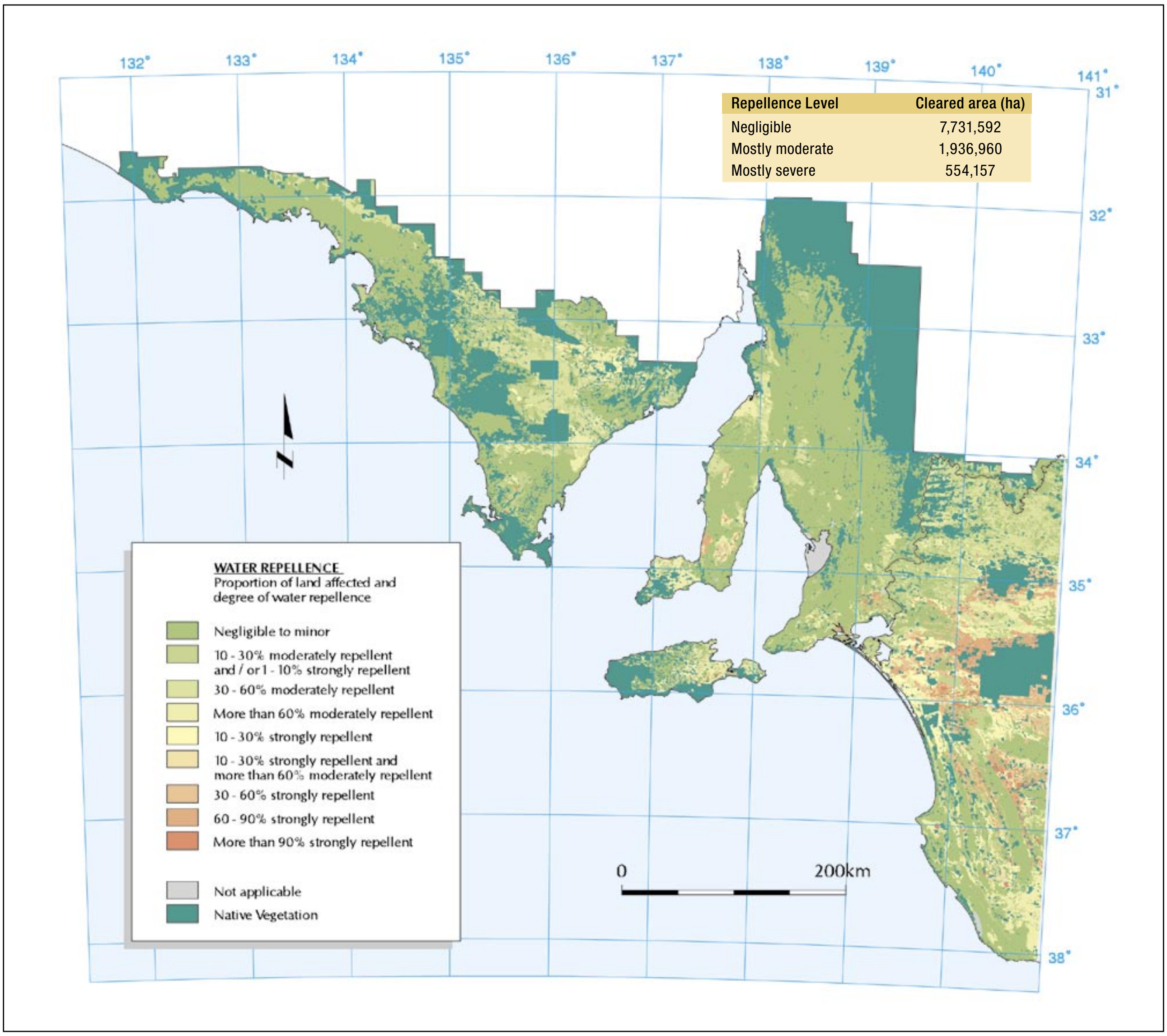


Figure 40. Distribution of water repellence in cleared land in the agricultural districts of South Australia

Table 13: Area of cleared land with soils of moderate and severe water repellence in regions of South Australia

Region	Moderate '000 ha	Severe '000 ha
Eyre Peninsula	445	11
Northern and Yorke	207	19
Mt Lofty Ranges	37	1
Murraylands	549	181
Kangaroo Island	92	8
South East	607	324
TOTAL	**1,937**	**544**

Overall, water repellence is an issue of moderate to high significance on 2.48 million ha of land cleared for agricultural production in South Australia. The 544,000 ha of severely repellent soils occur mainly in the dune-swale landscapes of the southern Murraylands (181,000 ha) and the Upper South East (324,000 ha) regions. Water repellence is also common in similar landscapes on central and north eastern Eyre Peninsula, parts of Yorke Peninsula and the Mid and Lower South East, although most is only of moderate severity.

MONITORING WATER REPELLENCE

No data is collected on the actual impact of water repellence in any one year. Land management practices carried out on siliceous sands are used as surrogate indicators.

Land Management Indicators for Water Repellence

Recognition of water repellence as an issue

In the land manager surveys an average of 39% of farmers across South Australia (Figure 41) considered that water repellent soils occurred on their property. The proportion ranged from 35% to 46% across all rainfall districts and from 22% in the Northern and Yorke Agricultural districts to 58% in Murraylands region. The average area of repellent soils was estimated to be 313 ha/manager over the two surveys.

Statewide, 58% of farmers with water repellence on their property thought that it limited their production ranging from 49% of land managers in the Northern and Yorke Agricultural Districts to 67% on Eyre Peninsula.

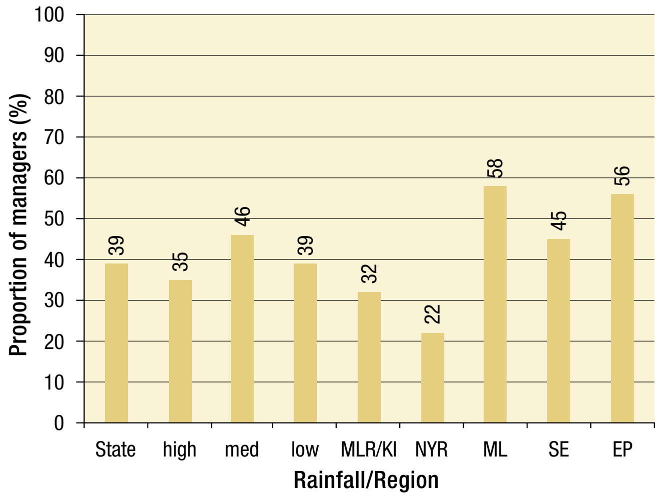
Implementing management options

A range of options has been developed for managing water repellent soils. Modified tillage technologies, sowing seed under furrows compacted with following press wheels and use of soil wetting agents in combination with tillage systems, have been tried with variable success.

More recently, mixing clay (particularly dispersive clay) with surface sand has proven an effective method for overcoming the effects of water repellence. Clay spreading has become a widely adopted practice particularly in the upper South East, where it has been very successful. Up to 200 t/ha of subsoil clay are spread and mixed with the surface soil. It is an expensive process initially, but has resulted in large yield increases in many areas.

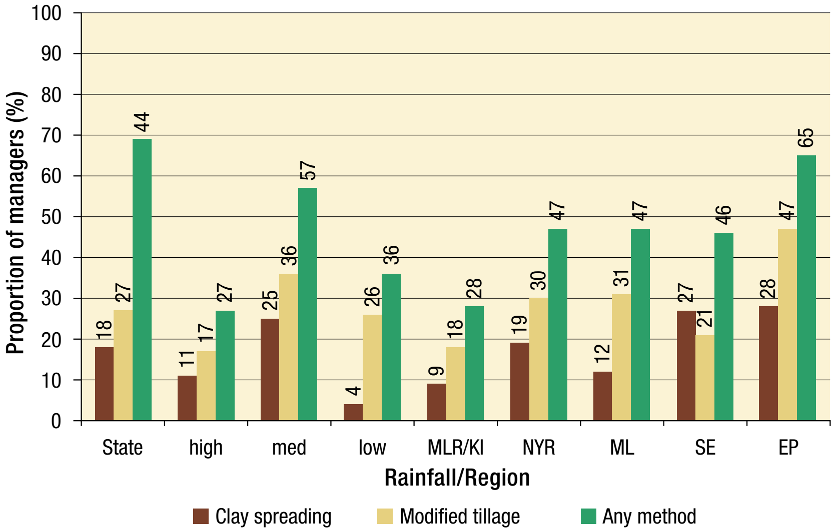
Despite the awareness, in the land manager surveys only an average of 44% of farmers who considered they had water repellent soils on their properties, had tried any of the available management options (Figure 42 - 'Any Methods') to try to improve the situation. The highest use of practices was on properties on Eyre Peninsula (65%) and the least in the Hills and Kangaroo Island region (28%).

Figure 41 Average proportion (%) of land managers considering water repellence a land management issue in their district in South Australia; LM survey 2000/2002



Clay spreading at Bordertown, South Australia
(Photo M. Cann, PIRSA)

Figure 42 Average proportion (%) of land managers using modified farm practices to overcome water repellence affects on productivity in South Australia; LM survey 2000/2002



The surveys indicated that the most frequently tried practices involved modification of tillage methods using furrow sowing with following press wheels (27%), a technique first developed in the late 1970's and early 1980's, and clay spreading (18%). Limited use had been made of clay delving (5%), probably because for many repellent soils suitable clay is not close enough to the surface. Soil wetting agents (7%) have also been tried as part of the modified tillage technique.

Clay spreading

The survey data show that, for properties where water repellence occurred, an average of 18% of farmers have used the technique. The highest average proportion was 25% in the medium rainfall areas and 28% on Eyre Peninsula. The proportion was lower in the high rainfall districts (11%), where the effects are less, and low rainfall areas (4%), where the potential for improved production is less in relation to the cost of the technique.

Regionally, the most widespread use of clay spreading has been in the South East (27%) and Eyre Peninsula (28%) and the least in the Hills and on Kangaroo Island (9%). On the properties of the farmers in the land manager surveys, an estimated 7% of the water repellent soils have been spread with clay.

WATER REPELLENCE SUMMARY

There is widespread awareness and recognition of water repellence as a land management problem. However, only half of the farmers who considered that water repellence was an issue had tried any of the available management options. There is therefore still scope for improved production and water use on significant areas of water repellent soils in South Australia.

Crop Water Use Efficiency (WUE)

BACKGROUND

Crop water use efficiency (WUE) is a measure of the amount of crop material produced per unit of water available to the crop. In dryland cropping systems this is usually expressed as kilograms of grain per millimetre of growing season rainfall. WUE can be used as an integrative indicator of limitations to crop production. A crop or pasture cannot achieve high WUE if its growth is in some way limited by adverse conditions. If a soil is being degraded it is likely to be reflected in a declining WUE.

It is not a diagnostic indicator since a low WUE value might be due to any of a range of soil and agronomic limitations. However, if there is an upward WUE trend, it is reasonable to assume that there has been an improvement in overcoming one or more of the limitations to growth. A flat trend in WUE, particularly if the level is relatively low, would suggest that either the existing limitations are intractable, or improved practices have not been adopted. A declining trend should sound a warning that limitations to plant growth are increasing, some of which might be associated with soil degradation.

MONITORING WATER USE EFFICIENCY

The amount of water used by a plant or crop is directly related to its production, so any change in yield can be generally interpreted as a proportional change in water use. The Australian Bureau of Statistics (ABS) undertake annual surveys to collect crop production data. Together with rainfall, this data is used to derive water use efficiency estimates as performance indicators for the agricultural areas of South Australia, on a Statistical Local Area (SLA) framework. Only SLA's with at least 2000 ha of crop sown in 80% of the years were included in the production and water use efficiency distribution maps.

No reliable data is available for pasture production.

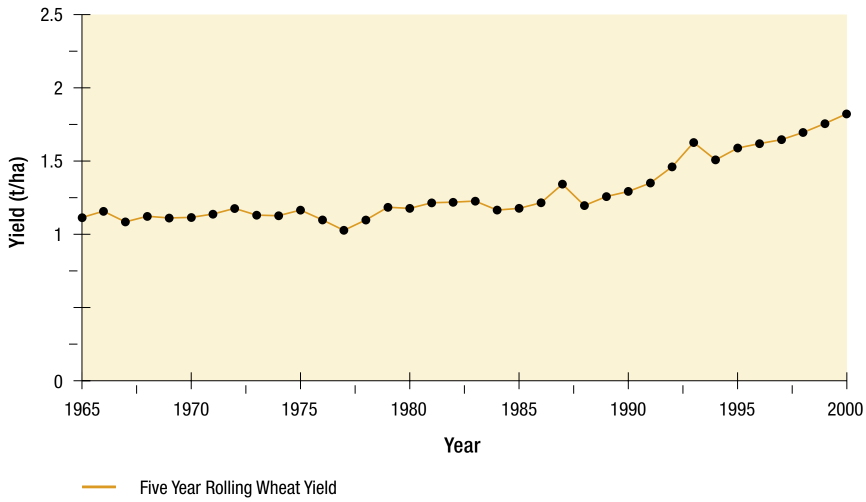
Crop Production

Crop Yield

The mean grain yield of wheat crops in South Australia has steadily increased particularly from the late 1980's, as shown by the 5 year rolling mean grain yield in Figure 43. The average wheat grain yield rose 58% from the 1965-1974 decade (1.14 t/ha) to the 1991-2000 decade (1.80 t/ha), while barley increased similarly (61%) from 1.19 t/ha to 1.92 t/ha over the same period.

More detailed data in Table 14 shows there were large differences between Statistical Local Areas across the state. While yields increased in all areas between the 1965-1974 and 1991-2000 decades, the increase ranged from only 0.03 t/ha in Ceduna SLA to 1.56 t/ha in Clare and Gilbert Valleys SLA. That represented a corresponding proportionate yield increase of 3.3% and 99.4%. The largest percentage increase was 118% in Yorke Peninsula South SLA.

Figure 43 5 year rolling mean wheat yield (t/ha) for South Australia (weighted for crop area/SLA) calculated from ABS agricultural census and survey data for the period 1965–2000



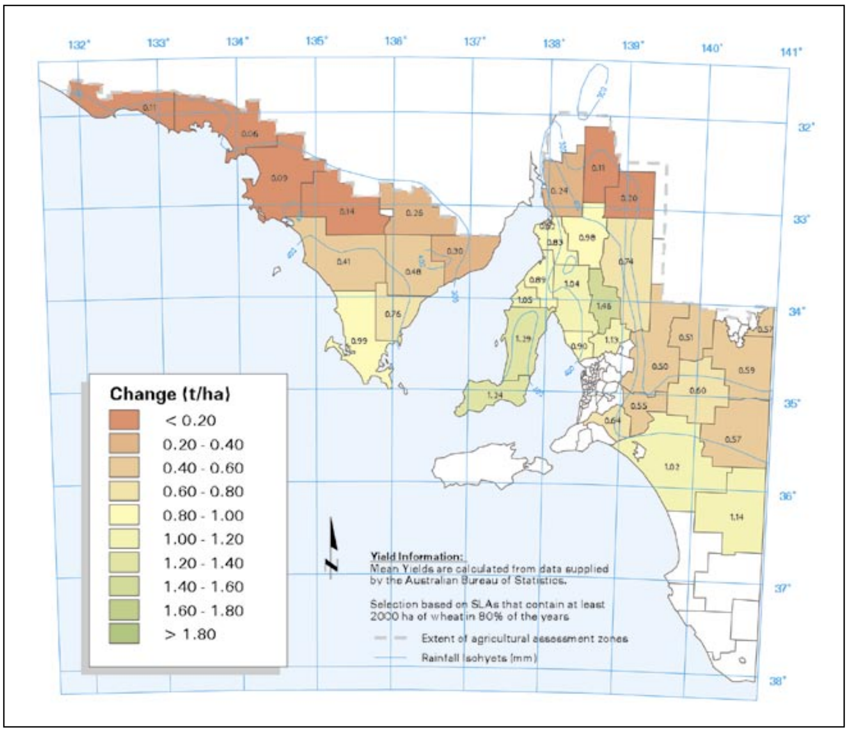


Figure 44: Change in wheat yields (t/ha) between the periods 1965–1974 and 1991–2000 for SLA's calculated from ABS agricultural census and survey data

Figure 44 shows the distribution of the wheat yield increase across South Australia and highlights the lower gains in the drier and less reliable rainfall areas of the state. The greatest gains were achieved in the more reliable rainfall areas of the Northern and Yorke Region, Lower Eyre Peninsula and Upper and Mid South East.

The mean wheat grain yield for the Northern and Yorke Region increased during the indicator periods from 1.43 t/ha to 2.31 t/ha. On the other hand, the overall Eyre Peninsula wheat grain yield increased from 1.07 t/ha to 1.37 t/ha, while for Murraylands it increased from 0.82 t/ha to 1.38 t/ha. Barley grain yields showed similar trends.

Table 14: Wheat and barley grain yield changes (t/ha) between the periods 1965–1974 and 1991–2000 in Statistical Local Areas of South Australia calculated from ABS agricultural census and survey data

	SLA	Mean Wheat Yield 1965-1974	Mean Wheat Yield 1991-2000	Change		Mean Barley Yield 1965-1974	Mean Barley Yield 1991-2000	Change	
#	Name	(t/ha)	t/ha)	(+/- (t/ha)	(%) Increase	(t/ha)	(t/ha)	(+/-t/ha)	(%) Increase
1	UnIncorp. West Coast	0.87	0.98	+0.10	11.5	0.77	1.10	+0.33	42.9
2	Ceduna	0.92	0.96	+0.03	3.3	0.83	1.02	+0.19	22.9
3	Streaky Bay	1.05	1.12	+0.07	6.7	0.98	1.28	+0.30	30.6
4	Le Hunte	1.07	1.20	+0.13	12.1	0.90	1.30	+0.40	44.4
5	Kimba	1.17	1.40	+0.23	19.7	0.90	1.47	+0.57	63.3
6	Elliston	1.12	1.55	+0.42	37.5	1.08	1.51	+0.43	39.8
7	Cleve	0.99	1.45	+0.47	47.5	0.93	1.48	+0.55	59.1
8	Franklin Harbour	0.93	1.21	+0.28	30.1	0.84	1.33	+0.50	59.5
9	Lower Eyre Peninsula	1.31	2.33	+1.02	77.9	1.35	2.21	+0.86	63.7
10	Tumby Bay	1.18	1.93	+0.75	63.6	1.20	1.98	+0.78	65.0
	Eyre Peninsula	**1.07**	**1.37**	**+0.31**	**29.0**	**1.07**	**1.63**	**+0.56**	**52.3**
13	Mount Remarkable	1.30	1.53	+0.23	17.7	1.09	1.82	+0.73	76.0
14	Orroroo-Carrieton	1.34	1.40	+0.05	3.7	1.01	1.39	+0.37	36.6
15	Peterborough	1.10	1.27	+0.17	15.5	0.87	1.21	+0.34	39.1
16	Pt Pirie City	1.00	1.44	+0.44	44.0	0.92	1.65	+0.73	79.3
17	Pt Pirie and Districts balance	1.37	2.15	+0.78	56.9	1.25	2.18	+0.93	74.4
18	Northern Areas	1.42	2.40	+0.98	69.0	1.26	2.33	+1.07	84.9
19	Goyder	1.24	1.95	+0.72	58.1	1.09	1.97	+0.88	80.7
20	Barunga West	1.46	2.40	+0.94	64.4	1.43	2.34	+0.91	63.6
21	Copper Coast	1.46	2.65	+1.19	81.5	1.38	2.65	+1.27	92.0
22	Wakefield	1.38	2.46	+1.08	78.3	1.24	2.33	+1.09	87.9
23	Clare and Gilbert Valleys	1.57	3.13	+1.56	99.4	1.48	2.73	+1.24	83.8
24	Yorke Peninsula North	1.54	2.91	+1.37	89.0	1.59	2.65	+1.06	66.7
25	Yorke Peninsula South	1.11	2.42	+1.31	118.0	1.33	2.29	+0.96	72.2
26	Mallala	1.28	2.18	+0.90	70.3	1.16	2.02	+0.86	74.1
27	Kapunda and Light	1.55	2.72	+1.17	75.5	1.54	2.46	+0.92	59.7
	Northern and Yorke	**1.43**	**2.31**	**+0.89**	**62.2**	**1.62**	**2.36**	**+0.74**	**45.7**
33	Mid Murray	0.89	1.43	+0.54	60.7	0.86	1.53	+0.67	77.9
34	Murray Bridge	0.95	1.49	+0.54	56.8	0.80	1.39	+0.59	73.8
35	Alexandrina Strathalbyn	1.24	1.83	+0.59	47.6	1.19	1.81	+062	52.1
36	Loxton Waikerie West	0.57	1.02	+0.45	78.9	0.49	1.07	+0.58	118.4
37	Loxton Waikerie East	0.68	1.25	+0.57	83.8	0.53	1.22	+0.68	128.3
38	Renmark-Paringa Paringa	0.73	1.26	+0.53	72.6	0.64	1.23	+0.59	92.2
39	Karoonda East Murray	0.67	1.26	+0.60	89.6	0.63	1.14	+0.51	81.0
40	Southern Mallee	1.16	1.72	+0.56	48.3	0.83	1.43	+0.60	72.2
	Murraylands	**0.82**	**1.38**	**+0.55**	**67.1**	**0.74**	**1.34**	**+0.61**	**82.4**
43	The Coorong	0.91	1.87	+0.96	105.5	0.90	1.61	+0.71	78.9
44	Tatiara	1.47	2.53	+1.06	72.1	1.15	1.89	+0.73	63.5
45	Lucindale Naracoorte	1.57	2.77	+1.20	76.4	1.24	2.31	+1.08	87.1
	South East	**1.24**	**2.20**	**+0.96**	**77.4**	**0.95**	**1.70**	**+0.75**	**78.9**
	South Australia	**1.14**	**1.80**	**+0.66**	**57.9**	**1.19**	**1.92**	**+0.73**	**61.3**

Figure 45a: Wheat yields in Wakefield Statistical Local Area calculated from ABS agricultural census and survey data for the period 1965–2000

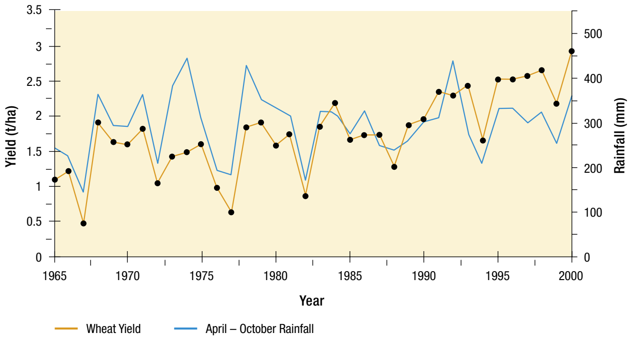


Figure 45b: 5 year rolling wheat yields in Wakefield Statistical Local Area calculated from ABS agricultural census and survey data for the period 1965–2000

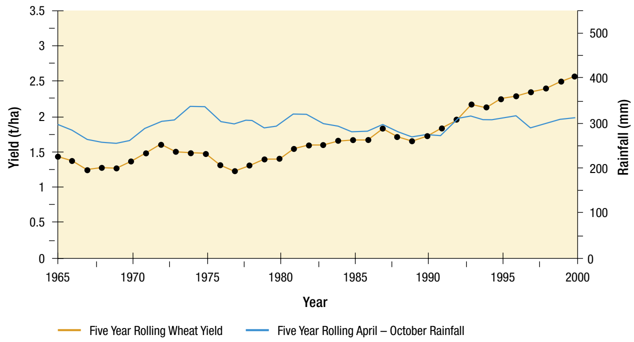


Figure 46a: Wheat yield for Unincorporated West Coast Statistical Local Area calculated from ABS agricultural census and survey data for the period 1965–2000

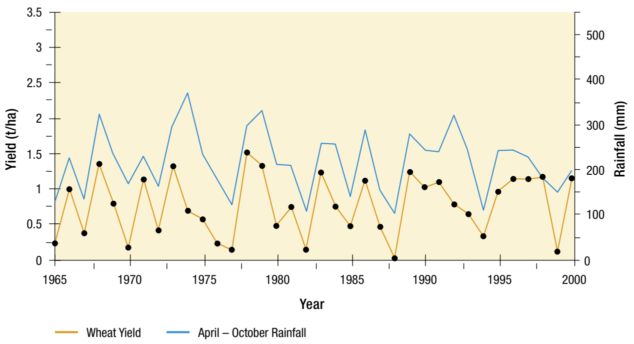
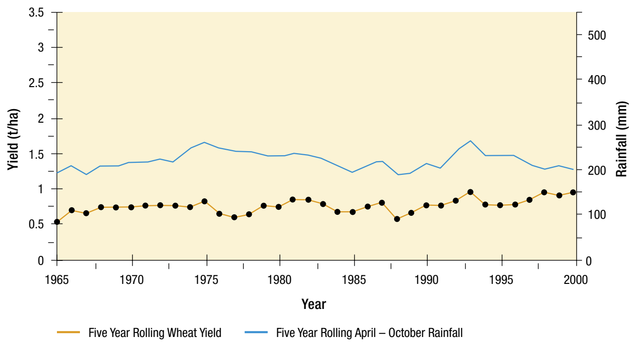


Figure 46b: 5yr mean rolling wheat yield for Unincorporated West Coast Statistical Local Area calculated from ABS agricultural census and survey data for the period 1965-2000



The South Australian climate is highly variable between years, as are crop yields. The variability is seen in a relatively reliable Wakefield SLA cropping area (Figure 45a), in the mid Northern and Yorke Region, as well as the lower rainfall Unincorporated West Coast SLA (Figure 46a), on far western Eyre Peninsula. Wheat yield is strongly correlated with the April October rainfall received.

Rolling 5 year mean grain yield data was used to smooth the variability and demonstrate the trends more clearly. The data in Figure 45b show the marked increase in grain yield in Wakefield SLA since the 1980's. In contrast, there was only a small gain in grain yield over the same period in Unincorporated West Coast SLA (Figure 46b).

Crop Water Use Efficiency

Crop yield can be related to rainfall water use by using the Potential Yield model of French and Schultz (1984). The proportion of rainfall-limited crop yield potential achieved is used as the main monitoring statistic for cereal crop water use efficiency (WUE).

The proportion of the combined wheat and barley yield potential achieved in South Australia is shown in Figure 47a and 47b. Figure 47a shows that there is significant annual variation in the proportion of yield potential achieved. However, the 5 year rolling mean in Figure 47b clearly shows that the overall combined proportion of yield potential achieved in South Australia increased significantly from around 30% in the 1980's to almost 60% in 2000.

Similar data are shown in Figures 48 and 49 for the two SLA's, Wakefield in the mid Northern Agricultural Districts and Unincorporated West Coast, on far western Eyre Peninsula. Although there is a direct relationship between rainfall and crop yield, the data for both SLA's in Figures 48a and 49a, illustrate that WUE is usually higher in dry rather than wet years. This is because there is relatively less loss of water directly from the soil surface through evaporation or run-off, or from deep percolation through the soil profile beyond the crop rooting depth.

Figure 47a: Mean proportion of combined wheat and barley yield potential (%) achieved for South Australia (area weighted) calculated from ABS agricultural census and survey data for the period 1965-2000

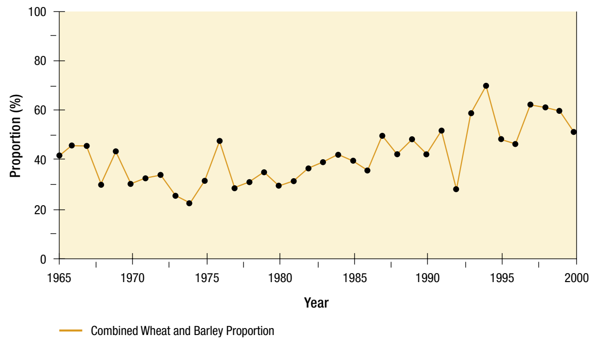


Figure 47b: 5 yr mean rolling proportion of combined wheat and barley yield potential (%) achieved for South Australia (area weighted) calculated from ABS agricultural census and survey data for the period 1965-2000

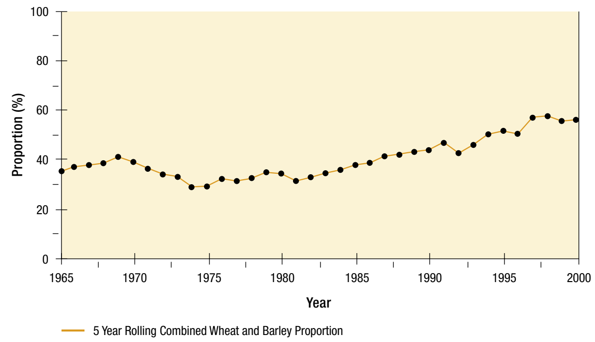


Figure 48a: The mean proportion of combined wheat and barley yield potential achieved in Wakefield SLA in South Australia (area weighted) calculated from ABS agricultural census and survey data for the period 1965-2000

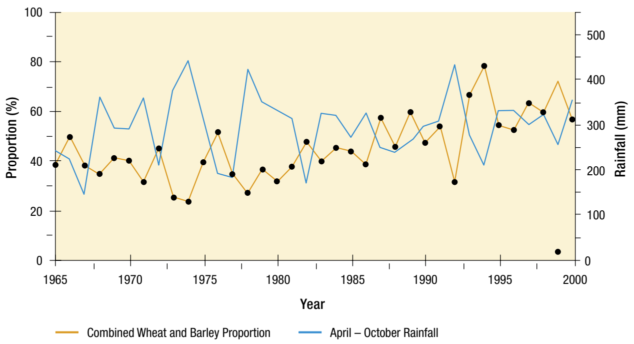


Figure 48b: 5yr rolling mean proportion of combined wheat and barley yield potential achieved in Wakefield SLA in South Australia (area weighted) calculated from ABS agricultural census and survey data for the period 1965-2000

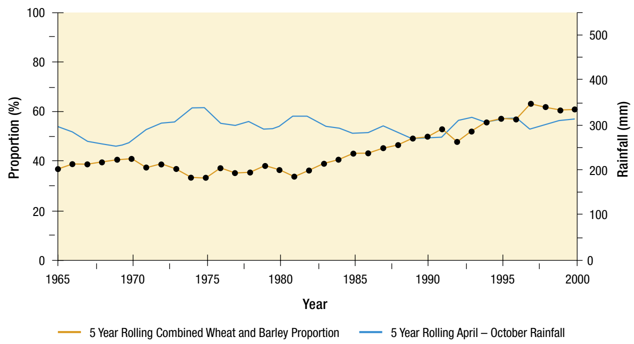


Figure 50 shows the distribution of the percentage change in the proportion of the combined wheat and barley yield potential achieved between the decade periods 1965-1974 and 1991-2000. The proportion of the yield potential that has been achieved by crops across South Australia rose by 18% absolute from a mean of 34% in 1965-1974 to

52% in 1991-2000 (mean of SLA's). The proportion increased in all SLA's, but there was a wide range in the improvement from 7-9% in Streaky Bay, Mount Remarkable and Murray Bridge SLA's to 38% in Loxton-Waikerie West in the northern Murray Mallee. Increases were most consistent in the more reliable districts of the Lower Eyre Peninsula, much of the Northern and Yorke Agricultural Districts and the mid and upper South East. Similar gains were also made in the Northern Mallee, although they were based on very low initial levels in this district for the 1965-1974 period.

Land Management Indicators for Water Use Efficiency

In the land manager survey carried out across the State in March 2000 and 2002, the majority (an average of 54%) anticipated that they would maintain the crop area sown, while a further 16% indicated an intention to increase the area sown. The most significant increases intended were in the low rainfall areas (33%) and, by region, in Murraylands (27%) and Eyre Peninsula (26%) regions.

If increased cropping brings land with more limitations or greater degradation potential into production, there might be a downward pressure on average WUE. This is not evident in the data to date.

The practice of farmers monitoring WUE using models like French and Schultz (1984), is widely understood and recognised by land managers in the survey. In the 2000 and 2002 surveys, 78% believed it was possible to improve WUE and 65% thought it would be economically worthwhile (Figure 51).

Figure 49a: The mean proportion of combined wheat and barley yield potential achieved in Unincorporated West Coast SLA in South Australia (area weighted) calculated from ABS agricultural census and survey data for the period 1965-2000

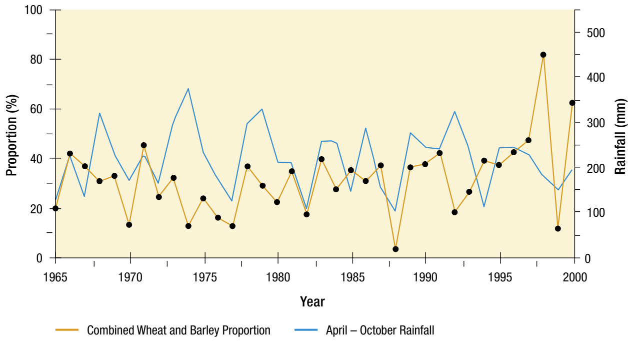
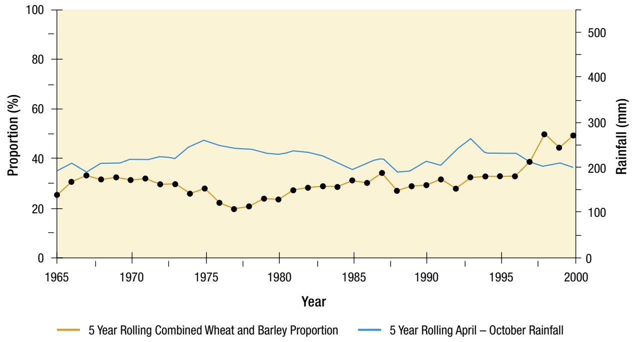


Figure 49b: 5yr rolling mean proportion of combined wheat and barley yield potential achieved in Unincorporated West Coast SLA in South Australia (area weighted) calculated from ABS agricultural census and survey data for the period 1965-2000



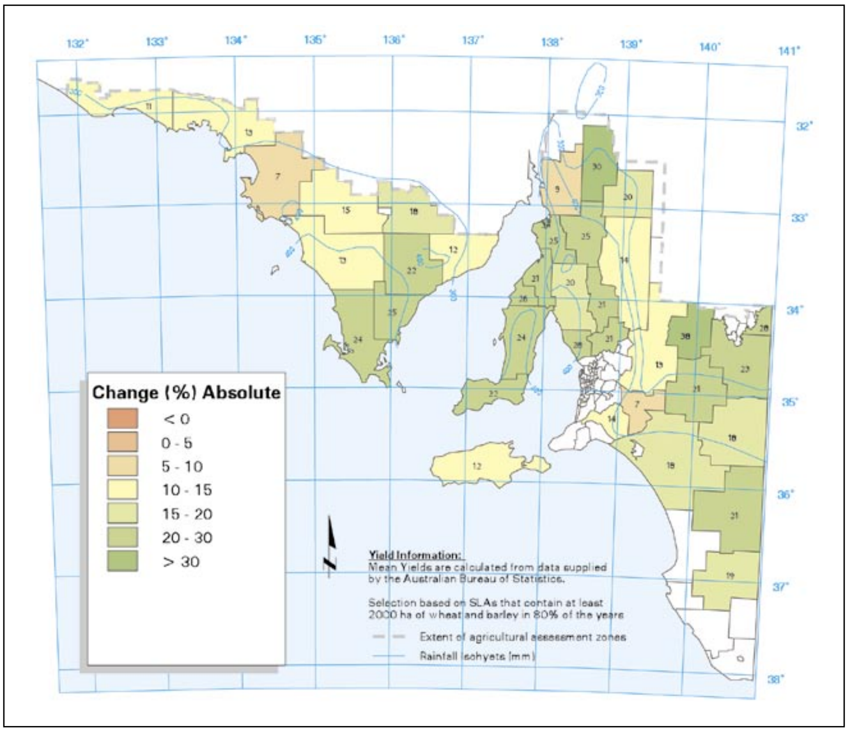
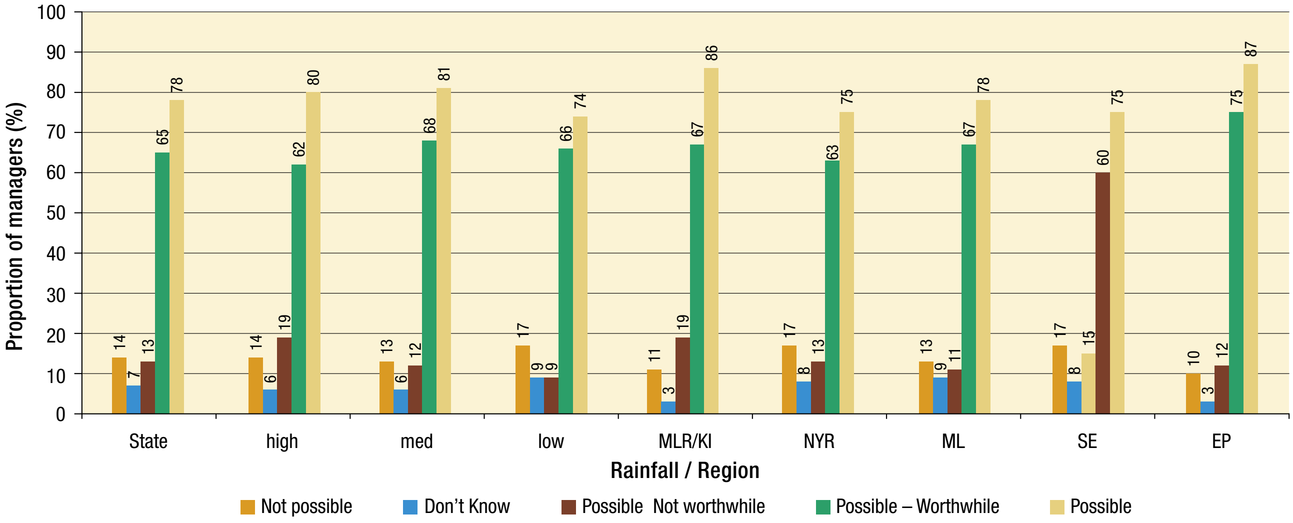


Figure 50: Percentage change (% absolute) in the proportion of the combined wheat and yield potential achieved between the periods 1965-1974 and 1991-2000 for SLA's calculated from ABS agricultural census data

Figure 51: Average proportion (%) of land managers holding beliefs with regard crop production and economic improvement from rainfall received in South Australia; LM survey 2000/2002



WATER USE EFFICIENCY SUMMARY

Grain yields of both wheat and barley have increased steadily since the mid 1980's, largely because of improved agronomic practices. Improved yield is also an indirect indicator of improving crop growth and ground cover and the likelihood of an improving economic return that is necessary to encourage and fund better land management on agricultural land.

Water use efficiency of wheat and barley crops improved with the proportion of yield potential achieved incresing from 34% to 52% in South Australia between 1980 and 2000. The largest and most consistent improvements have generally been in the more reliable rainfall districts, and this indicates that significant limitations to crop growth have been overcome during the period. The gains in WUE are positive but generally less in the lower rainfall districts, implying either that the limitations are relatively more intractable or that improved farming systems are not being adopted at as great a rate.

In both higher and lower rainfall districts, significant gains in crop production and WUE are still theoretically possible. However, limitations to root growth in hostile subsoils remain significant barriers to achieving those gains. The current data shows that all trends in WUE are positive, when averaged over large areas, although it is still possible that individual paddocks have shown a reduced WUE due to degradation such as wind or water erosion.

Revegetation

BACKGROUND

Perennial vegetation has a number of important positive impacts on the landscape. Without the need for regular cultivation, the soil surface is largely protected from erosion and structure decline. Deep-rooted perennial species also allow less water to pass their root systems into underlying groundwater. They therefore minimise contribution of rainfall to groundwater rise and soil salinity development.

Woody perennial trees and shrubs, particularly local native species, provide the basis for native ecosystem preservation and restoration. Remnant native vegetation in South Australia has been mapped (Department of Environment and Heritage) and its distribution is shown on many of the maps in this report. Of the 15 million ha of land in the agricultural districts of South Australia, only around 3.2 million ha (21.3%) remain under remnant native vegetation. Approximately 600,000 ha native vegetation on private land is now protected through Heritage Agreements. Hundreds of thousands of hectares are also incorporated in parks and reserves. A significant problem from an ecosystem integrity viewpoint, is uneven distribution. For example, in parts of the Northern Agricultural Districts less than 1% of the original vegetation remains.

Loss of such a large proportion of perennial vegetation systems has created a number of adverse environmental consequences. Biodiversity, salinity mitigation, buffering streams against pollution, protection of agriculture with shelter belts and wind breaks, or general land stabilisation and permanent protection of water courses and gullies, are all issues which might be addressed to some extent by revegetation

There is a range of revegetation options. In farming systems, lucerne is currently the most economically important deep-rooted perennial. It is a high quality pasture sown widely particularly in the South East region. A wide range of other perennial species has a direct economic value for grazing (eg. tagasaste, saltbush), timber (pine, various Eucalyptus species) or other purposes (eg. native species for cut flowers). These all can play an important revegetation role in a long-term vision for productive and sustainable farming systems.

Fodder Tagasaste trees planted on a sandhill at Marcollat, South Australia (Photo Z. Stokes, PIRSA)

However, accelerating revegetation with native species is important for supplementing the paucity of remnant vegetation in South Australia, particularly where little remains.

It is a key ingredient for enhancing biodiversity as well as contributing to landscape stability and salinity mitigation. For these reasons, it is the main revegetation focus and indicator in the Land Condition Monitoring Program

MONITORING REVEGETATION

Methodology for Estimation of Revegetation Area

Revegetation with perennials represents a fundamental change in land use, generally to a more stable system than cropping. The area planted is a key indicator. Two methods for estimating the area of revegetation are reported below.

The first method specifically targets known revegetation, with estimates based on the records of revegetation contractors and nursery sales, as well as Natural Heritage Trust funded programs. The method provides a useful comparison between regions.

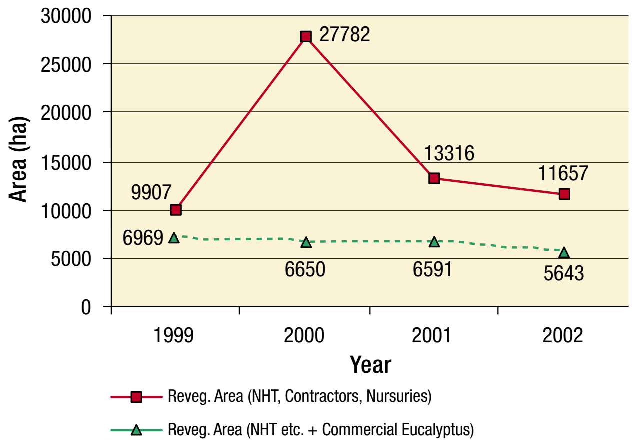
The estimates do not include fencing off of remnant vegetation, commercial plantings of pines or the area of plantings by individual landholders from their own private propagation of seedlings or seed collection.

The second method uses the statewide land manager surveys of 2000 and 2002 to estimate the area of perennial vegetation. This included the fencing off of remnant vegetation, revegetation plantings ranging from indigenous species to exotic plantation timber species and areas planted by individual landholders from their own private propagation of seedlings or seed collection.

1). Natural Heritage Trust, Contractors and Nurseries

Estimates of revegetation based primarily on NHT planting records show that in 1997 and 1998 nearly 6,000 ha were revegetated annually by tubestock and direct seeding (Dalby 1999). More recent estimates from revegetation contractors and nurseries (Wilson 2003) indicated that total plantings increased to nearly 10,000 ha in 1999 and peaked at almost 28,000 ha in 2000. Subsequently, the area of revegetation has fallen to around 11,600 ha in 2002 (Figure 52). The data included direct seeding and tubestock planting of indigenous species, as well as planting non-provenance native species, fodder and product shrubs, and farm and plantation hardwood forestry species. The data does not include new commercial plantings of pines.

Figure 52: Estimated area (ha) of revegetation in South Australia for the period 1999-2002. *Data from Wilson (2003 a)*



The area of new Blue gum (*E.globulus*) and other hardwood plantations was the main difference between years, when comparing total estimates. An estimated 21,000 ha of Eucalypt plantations were established in 2000, compared with the 3,000 to 6,000 ha in other years of the 1999-2002 monitoring period. There was a decrease in the expected revegetation in 2002, perhaps because of the dry conditions affecting most of the State.

The area of indigenous (4,000 ha/yr), native non-indigenous (400-1,000 ha/yr) remained relatively stable from 1999 to 2002. Saltbush (1,200-1,400 ha/yr) plantings were consistent to 2001 but fell to 300 ha in 2002.

The distribution of revegetation is highlighted in Table 15. Around 74,000 ha has been undertaken across the State since 1997 with most in the South East and Mount Lofty Ranges/Kangaroo Island regions.

2). Land manager survey

The variability and low number of responses in most categories means there is insufficient data for reliable estimates of revegetation in regions or rainfall zones. The data is aggregated up to a State level from random sampling across the agricultural areas of the State. While the statewide estimates are more variable, the data provides similar results to that from Method 1. Total estimated plantings in 1999 were in the order of 16,000 ha but declined to around 4,500ha in 2001. The data represents the areas planted on the properties of individual landholders, including farm forestry, but not commercial softwood or hardwood plantations.

There is an additional area of remnant vegetation fenced off to either protect it from decline or enhance regeneration. An estimated 12,000 ha and 7,000 ha of remnant vegetation was protected by fencing in 1999 and 2001 respectively.

Statewide levels of revegetation were;

> **Fencing remnant native vegetation –** In 1999, 15% of landholders fenced an average area of 4.8 ha each and 5% had also fenced 15km of remnant vegetation belts. The highest regional figure was for the South East, which broadly reflects Natural Heritage Trust investment in local devolved grant schemes. In 2001 the area fenced declined significantly - 11% fenced 5.7 ha and 5% had fenced 0.2 km of belts. The largest reported individual area fenced off was 600 ha in 1999 and 2,400 ha in 2001, although 61% of fencing was less than 10 ha.

> **Planting local native species –** In 1999, 18% of landholders planted an average area of 4.5 ha each and 10% planted strips averaging 0.3 km. In 2001 14% planted areas of 1.9 ha and 4% planted strips averaging 0.09 km. The largest reported individual area planted to local native species was 200 ha in 1999 and 500 ha in 2001, although most plantings (88%) were less than 10 ha.

> **Planting of non-local native species –** In 1999, 14% of landholders planted an average area of 3.9 ha each and 8% planted strips of 0.2 km. In 2001 - 11% planted areas of 0.4 ha and 4% planted strips averaging 0.07 km. The largest reported individual area planted was 300 ha in 1999 and 50 ha in 2001 with most (89%) less than 10 ha.

Table 15: Regional distribution (ha) of revegetation (not including pine forestry) in South Australia, 1999-2002. *Data from Wilson (2003 a)*

	Year				
Region	**1999**	**2000**	**2001**	**2002**	**Total**
Eyre Peninsula	1,243	1,020	532	456	3,251
Northern and Yorke	456	710	497	708	2,371
Mount Lofty Ranges	660	337	576	381	1,954
Murraylands	404	962	841	629	2,836
Kangaroo Island	2,338	6,002	2,261	3,149	13,730
South East	3,604	18,482	7,329	5,880	35,295
State (Region unknown)	1,184	269	1,279	453	3,185
TOTAL	**9,889**	**27,513**	**13,315**	**11,656**	**62,642**

> **Planting of fodder trees and shrubs –** In 1999, 5% of landholders planted an average area of 0.7 ha each and 1% planted strips averaging <0.1 km. In 2001 the amount of planting was similar - 7% planted an average area of 0.9 ha and 1% planted strips of <0.1 km. The largest reported individual area planted was 100 ha in 1999 and 240 ha in 2001 with most (76%) less than 10 ha.

> **Planting trees and shrubs for a specific product –** In 1999, 4% of landholders planted an average area of 1 ha each and 1% planted strips averaging <0.1 km. In 2001 – 3% planted an average area of 0.7 ha and 1% planted strips <0.1 km. The largest reported individual area planted was 150 ha in 1999 and 148 ha in 2001 with most (77%) less than 10 ha.

The data highlighted that:

a) Revegetation is carried out on relatively few properties,

b) Individual areas of revegetation vary widely, and,

c) Most revegetation is in quite small areas.

Other Revegetation Indicators

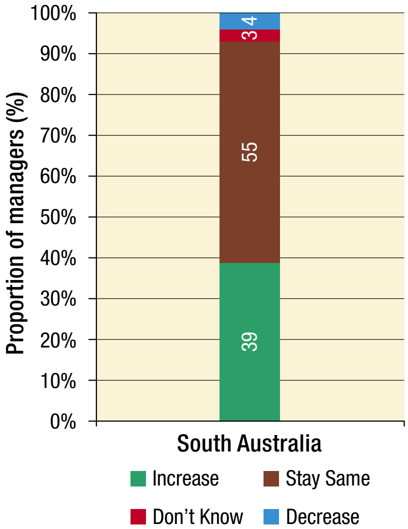
Benefits of revegetation

The data from the land manager surveys is quite variable and no regional or rainfall zone pattern was detected. Most plantings were single or double line amenity plantings or windbreaks rather than blocks and most landholders at this stage see few benefits in terms of direct income from revegetation products. In the 2000 and 2002 surveys a significant proportion of landholders recognised there were benefits from shelterbelts for stock (an average of 37%), erosion prevention (24%), fodder for stock (20%), salinity control (16%) and shelter belts for protecting crops and pasture (15%). Shelter belts to protect stock were the most frequently recognised main benefit in all regions (31-43%) except on Eyre Peninsula, where prevention of erosion (38%) was most important.

Barriers to revegetation

High cost of establishment (20%), particularly fencing (14%), and lack of time available to do the work (25%), together with loss of productive land or no land available (20%), were identified as the main barriers to undertaking greater areas of revegetation. In the South East many respondents could not nominate any barriers but the most frequent concern (23%) was the overall cost, while in the Northern Agricultural Districts the main barrier was the perceived lack of availability of suitable land (33%). Productive land was not considered an option for revegetation. In the other regions the main concern was the lack of time to undertake the planting.

Figure 53: The proportion (%) of land managers intending to plant perennial vegetation in the next 5 years in South Australia; LM survey 2000/2002



REVEGETATION SUMMARY

Overall, the data highlight;

1). That the rate of revegetation on farms is relatively low, in the context of the total area of agricultural land.

2). An apparent decline in the rate of revegetation and remnant vegetation fencing between 1999 and 2001.

Despite this, 39% of land managers (Figure 53) indicated they intended to increase their perennial vegetation planting over the next 5 years. While there is widespread interest and endeavour, only small areas tend to be established at any one time. These are likely being targetted at small local issues, through NHT projects and as a result of general increase in environmental awareness. However, the rate of revegetation, dispersed as it is across the whole landscape, would need to increase many times over to achieve a scale likely to significantly ameliorate dryland salinity or other degradation issues.

There is a range of perceived barriers to investment in revegetation on farms and economically viable production systems and industries need to be developed for medium and low rainfall areas if a major impact is to be achieved.

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