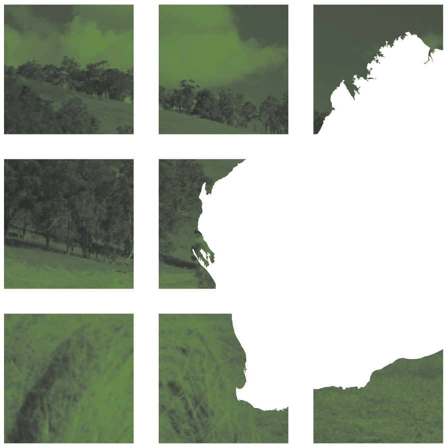
STATE OF THE ENVIRONMENT REPORT Western Australia 2007

Theme 3

KEY FINDINGS

- There is inadequate information about WA soil and landform condition.
- Vegetation cover, which provides a protective layer for land, decreased in 64% of monitored bioregions in the South West between 1996 and 2004.
- Vegetation cover decreased in 22% of monitored bioregions in the rangelands over the last decade.

LAND



INTRODUCTION

Western Australia has a total land area of 253 million hectares, equivalent to one-third of Australia. The Western Plateau is the dominant landmass, consisting of very old rocks, some over 3000 million years old. Several areas have been given individual 'plateau' names such as Kimberley, Hamersley, Arnhem Land and Yilgarn. In the Perth area, younger rocks along the Swan Coastal Plain are separated from older parts by the Darling Fault escarpment. The Nullarbor Plain is an uplifted limestone sea floor, estimated to be 25 million years old.

The land resource is fundamental for sustaining life and ecological processes. It is essential for supporting native ecosystems and maintaining biodiversity; providing a foundation for humans to live; supporting the production of food, fibre, timber and minerals; preserving historical and landscape information; and supporting spiritual, recreational, scientific, cultural and educational values.

Landscapes include landform, soils, human settlements and all natural resources and ecosystems on the land, including inland waters and biodiversity. However, landform and soils are the focus of this theme; the other aspects of landscape have been addressed elsewhere in this report. The land resource has been highly modified since European settlement. Native vegetation, which provides a protective cover for the land, has been removed or degraded in many areas to allow for urbanisation, agriculture, mining, pastoralism and infrastructure development (including buildings, pipelines, roads and railways). The amount and rate of removal or degradation of native vegetation is a consequence of population growth, the consumption of natural resources to support it and economic productivity (see '*Fundamental pressures*'). Altering land from its natural state inevitably results in changes to soil health and landscape functionality. If persistent, these changes can lead to environmental problems and rapid deterioration of both aquatic and terrestrial ecosystems.

Objectives

- Protect and enhance the condition of the State's land resources so that they sustain other natural resources and productive capacity.
- Reduce and eliminate where practical the major processes that degrade or threaten to degrade the State's land resources and its associated environmental values.
- Conserve land resources, landscapes and land values identified as most important to the State. Manage and use the land resource in a sustainable manner and rehabilitate land where practical.
- Ensure that land users have production systems based on land capability, innovation and the best possible management practices.

Headline indicators

Indicator L1: Percentage of monitored bioregions in the South West showing a net decline in vegetation cover.

Land Monitor satellite images between 1996 and 2004 provide a measure of change in vegetation cover, with 64% of monitored bioregions showing a net decline and 36% showing a net increase. There are thirteen bioregions in the South West, which includes the land between Geraldton and Esperance. A decline in South West vegetation cover is likely to have contributed to several land issues including salinisation, erosion and loss of soil health. There was no information available for two of 13 bioregions.

Indicator L2: Percentage of monitored bioregions in the rangelands where a net decline in vegetation has occurred.

Declines in rangeland vegetation contribute to soil erosion and loss of soil health. Changes to perennial shrubland density and grassland frequency are assessed at sites in the Western Australian Rangelands Monitoring System (WARMS). Site comparisons were made between recent and historical assessments – roughly three years apart in the Kimberley and five years apart in other rangeland areas. Only 22% of monitored bioregions showed a net decline in rangeland vegetation (that is, more sites showed a decline compared to those that remained stable or improved). Seventy eight per cent of monitored bioregions showed either no change or a net increase in rangeland vegetation. There was insufficient or no information for 14 of 41 bioregions in the State's rangelands, located mostly in the interior desert region.

Overall condition

Landforms are the terrain and underlying rocks and soils that help shape the land. In WA they include major features such as basins, plains, plateaus and ranges, and minor features such as hills, valleys, slopes and dunes. Mining activities, road construction and development of human settlements have the largest impact on natural landforms. Mining involves the extraction of minerals and ores from hills and ranges (e.g. pits or quarries), often resulting in significant landform modification. New landforms can be created (e.g. artificial hills) as a result of dumping of waste rock left over from mining. Landforms are also modified to make the land more suitable for human settlements, such as providing for transport, infrastructure, and the construction of houses. At this time, it is not possible to broadly assess landform condition in WA.

Soils consist of small rock and mineral particles (which may include mixtures of clay, silt, sand and gravel), organic material, air, moisture and living organisms. Humans often modify soil properties to enhance plant growth, build infrastructure, increase water infiltration, and resist erosion by wind and water. When soils are used beyond their natural capacity, soil rehabilitation and treatments are often required. Generally, information about soil condition is only collected where it is considered to be of value for determining agricultural or pastoral productivity. At this time, it is not possible to broadly assess soil condition in WA.

Agricultural productivity can provide a general indication of soil condition. Soils in good condition are generally more productive and profitable than those with nutrient deficiency, poor structure, low organic content, or affected by salinisation, acidification, contamination or erosion. Profit-at-full equity for farmland represents the economic return on the land from agriculture and pastoralism (Commonwealth of Australia, 2001b; Figure L0.1). These data must be interpreted with some caution given their age and the limited number of farms actually surveyed. However they provide a general indication of land productivity across the State. Land in the South West is generally more profitable than in the rangelands where returns are typically lower. However, negative returns are also evident in some parts of the South West, which may indicate marginal productive farmland or land degradation problems (such as salinisation, acidification, erosion and loss of soil health). While there are many options to make soils more productive, the challenge is to ensure these methods are implemented across a wide scale.

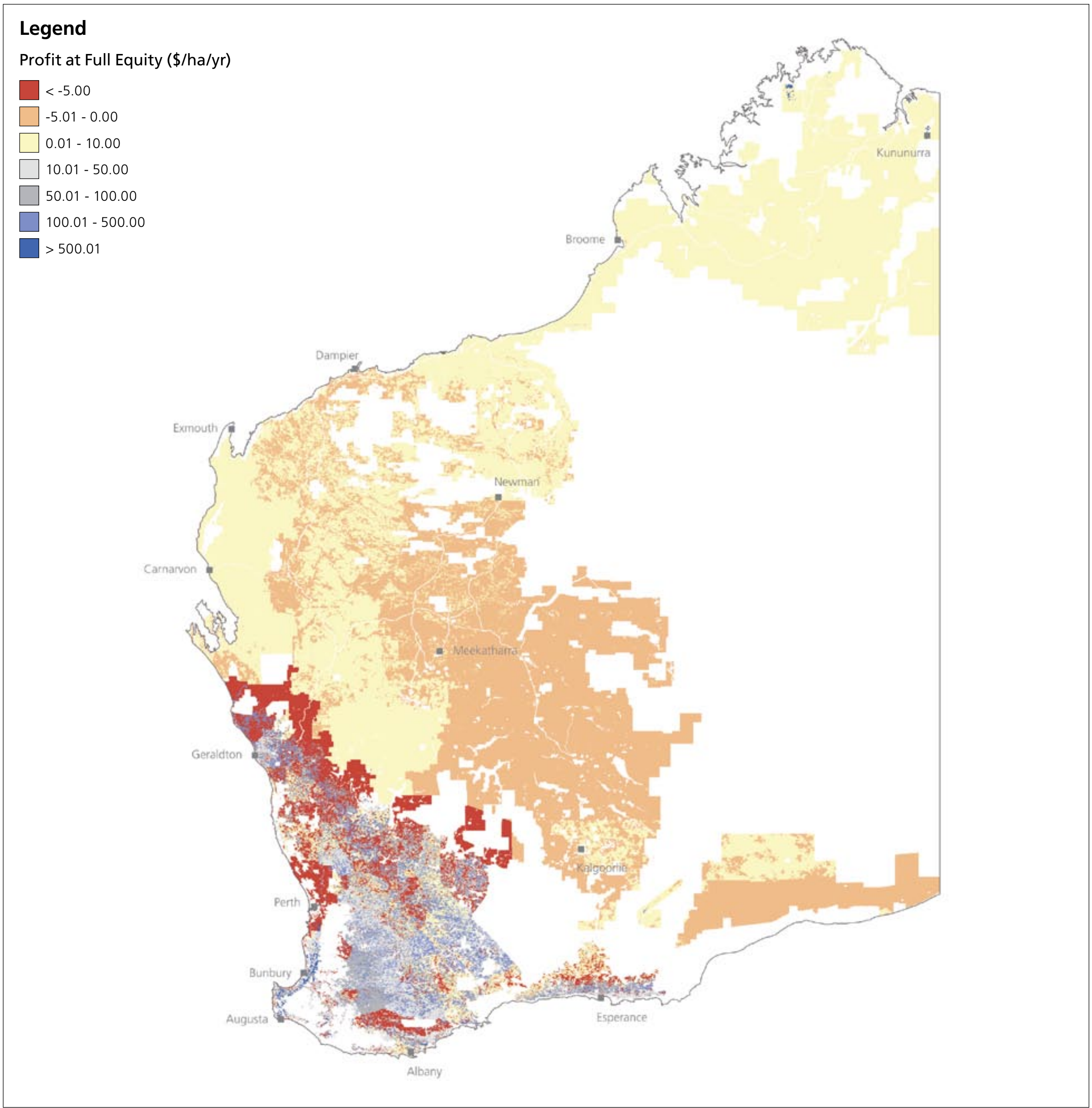


Figure L0.1: Profit-at-full-equity for agriculture, a five-year average, 1992–97.

Data source: CSIRO [ver.1997]; Analysis: CSIRO; Presentation: EPA.

Western Australia has an abundance of unique geological landforms, such as those found in Purnululu National Park (Tourism WA)

Effectiveness

Fifty actions were identified for the '*Land*' theme in response to the 1998 *State of the Environment Report* (Government of Western Australia, 1998). Of these 28% remain incomplete, 60% have been completed but not evaluated, and only 12% have been completed and evaluated. With the exception of land salinisation, monitoring of other land issues is sparse and relies heavily on modelling. In addition, the effects of on-ground actions are difficult to detect and it may take many years of monitoring before environmental outcomes become apparent. Consequently, even though a large proportion of these programs are complete, it has been very difficult to evaluate actual environmental outcomes, and increased monitoring and evaluation efforts are urgently needed. Initiatives of the National Action Plan for Salinity and Water Quality and the Natural Heritage Trust programs may improve monitoring of land issues, such as land salinity, soil erosion and soil acidification.

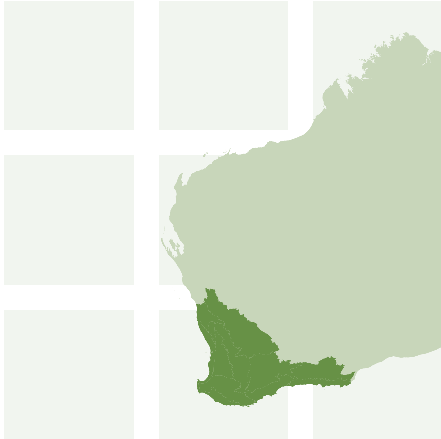
SUGGESTED RESPONSES

3.1 Develop and implement a State Soil Protection Policy to ensure that all soil resources are managed in a sustainable manner and protected for the long term.

See also '*Loss of degradation of native vegetation*':

- Prohibit clearing in local government areas with less than 15% native vegetation remaining and prohibit further clearing of vegetation types that have less than 10% of their pre-European extent.
- Develop and implement a policy of 'no net loss' of native vegetation due to land use that comprehensively considers biodiversity values in clearing applications.
- Establish a central database to make information on all clearing activities (including environmental impact assessment) publicly available.
- Carefully monitor for illegal clearing and breaches of conditions set under the *Environmental Protection Act 1986* and take appropriate action should they occur.

3.1 LAND SALINISATION



INDICATIVE EXTENT OF ISSUE

PRIORITY RATING: 1

KEY FINDINGS

- It is estimated that 75% of Australia's dryland salinity problem is in WA.
- About 1.1 million hectares of South West land is currently salt-affected.
- Over 14 000 hectares of land is lost to land salinisation each year (equivalent to 19 football ovals per day).

Description

Saline landscapes are a natural feature of low rainfall parts of WA to which many flora and fauna species have adapted over time. Salt is normally stored deep in the soil below the root zone of native vegetation. Problems arise when unaffected land becomes salty due to widespread land clearing and replacement of native vegetation with annual crops and pastures that use less water. This can have deleterious impacts for native ecosystems that are not accustomed to persistent elevated salinity.

Shallow rooted annual crops and pastures and bare soil typically use much less water compared to native vegetation. Excess water not used by vegetation seeps into the soil, past the root zone, and contributes to groundwater stores. This increase in storage in areas from which native vegetation has been removed occurs at a much faster rate than would otherwise occur naturally. Over time, continued recharge causes groundwater watertables to rise, bringing with them salt stored deep in the soil. For this reason it may take several decades for land salinisation to become noticeable on the land surface following clearing of native vegetation. This process is called 'dryland salinisation' and now affects a significant area of agricultural soils in the South West (Government of Western Australia, 2000). Local geology, topography and groundwater aquifer characteristics also play an important role in the susceptibility of land to salinisation.

Land salinisation can also result from irrigation of agricultural land. 'Irrigation salinity' is typically caused by recharge of groundwater from excessive irrigation and leakage from irrigation channels, causing watertables to rise and bringing salt to the surface. In both dryland and irrigation salinity, saline groundwater near the soil surface kills native vegetation, reduces biodiversity, results in loss of agricultural productivity, and damages infrastructure.

Objectives

The *State Salinity Strategy* lists specific goals for managing the impact of land salinisation in the South West agricultural zone (Government of Western Australia, 2000). Objectives relevant to the land resource include to:

- Reduce the rate of degradation of agricultural and public land, and where practical recover, rehabilitate or manage salt-affected land;
- Protect and restore high value natural ecosystems and maintain natural diversity (biological and physical) within the South West; and
- Provide communities with the capacity to address salinity issues and to manage the changes brought about by salinity.

Condition

Indicator L3: Area of salt-affected land.

The National Land and Water Resources Audit estimated that about 75% of Australia's dryland salinisation problem is in WA, the worst affected area being the South West agricultural zone (Commonwealth of Australia, 2001a). The extent of salt-affected land has historically been difficult to ascertain. Modelling methods, expert assessments and farmer surveys have produced estimates of area affected and possible trends that often disagree. Recent analysis of Land Monitor data, using a combination of satellite imagery and ground truthing, has proven to be a more reliable means of generating accurate information (McFarlane et al., 2004). In 1989, over 859 300 hectares (ha) were impacted by dryland salinity, representing 2.6% of local government land and 4.6% of agricultural land. By 1996, nearly 957 600 ha had been affected, representing 2.9% of local government land and 5.1% of agricultural land. The increase in salt-affected land over this seven-year period is an increase of 14 000 hectares per year. A continuation of this rate would suggest that about 1 112 000 ha of South West land is likely to be affected by dryland salinisation in 2007.

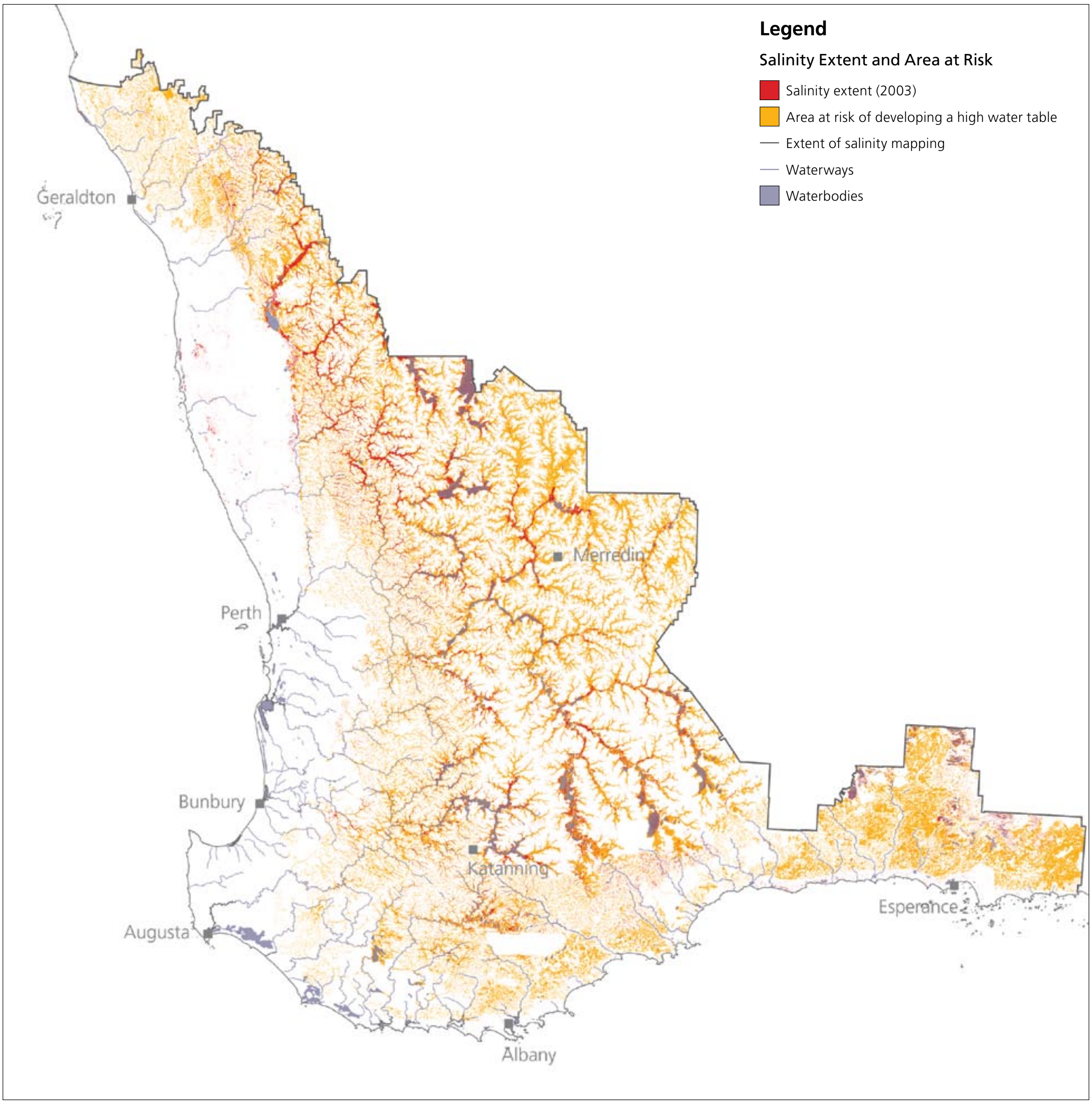


Figure L1.1: Extent of salt-affected land in 2000 and the area at risk of developing high water tables.

Data source: Department of Land Information – Land Monitor [ver. 2005], Presentation: EPA.

Most salt-affected land is located in low-lying valley floors, adjacent to Wheatbelt waterways and wetlands (Figure L1.1). The extent of salt-affected land varies among local government areas, with many waterways and wetlands in the eastern Wheatbelt being naturally saline. However, the extent of dryland salinisation in some local government areas is significant, some being more than 10% affected in 1996 (Table L1.1). Eight of the top 10 local governments with a dryland salinity problem are situated in north-west parts of the Avon Wheatbelt, where average annual rainfall is low (300–450 mm per year). The extent of salt-affected land continues to worsen in many areas. Seventeen local governments recorded increases in affected land of more than 0.5% between 1989 and 1996. While this rate of growth appears small, land salinisation is a slow-developing problem and has cumulative effects over time.

Land salinisation results in a reduction of productive agricultural land (Department of Agriculture and Food)

Table L1.1: Top 10 local governments most affected by dryland salinisation in 1996, excluding natural salt-affected areas.

Local government district	Local government area (hectares)	Per cent salt-affected land in 1996	Per cent change 1989–96
Koorda	283 268	15.1%	0.48%
Dalwallinu	722 071	11.7%	0.14%
Nungarin	116 236	11.1%	3.40%
Wongan–Ballidu	336 712	10.9%	0.70%
Wyalkatchem	159 561	10.9%	–0.24%
Goomalling	183 480	8.9%	0.27%
Tambellup	143 634	8.6%	0.92%
Lake Grace	1 038 210	7.7%	0.68%
Moora	376 296	7.7%	1.46%
Tammin	110 108	7.7%	0.31%

Data source: McFarlane et al., 2004; D McFarlane, CSIRO, pers. comm.

Indicator L4: Area of land at risk of salinisation.

Recent estimates indicate that up to 5.4 million hectares of land in the South West is potentially at risk of salinisation (McFarlane et al., 2004; Department of Environment, 2003). About 80% of this is agricultural land, but it also includes important areas of native vegetation, wetlands and infrastructure. Estimates of future land salinisation should be treated with some caution because areas at risk may not become saline due to factors such as climate change or changes in land use or water balances. Even local hydrogeology and soil types may affect how susceptible a particular area of land is to salinisation.Land at future risk of dryland salinisation represents an expansion of existing salt-affected areas (Figure L1.1). As watertables continue to rise, land situated higher in valleys becomes saline. As much as 43% of land in some local government areas is potentially at risk (Table L1.2). Seven of 10 local government districts most at risk of dryland salinisation (in terms of area of land affected) are located in the mid to north-west Wheatbelt areas of the Avon River Basin. Most of these districts are characterised by a flat landscape, low rainfall (<350 mm per annum) and poor drainage.

Table L1.2: Top 10 local governments at highest potential risk of dryland salinisation.

Local government district	Local government area (hectares)	Per cent of land at potential risk of dryland salinity
Nungarin*	116 236	43.0%
Tammin*	110 108	36.9%
Koorda*	283 268	35.9%
Wyalkatchem*	159 561	35.8%
Kellerberrin	191 363	35.2%
Tambellup*	143 634	34.3%
Trayning	165 020	32.2%
Woodanilling	112 882	32.1%
Dowerin	186 012	31.7%
Morawa	350 840	31.5%

Data source: McFarlane et al., 2004; D McFarlane, CSIRO, pers. comm. Note * : These local governments were among the top 10 local governments most affected by dryland salinisation in 1996.

Clearing of native vegetation for agriculture has caused widespread salinity including in the Durrokoppin Nature Reserve in the Yilgarn District (Department of Environment and Conservation).

In some areas, such as the Swan and Scott coastal plains, a salinity hazard is present despite little evidence of land salinisation. These areas are particularly prone to irrigation salinity, having poorly drained soils that are subject to waterlogging. About 40% of the Swan Coastal Plain (a stretch from Gingin to Dunsborough) is at risk of increased salinity and there is already some evidence of salt scalds appearing (Government of Western Australia, 2000). Irrigation salinity is also a possible threat to the Ord River Irrigation Area with groundwater salinity levels being elevated in some areas.

Pressures

Historical widespread clearing of perennial native vegetation and its replacement with low water-using annual crops and pastures has contributed to altered hydrological regimes in the South West agricultural zone. Although most broadscale clearing ceased many decades ago, clearing controls and legislation are now in place to protect native vegetation remnants. Unfortunately, excessive overclearing of native vegetation occurred in some areas. For example, 93% of native vegetation in the Avon–Wheatbelt bioregion has been cleared, resulting in significant land salinisation problems and loss of biodiversity.

Surprisingly, loss or degradation of vegetation cover is still continuing in the Wheatbelt, as shown by changes apparent from Land Monitor data (see '*Loss or degradation of native vegetation*'). Temporary loss or degradation of vegetation cover in eastern areas (rangelands) may be attributed to broad scale fires, with much of this bushland likely to regenerate over time. In coastal and Wheatbelt areas, vegetation loss or degradation is likely to be caused by clearing of native vegetation for agriculture or urban development, harvesting of plantations, land salinisation or Phytophthora-induced dieback. Further investigation and on-ground truthing of satellite imagery data is required to explain why loss or degradation of vegetation is still occurring. Irrespective of the cause, the continued loss of perennial vegetation cover is not desirable and further exacerbates salinisation in susceptible areas.

Although local improvements have been noted, regional groundwater modelling across the South West agricultural zone suggests a long-term trend of mostly rising or stable groundwaters and none falling significantly (see '*Altered water regimes*'). Under these conditions dryland salinisation can be expected to worsen. About 16% of land (4.65 million hectares) in this region already has shallow watertables (Department of Agriculture, 2001). Assuming groundwater trends remain constant, 20% (6.37 million hectares) of the region is at high risk of shallow watertables by 2020, and 33% (13.66 million hectares) by 2050 (Short & McConnell, 2001). These figures were calculated on the basis that watertables were less than 2 m from the soil surface or between 2–5 m and rising. It should be noted that not all land with shallow watertables will be affected by salinisation.

There is recent evidence to suggest that the drying climate in the South West has lowered local groundwater levels in some places. A decrease in winter rainfall and general lack of 'wet winters' are likely to have slowed the rate of land salinisation, especially for central and eastern Wheatbelt areas. Some areas cleared a long time ago appear to be reaching groundwater equilibrium, while the trend of rising groundwater continues in recently cleared areas, such as high rainfall parts of the Wheatbelt and south coast (Indian Ocean Climate Initiative, 2005).

Current responses

State Salinity Strategy: was released in 2000 and focused on developing a partnership-based approach, prioritisation tools, improved protection and conservation mechanisms, promoting further research and development, and ways to help the farming community move to more sustainable production systems. In response to the strategy, the State Government formed the Natural Resource Management Council and a stronger strategic role for regional natural resource management groups in managing salinity.

Natural Heritage Trust/National Action Plan for Salinity and Water Quality (NHT/NAP): are two Commonwealth Government programs that aim to ensure environmental (on-ground) improvements occur via a targeted strategic approach at the regional level. Natural resource management groups in the South West, South Coast, Northern Agricultural, Avon and Swan regions have recognised dryland salinisation as a threat to natural resources, and have projects to manage salt-affected land and protect valued natural assets at risk. Irrigation salinity has been recognised as a threat in the Ord River catchment by the Rangelands regional group.

Engineering Evaluation Initiative: is a State Government project to mitigate land salinisation by investigating a range of engineering options including deep drains, groundwater pumping, diversion and surface water management. It is also investigating options for safe saline water disposal and regional drainage planning.

Monitoring: Land Monitor produces satellite images that accurately map the extent of salt-affected land and its change over time and changes in areas of forest and perennial wood vegetation. Groundwater monitoring by the Department of Agriculture and Food is undertaken across the South West agricultural zone to assist in modelling and management of salt-affected and at-risk areas.

Salinity Investment Framework: is a prioritisation tool developed to help guide investment of funds towards projects that have the best chance of protecting high value assets from salinity. This prioritisation method has since been applied to broaden natural resource management investment to consider other environmental issues.

Remnant vegetation protection and management: The revised *Environmental Protection Act 1986* now protects all native vegetation and replaces former Regulations under the *Soil and Land Conservation Act 1945*. Clearing of remnant vegetation is prohibited unless a permit is granted or an exemption applies. Clearing controls still apply in some recovery catchments where total clearing bans are in place. Significant areas of remnant vegetation are protected in conservation reserves managed by Department of Environment and Conservation.

Revegetation: Combined with other management efforts, revegetation of cleared areas has been pivotal in reducing the threat of land salinisation and lowering salinity in waterways. There are currently no reliable estimates of land revegetated with perennial woody vegetation. However, specific estimates are available in the Denmark and Collie river catchments, where dedicated restoration work has been undertaken to recover salt-affected water supplies. Between 1990 and 2002, nearly 50% of previously cleared areas in the upper Denmark River catchment were converted to plantations. In the Collie River catchment, 27% of previously cleared areas had been converted to plantations by 2000. Recent surveys (Department of Agriculture, 2006) indicate that 40% of farmers in the Wheatbelt planted non-irrigated perennial pastures and 32% planted saltland pasture species. Twenty per cent of farmers across the South West planted trees for commercial production (e.g. oil mallees, pines and bluegums) and 60-70% planted trees and shrubs. Between 60–80% of farmers acted to preserve or enhance areas of conservation value.

Commercial revegetation projects: Innovative tree farming programs, such as Infinitree, have been established in recent years, partnering the Forest Products Commission with farmers and investors to create commercial tree plantations (largely blue gums, sandalwood, and pine) on farm properties. In addition the Department of Environment and Conservation, in conjunction with the Collaborative Research Centre for Plant Based Management of Dryland Salinity, is developing new commercial industries based on native plants such as oil mallee.

Research: Murdoch University is investigating Wheatbelt deep drains and whether they are an effective strategy for alleviating salinisation in the Wheatbelt. The CSIRO Water for a Healthy Country program is undertaking research evaluating Wheatbelt drainage and developing models to help assess drainage plans. Recent biodiversity surveys of the South West agricultural zone will also provide important baseline information for future research and monitoring.

Recovery catchment programs: focus on stabilisation and improvement of important natural resource assets impacted by salinity. For drinking water resources, action is currently being taken in the Collie, Denmark, Warren, Kent and Helena catchments to reduce salinity levels in runoff to water supplies. There are also six natural diversity recovery catchments (Toolibin Lake, Muir–Unicup, Lake Warden, Lake Bryde, Buntine-Marchagee and Drummond) focused on the conservation and recovery of wetlands and other salinity-threatened assets. The Rural Towns Program provides 38 rural communities with necessary tools to fight townsite salinity. Monitoring bores in these towns have enabled improved modelling of salinity spread and the development of town-specific salinity management strategies.

Collaborative Research Centre for Plant Based Management of Dryland Salinity: The centre is at the forefront of research in understanding ecosystem functions and their responses to salinisation, in developing and trialling various land use systems and vegetation options for sustainable farming, and in best productive use for salt affected land. The centre is soon to become the Future Farm Industries Cooperative Research Centre with a focus on research into novel dryland farming methods in a changing climate, and industry opportunities based on perennial plants.

Implications

Land salinisation results in a rapid and catastrophic collapse of terrestrial and aquatic ecosystems. Biodiversity has already declined in the South West and some 450 plant and 400 animal species are at risk of global or regional extinction as a result of salinisation and other hydrological changes. Previous estimates indicate that up to 80% of bushland on farms and 50% of bushland on public lands in agricultural areas will eventually be affected (George et al., 1995). Salinisation is likely to reduce animal species by 30% in affected areas; a 50% reduction for waterbirds is anticipated due to salinity-induced loss of habitat (Government of Western Australia, 2000). Ecosystems situated low in the landscape, especially those associated with wetlands and waterways, are most at risk. Loss of vegetation to land salinisation also results in a loss of carbon storage, effectively contributing to increased greenhouse gases.

Land salinisation already results in significant impacts on agricultural productivity, such as reduced pasture, crop growth and shelter for livestock. Estimated annual economic costs of dryland salinity across Australia are $664 million, based on best-guess estimates and not including the costs of strategies to combat salinity impacts on biodiversity (Commonwealth of Australia, 2001a). The true economic cost of dryland salinisation, taking into account off-site costs, is not known but is conceivably in the billions of dollars (Land and Water Resources Research and Development Corporation, 1999). Farmers in affected areas, already under difficult circumstances, are faced with having to modify their farming practices and investigate alternative land use options. However, land use changes will generally not have any significant impact on the effects of salinisation for at least 20 years (Commonwealth of Australia, 2001a; Short & McConnell, 2001). Damage from flood flows may also increase significantly as the proportion of land affected by shallow watertables increases (Bowman & Ruprecht, 2000; George et al., 1999).

Twenty South West towns are currently affected by dryland salinity and about 15 000 km of rail and road networks are currently at risk, with shorter infrastructure lifespans expected. Impacts on road and rail infrastructure are expected to double in the next 50 years (Commonwealth of Australia, 2001a). Social ramifications of land salinisation can also be significant. Apart from lost farm income, land owners may have to spend more time and money combating lost agricultural productivity and damaged infrastructure. Adaptation and changes to traditional production systems may be required and families unable to cope with the uncertainty and change may leave farming. This is already occurring in some Wheatbelt towns where falling population has led to withdrawal of services and closure of businesses in a cycle leading to further rural community decline. Salinised landscapes may also reduce recreational, cultural and spiritual values and affect the tourism industry.

SUGGESTED RESPONSES

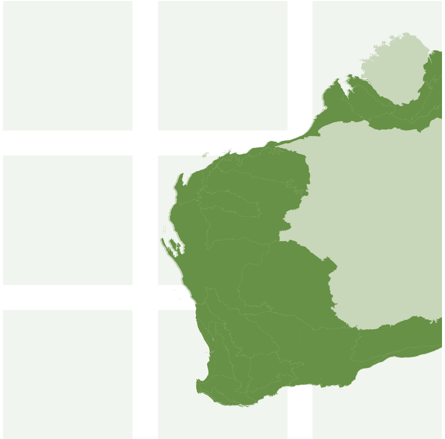
3.2 Continue to implement the recommendations of the *State Salinity Strategy*, recognising it as a component of the proposed State Soil Protection Policy. Although significant progress has been made, more focus should be given to integrating engineering and plant based solutions to cater for a variety of farm and catchment characteristics, and promoting alternative farming systems in low to moderate rainfall areas.

3.3 Continue the Land Monitor program to provide five-yearly updates of the extent of land salinisation in the South West. Land Monitor remains one of the few tools to accurately measure regional trends in land salinisation and to evaluate the effectiveness of actions.

See also '*Salinisation of inland waters*':

- Develop and implement a strategic policy and governance framework for agricultural deep drainage which fully incorporates environmental principles.
- Develop and implement an evaluation framework to consider deep drainage in the context of integrated solutions where such options are environmentally sound.
- Enhance routine monitoring of waterways and wetlands currently impacted by, and at future risk of, salinisation.

3.2 SOIL EROSION



INDICATIVE EXTENT OF ISSUE

PRIORITY RATING: 2

KEY FINDINGS

- Erosion rates vary significantly across the State, with the Kimberley and the west Pilbara having the highest average rates of soil loss.
- Declines in soil stability have been noted in the Gascoyne, Murchison, Pilbara and Kimberley. Improvements in soil stability have been noted in the Goldfields and Nullarbor.
- About 50–60% of Wheatbelt farmers are using land management techniques to reduce soil erosion.

Description

Soil erosion occurs through soil being blown or washed from the land. It is a natural process that usually occurs at low rates and is influenced by slope of landscapes, climate, soil type, vegetation cover and land use. Water erosion occurs when flowing water mobilises soil. It has the potential to redefine landforms, often contributing to landslides on hill-slopes, river bank collapses and the creation of gullies (steep incised channels). Eroded soil can enter inland waters causing sedimentation and eutrophication problems. Wind erosion occurs where wind detaches and removes bare dry soil. Erosion of fine soils by wind often contributes to dust storms and high levels of airborne particulates.

Soil erosion is accelerated by activities such as vegetation clearing, cultivation, mining, fires, earthworks and livestock grazing. Soils are more susceptible to erosion if they are not protected by vegetation cover or are left exposed to wind or water flow. This becomes exacerbated during intensive storm events, floods or drought conditions. Loss of fertile topsoils to erosion exposes less fertile subsurface soils and results in reduced agricultural productivity and health of native vegetation. It may also cause the undermining of infrastructure (such as roads, buildings, bridges, fences, etc.) or the filling of drains, water supplies and inland waters. Severe erosion leads to poor soil structure in remaining soil, reduced water infiltration and general loss of soil health.

Objectives

- To minimise the extent and severity of soil erosion.
- To stabilise eroded lands and where practical, rehabilitate them.

Condition

Indicator L5: Extent and rate of soil erosion.

Soil erosion data in WA are generally inadequate. Determining the extent of soil erosion across the State is difficult because of the large area of land potentially affected, the diversity of land uses and climate variability. Models can be used to predict erosion-susceptible areas, using factors such as rainfall erosivity, surface vegetation cover, soil erodability, slope of the land and soil management practices.

Reconnaissance surveys at 70 sites undertaken for the National Landcare Program in the 1990s, demonstrated potential rates of soil erosion across the State (McFarlane et al., 2000; Loughran et al., 2004). Small amounts of the radioactive isotope, caesium-137, were deposited in WA soils in the 1950s following atmospheric nuclear weapons testing. Subsequent disappearance of the isotope from soil has been used as a measure of the cumulative loss of soil from both wind and water erosion. Soil erosion rates varied enormously across the State, ranging from less than 1 tonne per hectare per year (t/ha/yr) to 46 t/ha/yr recorded at a pasture-cropping rotation site near Kendenup. Nearly two-thirds of selected sites across the State had erosion rates of less than 5 t/ha/yr. On average the highest rates of soil erosion were recorded in the Kimberley, west Pilbara and Gascoyne districts (Table L2.1). These survey results should be interpreted with some caution given the limited number and representativeness of sites across a very large area of land and land uses. Nevertheless, the survey does provide an indication of soil erosion rates possible in WA.

Table L2.1: Average net soil loss as determined by caesium-137 depletion in soils of various regions and rainfall zones.

Region	Average rainfall (mm)	Average net soil loss (t/ha/yr)
South West horticulture – Pasture Belt	700–1400	4.75
South West pasture – Wool Belt	500–700	9.82
South West crop – Pasture Belt	300–500	6.56
West Pilbara & Gascoyne	<300	14.5
Goldfields	<300	1.03
Kimberley	500–700	13.5

Data source: McFarlane et al., 2000.

Indicator L6: South West erosion risk.

Modelling of water and wind erosion risk is undertaken in the South West by the Department of Agriculture and Food. A complex mix of factors contributes to wind and water erosion. Soils on steep sloping lands in high rainfall areas are most susceptible to water erosion because of higher flows and speed of runoff. Landscapes that concentrate water flow also increase potential water erosion, while adequate vegetation cover helps to slow water flow across the soil, allowing infiltration to occur. The parts of the South West most susceptible to water erosion are hilly with high rainfall, such as forested areas of the Darling Range and coastal areas of the south coast (Figure L2.1). Areas susceptible to wind erosion include those with dry soils and a high proportion of fine sands. Soils with weak structure and water repellent properties may also be susceptible. Vegetation cover and undulating landscapes help to reduce wind velocity, thereby reducing the susceptibility of soil to wind erosion. The parts of the South West most susceptible to wind erosion are coastal areas from Bunbury to Geraldton, the western Wheatbelt and south-east agricultural areas (Figure L2.2).

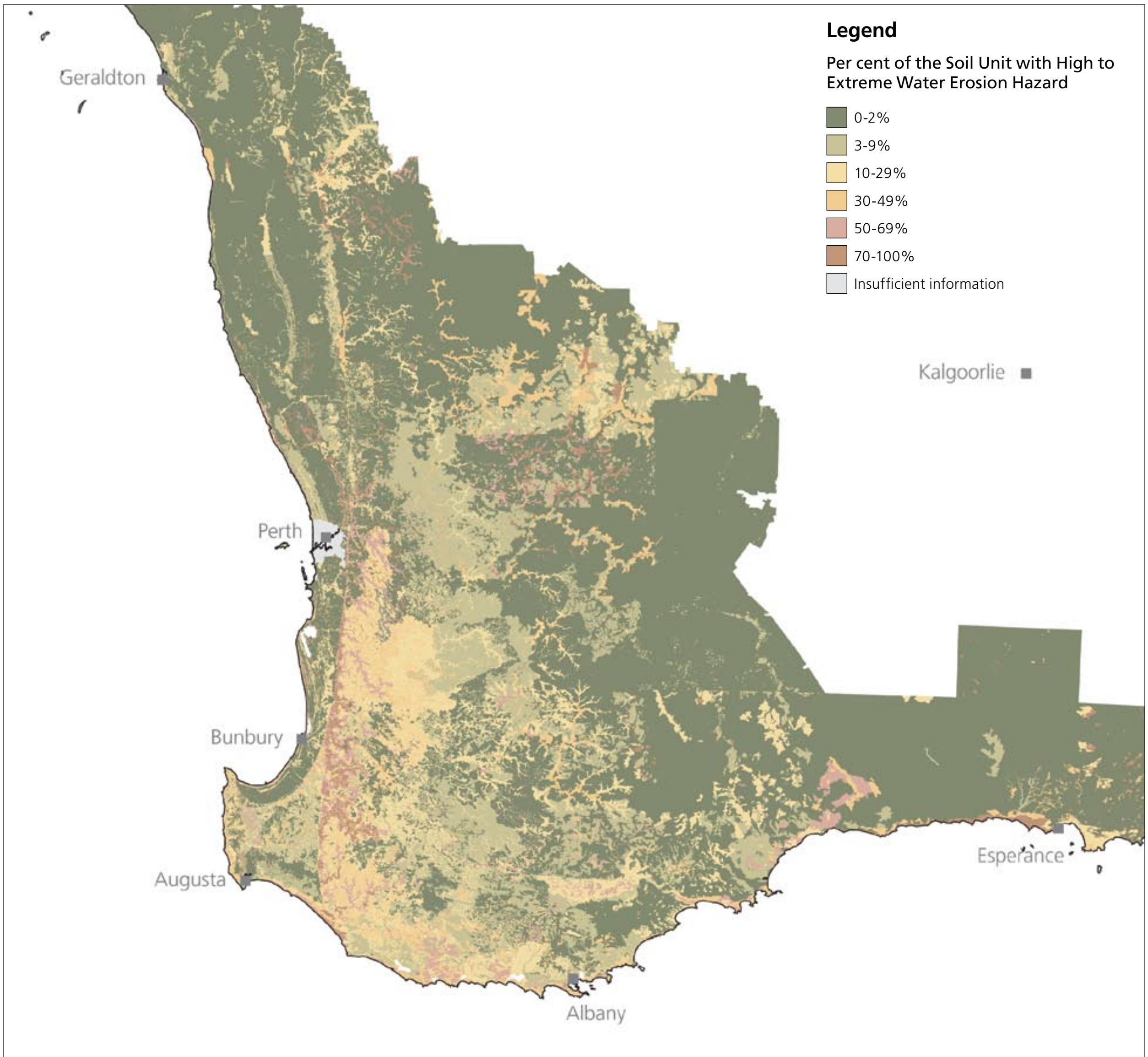


Figure L2.1: Modelled water erosion risk for the South West.

Data source: Department of Agriculture [ver. 2005]; Presentation: Department of Agriculture.

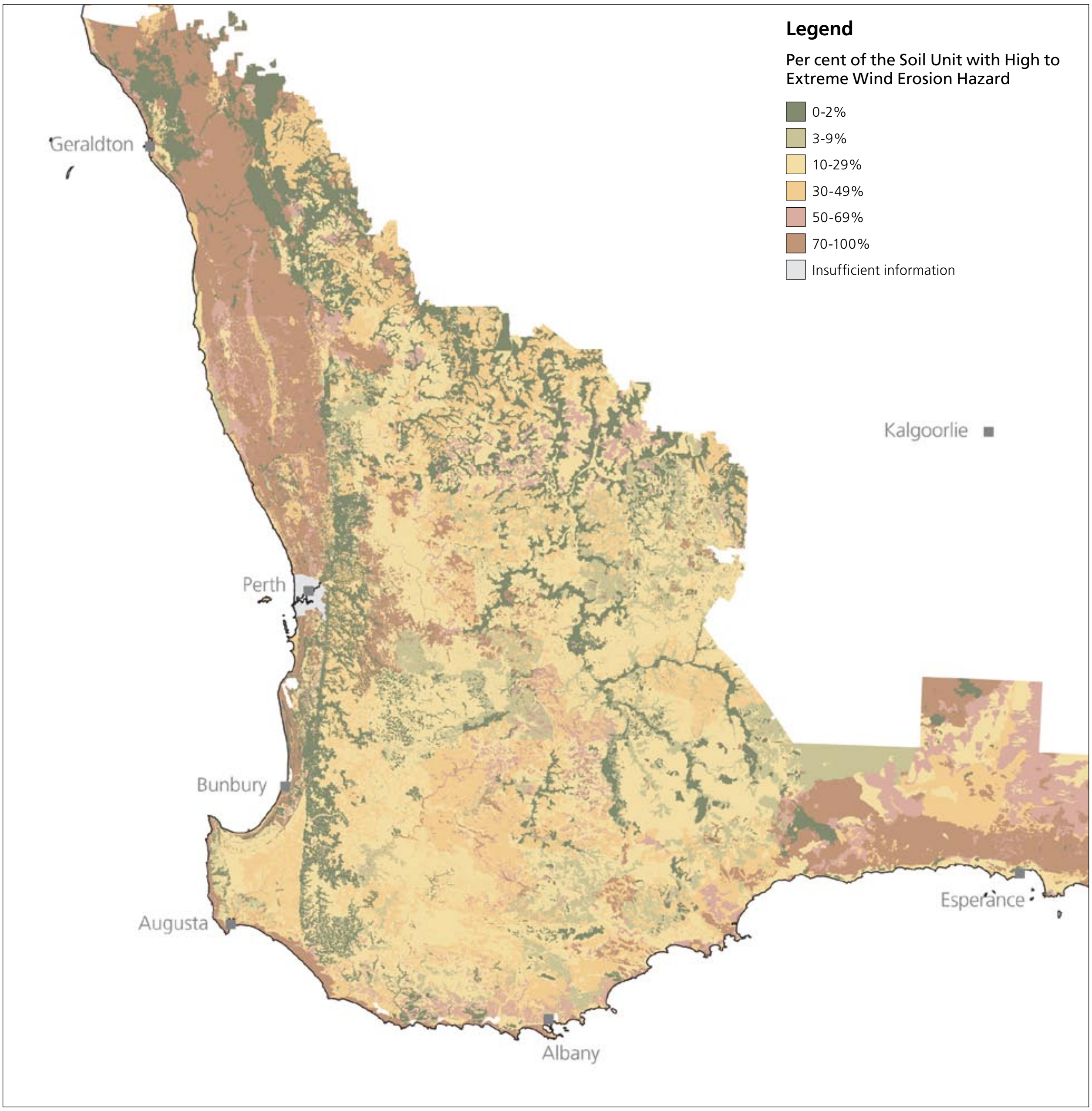


Figure L2.2: Modelled wind erosion risk for the South West.

Data source: Department of Agriculture [ver. 2005]; Presentation: Department of Agriculture.

Wind erosion of soil can smother vegetation and accumulate in drains and roads (Department of Agriculture and Food)

Indicator L7: Rangeland erosion risk.

The Western Australian Rangelands Monitoring System monitors changes in vegetation and soil at sites in the pastoral rangelands (Watson & Novelly, 2004). Its soil stability index shows the ability of soil to withstand erosive forces and reform after disturbance (Figure L2.3). A greater proportion of sites in the Goldfields and Nullarbor districts show stable or improved soil stability compared to previous assessments. In contrast, a greater proportion of sites in parts of the Gascoyne, Murchison, Pilbara and Kimberley districts show some decline in soil stability. These areas may be susceptible to increased soil erosion.

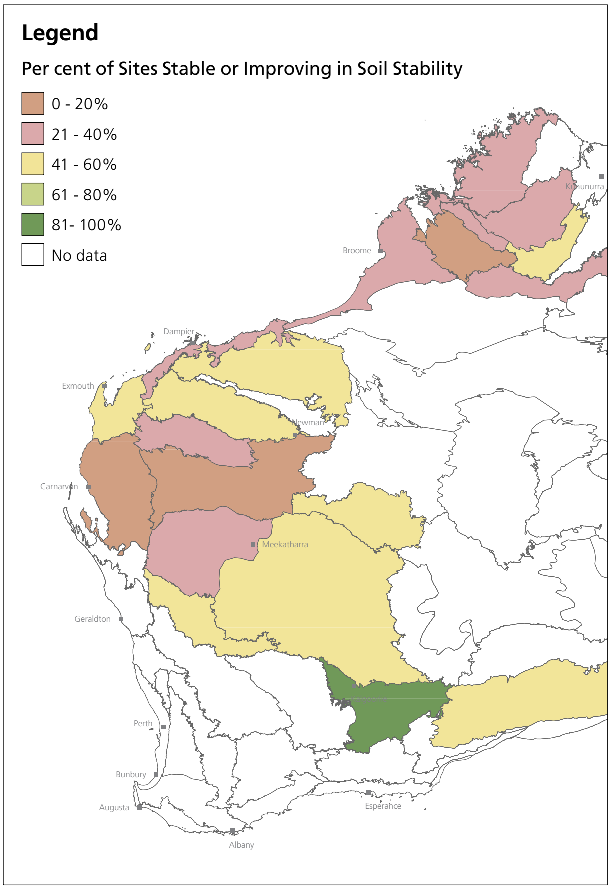


Figure L2.3: Soil stability in the pastoral rangelands, by bioregions.

Data source: Department of Agriculture – WARMS [ver. 2005]; Analysis: EPA; Presentation: EPA. Note: Data derived from WARMS Landscape Function Analysis – Soil Stability Ratio.

Pressures

The most significant pressures leading to erosion are agricultural or pastoral practices that increase exposure and vulnerability of soils. These include removal of protective vegetation cover through clearing or grazing, cultivation of crops and chemical changes to the soil (e.g. salinisation or increased water repellence). Density of livestock or feral and native animals on pastoral land can have a significant influence on soil erosion. Comparing actual livestock stocking rates with the land's carrying capacity is useful for tracking sustainable use of pastoral land (see '*Pastoralism*'). Stocking rates in the Pilbara district have been increasing over the past decade in areas known to have naturally erosive soils. In contrast, stocking rates in the Gascoyne and Murchison districts have fallen in recent years, more than likely due to drought conditions.

Retention of native vegetation minimises wind and water erosion, although this is not always achievable for developed land. Soil erosion in the rangelands can be a significant problem due to low vegetation cover. Monitoring results from WARMS sites were analysed at the bioregion scale to determine general change in perennial vegetation density (in the shrublands) and frequency (in the grasslands). A majority of sites in bioregions had stable or improving vegetation cover over the past decade (see '*Loss or degradation of native vegetation*'). Only a few bioregions in the Murchison and Pilbara had a majority of sites with declining vegetation density or grassland frequency.

Vegetation cover in the South West has generally declined in the period 1996–2004, and by more than 8% in some areas according to Land Monitor satellite imagery (See '*Loss or degradation of native vegetation*'). Significant potential for soil erosion is likely in coastal areas from Busselton to Geraldton, where significant loss of vegetation cover has already occurred. Many Wheatbelt areas have a low rate of vegetation loss over this period because many areas have already been cleared with few areas of remnant vegetation.

Several studies of agricultural land show that 20–30% vegetation cover reduces soil erosion by as much as 80–90% (Findlater et al., 1990; Freebairn, 2004). In the largest erosion events, water runoff and soil movement are greatest for bare soil but reduce where minimal tillage (i.e. retaining crop stubble after harvesting) soil management is employed. Stubble or vegetation reduces the speed of water runoff by creating a more meandering pathway for water flow and allows more water to infiltrate into the soil. Eastern states studies show a 50% reduction in maximum speed of water runoff and a ten-fold reduction in soil movement in paddocks where stubble is retained, compared to bare soil (Freebairn & Wockner, 1986). Recent surveys (Department of Agriculture, 2006) indicate that about 60% of farmers in the Wheatbelt currently use stubble retention or mulching practices to reduce soil erosion.

Erosion can be caused by water repellence of soils, where soil particles become hydrophobic ('water-hating'). Dry coatings of organic matter can build up around soil particles, forming a waxy, water-repellent barrier. In heavy rains this can result in significant runoff and erosion on sloping land. Rills and gullies have been observed on soils that would have negligible runoff if they were not water repelling. Modelling by the Department of Agriculture and Food show the most water repellent soils in the South West are found on coastal soils between Bunbury and Geraldton, scattered parts of the central Wheatbelt, and coastal soils along the south coast.

Current responses

Natural Heritage Trust/National Action Plan for Salinity and Water Quality (NHT/NAP): are two Commonwealth Government programs that aim to ensure environmental (on-ground) improvements occur via a targeted strategic approach at the regional level. All regional natural resource management groups have recognised soil erosion as a threat to natural resources and have identified projects for the remediation of eroded land and protection of valued natural assets at risk from erosion.

Agriculture extension program: The Department of Agriculture and Food promotes application of best practice by farmers to minimise soil erosion, including use of grade banks, stubble retention, soil testing, and retention and protection of native vegetation. Recent surveys (Department of Agriculture, 2006) indicate that 64% of farmers in the Wheatbelt currently use stubble retention or mulching practices to reduce soil erosion. The surveys also show 58% of farmers in the Wheatbelt undertake regular monitoring of pasture and vegetation cover, and 41% of farmers undertake regular monitoring in high rainfall South West agricultural areas. Up to 73% of farmers in the Wheatbelt regularly utilise erosion and surface runoff controls such as grade

Severe gully erosion on a farm near York (Department of Agriculture and Food)

banks compared to 36% in high rainfall parts of the South West. About two thirds of pastoralists deliberately excluded stock from areas impacted by land degradation and about 80% undertake formal monitoring of vegetation and pasture conditions.

Ecosystem Management Unit (EMU): Although this project has recently ceased, it provided many pastoralists with tools for the ecologically-based management of leases which brought together production, productive capacity and biodiversity management. The process utilised both the pastoralist's local knowledge and the technical knowledge of ecologists to plan and implement on-ground actions for pastoral sustainability, including minimising soil erosion.

Monitoring: A number of initiatives are underway to measure erosion potential and the effects of erosion. The Western Australian Rangelands Monitoring System provides regional scale assessments of trends in perennial vegetation and soil surface condition. The system is made up of 1628 sites where changes in vegetation, soil and landscape are monitored. Satellite imagery has also been used to identify areas of wind erosion in the South West. Limited areas have been surveyed by this technique, which has proven cheap and effective compared to on-ground survey techniques.

Total grazing management yards: Pastoral grazing can now be managed primarily through the distribution of watering yards on stations and by controlling animal access to them, thereby limiting uncontrolled grazing of vegetation and consequently limiting the extent and severity of erosion. The number of yards is difficult to ascertain, but estimates indicate approximately 1000 yards have been installed across 8 million hectares of pastoral land in the Gascoyne–Murchison region (Rangelands Natural Resource Management Coordinating Group, 2005).

Implications

Soil erosion leads to land degradation and may also contribute to problems in inland waters and the atmosphere. It results in a loss of topsoil, often resulting in reduced soil fertility and structure and poor soil health. Erosion and corresponding deposition of soil can affect biodiversity by stripping native vegetation seed banks from topsoil, spreading weed seed and smothering habitat. Loss of valuable topsoil can dramatically reduce productivity of agricultural land, requiring additional soil treatments. It may also result in significant cost to the community through damaged infrastructure (e.g. collapsed fences and roads, filling of dams and reservoirs, clogging of irrigation systems, and the undermining of buildings). Eroded soil may accumulate on roads and railways affecting transportation, and cause increased flooding by filling drains and blocking outlets. Increased community effort may be required for restoration works, bank stabilisation and revegetation. Soil erosion can cause other environmental problems such as contributing to eutrophication problems in inland waters and contributing to fine particle air pollution (i.e. dust storms and high levels of particulates). Although the actual cost associated with soil erosion is difficult to quantify, it is undoubtedly substantial.

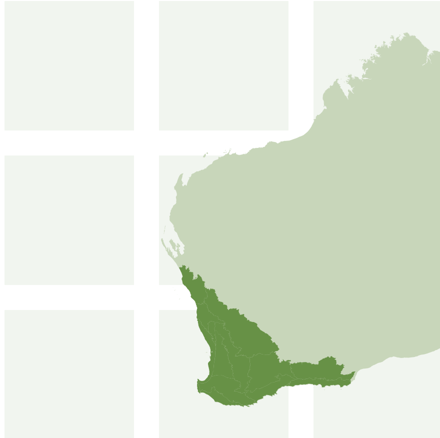
SUGGESTED RESPONSES

3.4 Enhance agricultural and pastoral programs addressing soil erosion and provide incentives to farmers and pastoralists to promote high adoption rates of best practice in managing soil erosion.

3.5 Ensure integration of erosion control measures into farm and pastoral management plans.

3.6 Develop an agreed baseline of the extent and severity of soil erosion in WA.

SOIL ACIDIFICATION



INDICATIVE EXTENT OF ISSUE

PRIORITY RATING: 3

KEY FINDINGS

- About two-thirds of South West agricultural soil is at risk of acidification.
- Between 1990 and 2004, use of lime and dolomite as a soil treatment increased nearly 900%.
- Farmers are using about half of the lime required to maintain current acidity levels in South West soils.
- Subsurface acidification is now recognised as a serious and growing problem.

Description

Many soil types are naturally acidic. Problems arise when acidity increases and affects plant growth. Soil acidification occurs due to a gradual increase in the hydrogen ion content of the soil, and is measured by a decrease on the 'pH' scale. This scale varies from pH 0 (strongly acidic) to pH 14 (strong base), with pH 7 being neutral. The most widespread cause of soil acidification is from agriculture practices including application of nitrogenous fertilisers, the leaching of nitrate from legume crops and pastures, and the gradual removal of alkalinity (material that buffers against soil acidity) from soil into harvested or grazed plants. Unfortunately, these are side-effects of agricultural production. Acidification can also be caused by the oxidation of sulphide soil minerals during mining or land development, acid deposition from industrial atmospheric pollutants (e.g. sulphur dioxide) or land contamination.

Soil acidification is difficult to identify, particularly when it occurs below the soil surface. A decline in vegetative condition or agricultural productivity is often the first sign. The critical point for this decline is generally accepted to be about pH 4.5, but this varies among plant and crop species. Soil acidification is primarily managed through lime application, either as lime sand or crushed limestone. Dolomite is also used in some areas. Other practices such as reduced nitrogen fertiliser input, the use of nitrate-based fertilisers, improved timing of fertiliser application with regard to plant growth, and efficient irrigation practices can also be adopted to help reduce acidification. Over time, unchecked acidification can result in nutrient deficient soils and the accumulation of toxic materials, such as aluminium and manganese, which inhibits plant root growth and reduces crop yields. Unmanaged, it may also cause subsurface soil acidification (10–30 cm below the soil surface) which is much more difficult to treat.

Objectives

- To prevent the development of critical levels of soil acidification (pH < 4.5) in agricultural systems and return acidified soils to pH levels suitable for agricultural production.
- To minimise and prevent, where possible, formation of acid soils.

Condition

Indicator L8: Area of land with soils at risk of acidification.

Most farmers have a general awareness of soil acidity and knowledge of how to treat acidity problems. While no broadscale monitoring exists, regional modelling for the South West is available to determine areas at risk of surface and subsurface acidification. Most of the South West shows evidence of elevated surface soil acidity risk, although some soils are more susceptible than others (Figure L3.1). It is estimated about two-thirds of the agricultural Wheatbelt is affected by surface soil (topsoil) acidity, or is at risk of acidification. The estimated area of strongly acidic soils (pH < 4.8) is 1–8 million hectares, and of moderately acidic soils (pH 4.8–5.5) is an additional 7–19 million hectares (Commonwealth of Australia, 2001b). This area is much greater than the land affected by dryland salinisation (see '*Land salinisation*').

Subsurface soil acidity can have as much effect on plant growth as surface acidity, but is more difficult and costly to treat, and in the long term may be more problematic and threatening. It is estimated there are 0.2–4.8 million hectares of acid subsurface soils in Western Australia (Commonwealth of Australia, 2001b). The areas with, or at highest risk of, subsurface acidification include the northern Wheatbelt and soils from Perth to Geraldton and Augusta to Albany (Figure L3.2). Estimates for the Avon River Basin, indicate that about 93% of surface soils and 83% of subsurface soils have moderate to high risk of acidification (Department of Agriculture and Food, unpublished).

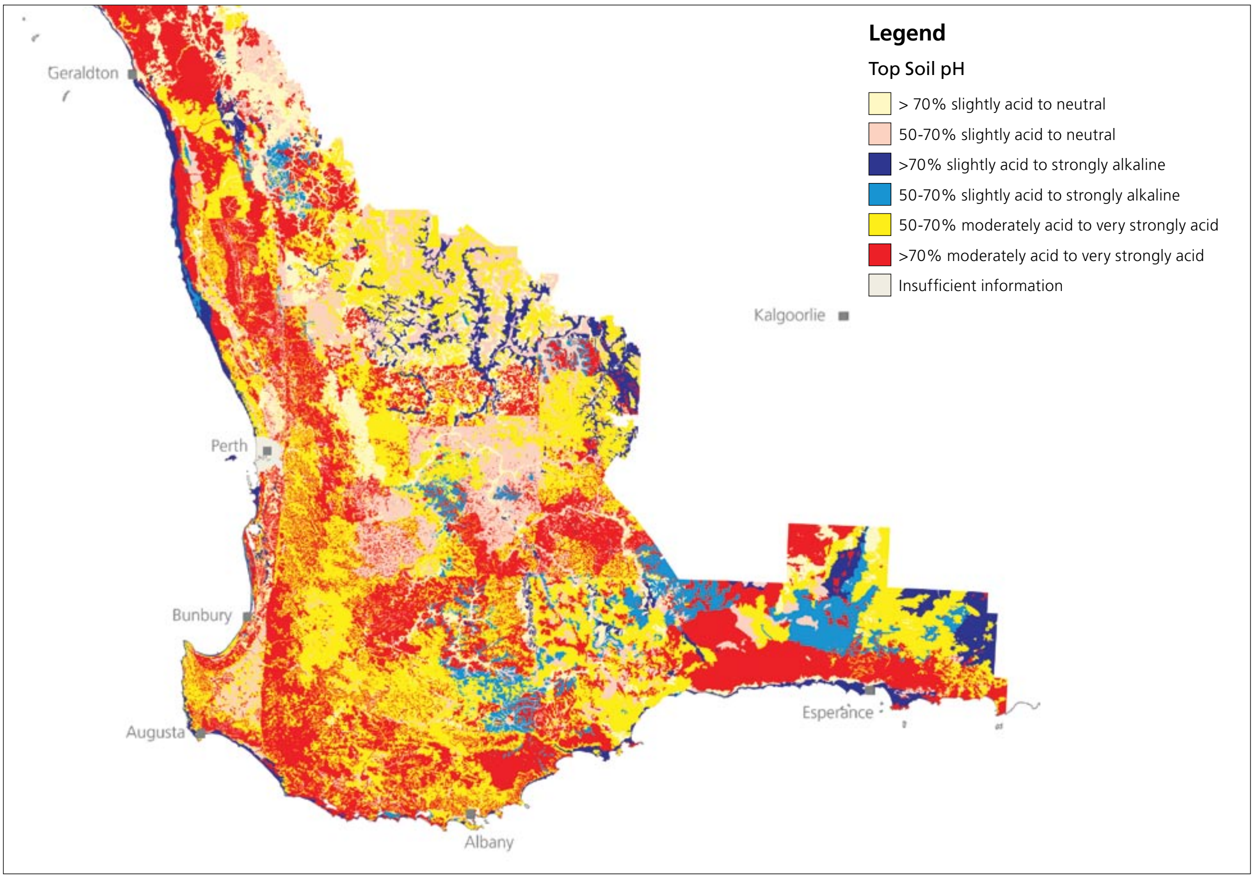


Figure L3.1: Modelled surface soil acidification risk for the South West.

Data source: Department of Agriculture [ver. 2005]; Presentation: Department of Agriculture.

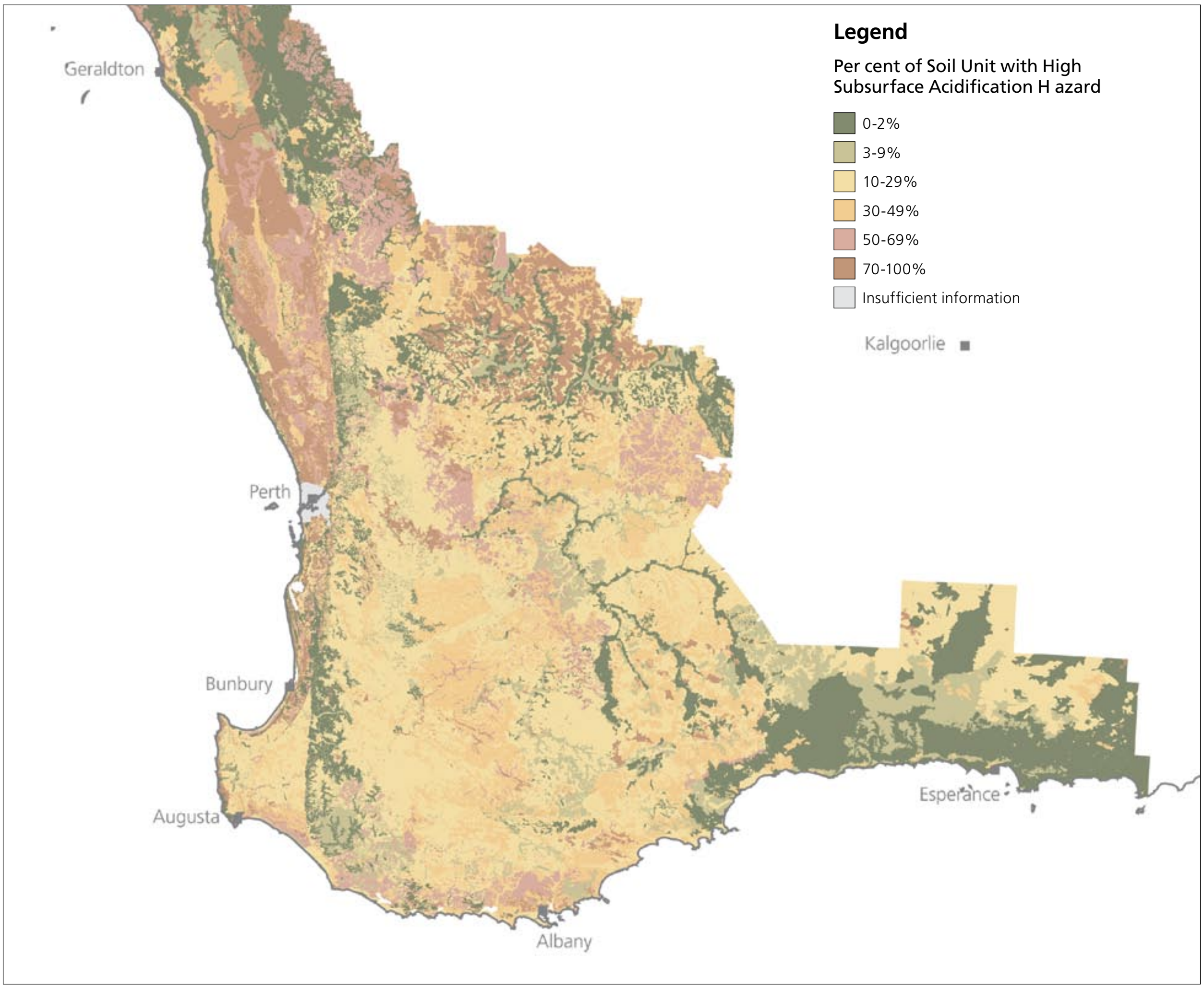


Figure L3.2: Modelled subsurface soil acidification risk for the South West.

Data source: Department of Agriculture [ver. 2005]; Presentation: Department of Agriculture.

Pressures

Indicator L9: Area of land planted for cropping, including legumes and wheat crops.

Plants take up nutrients (including acid-buffering chemicals) from soil, resulting in a separation of acidity in the soil and alkalinity in the plant. As agriculture removes plants from land (by harvesting crops or grazing pasture) less alkalinity is returned to the soil and over time it becomes progressively acidic. In the 10 years from 1994–2004, the total area of land dedicated to cropping has increased by about one-third, from 6.1 to 8.1 million hectares (Commonwealth of Australia, 2001b; Australian Bureau of Statistics, 2005). More land dedicated to cropping puts a greater area of land at risk of soil acidification.

Grasses, legumes and wheat typically acidify the soil faster than pasture due to their inefficient use of nitrate. In contrast, annual and perennial pastures are able to establish earlier at the break of the season (when rain starts) and effectively utilise the nitrate thereby reducing the rate of acidification. The area under legume production has decreased by nearly 40% between 1999 and 2005. This may help to alleviate high rates of soil acidification in some areas. The area under wheat production is about 13% higher and has increased in recent years due to favourable growing conditions (Table L3.1).

Testing for soil acidification (C.Gazey)

Table L3.1: Area of Western Australian land under legume and wheat production, 1999–2005.

Year ending (June)	1999	2000	2001	2002	2003	2004	2005
Area of legume crop ('000 hectares)	1229	1166	1077	990	866	732	776
Area of wheat crop ('000 hectares)	4515	4556	4460	4350	4458	4917	5118

Data source: Australian Bureau of Statistics – Agricultural Commodities Australia reports.

Indicator L10: Annual amount of nitrogenous fertiliser applied per hectare in agricultural areas.

Fertiliser containing nitrogen is primarily used for enhancing grain and pasture production. Dependency on fertiliser in WA is rising. Between 1989–90 and 2001–02, the amount of nitrogen-based fertiliser applied to soil grew about 450%, from 88 000 tonnes to 399 000 tonnes (McLennan, 1996; Australian Bureau of Statistics, 2002). When these fertilisers leach into soil, 'nitrification' (the natural process of conversion of ammonium to nitrate) occurs, during which acid is produced. If growing plants take up nitrate the potential for acidification is reduced, but if nitrate is leached from the root zone then acidity can build up. All ammonium-based fertilisers cause acidification, whether leached or not. Fertilisers that are not ammonium-based (such as urea) only cause soil acidification if the nitrate, into which they are converted, leaches from the root zone. Superphosphate fertilisers are not directly acidifying, but indirectly add to soil acidity by improving plant growth, and hence the amount of plant material (containing acid buffering chemicals) removed by harvesting or animal grazing. Application of sulfur to soil is also acidifying.

Current responses

Indicator L11: Annual amount of lime applied per hectare in agricultural areas.

Soil acidification in agricultural areas is primarily managed through lime or dolomite application. Best practice guidelines indicate that lime should be applied at one to 1.5 tonnes per hectare every 3–7 years. If soil pH is below 4.5, then two applications of lime are required within 5 years to lift the pH to within the normal range, which is then maintained by a liming maintenance regime. The best agricultural production responses to lime have occurred when the topsoil pH is very low (i.e. pH < 4.5). Moderately acidic soils (pH 5–5.5) typically show little yield response but depending on the crop, season and yield potential this may not always be the case.

In 2004, the amount of lime and dolomite applied to agricultural soils affected by acidity was 1.03 million tonnes – the highest level of use yet recorded in WA (Figure L3.3). There is evidence of a gradual rise over the past decade in both the area of farmland treated and the quantity of lime being used. While growth in lime use is encouraging from an agricultural perspective, the actual amount of lime required to maintain current acidity in agricultural soils is about double (2 million tonnes per year). Unfortunately, monitoring of lime use has since ceased and was not undertaken in 2005 and 2006.

Treatment of subsurface soil acidity with surface applications of lime can take many years. Subsurface soil acidification under crops has the potential to severely limit crop and pasture production. For long-term soil health, the prevention or minimisation of subsurface soil acidity is vital.

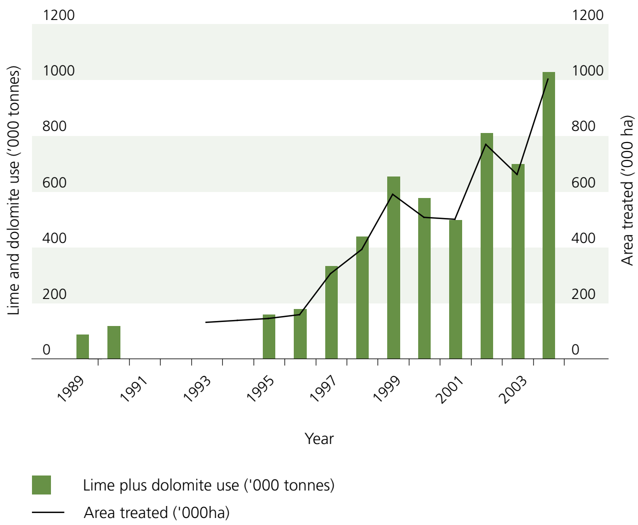


Figure L3.3: Western Australian lime and dolomite use and area treated over time.

Data source: Australian Bureau of Statistics, 1996 & 2002; O'Connell & Gazey, 2003; C Gazey, Department of Agriculture and Food, pers. comm.

Indicator L12: Percentage of farmers undertaking soil pH testing.

Estimates of surface soil testing for pH vary from 30% of farmers testing portions of their farms (Nutrient Management Systems, pers. comm.) to 65–75% of farmers undertaking regular pH testing of surface soils (Department of Agriculture, 2006). It is estimated that only 10% of farmers test acidity levels of subsurface soils (C Gazey, Department of Agriculture and Food, pers. comm.). Surveys also show that farmers have developed an increased awareness of acidification problems and the skills to help correct the problem (Department of Agriculture, 2006).

Draft State Lime Supply Strategy: was initiated in 1998 with the intention of enabling informed decisions about lime production and supply in relation to environmental, conservation, urban and heritage issues. The Department of Industry and Resources oversaw development of the strategy, with guidance from other government agencies (Department of Industry and Resources, 2001). The strategy is currently in draft form and is considered to be an evolving document.

Natural Heritage Trust/National Action Plan for Salinity and Water Quality (NHT/NAP): Through these two Commonwealth Government programs, the South West, Swan, Avon, Northern Agricultural and South Coast regional natural resource management groups have recognised soil acidification as a threat to natural resources. Strategies have outlined specific targets and onground projects to address soil acidification.

Integrated Soil Acidity Research, Development and Extension Program, 1992–2002: The Department of Agriculture and Food in conjunction with University of Western Australia, the Grains Research Development Corporation, and the Natural Heritage Trust coordinated this program. It investigated methods for slowing the rate of soil acidification, establishing the relationship between the level of subsurface acidity and crop yield losses, and developed techniques to add alkalinity back to acidifying soils. It was supported by a promotional extension campaign 'Time to Lime', during which annual lime use by farmers increased by 530% from 150 000 tonnes in 1994 to more than 800 000 tonnes in 2002 (Figure L3.2). The number of farmers using lime rose by 240% from 1353 to 3292 over the same period (Department of Agriculture, 2003).

Acid soils can inhibit plant root growth (shown in seedlings to right) reducing crop yields (C.Gazey)

Implications

Across Australia, the economic implication of soil acidification is estimated to be five to six times higher than dryland salinity (Commonwealth of Australia, 2001b). Acidity is insidious, with yield declines of 20–30% occurring over time (Department of Agriculture, 2000). Such losses may go unnoticed if farm productivity is improving for other reasons, such as increased fertiliser use. Plant and crop growth is often limited because of a reduction in the availability of nutrients (calcium, magnesium, boron, molybdenum) or an increase in toxic levels of aluminium, iron or manganese. Toxic levels of aluminium decreases root growth which leads to reduced water uptake by plants and crops, hence contributing to other problems such as waterlogging, erosion and salinisation. Extreme acidification can result in poorly structured or hard-setting topsoils that don't support enough vegetation to prevent soil erosion. Soils may also acidify to the point where acid, nutrients, sediment and heavy metals are exported and impact nearby inland waters (see '*Acidification of inland waters*').

Liming is viewed as the major remediation option for soil acidification on farms. Risks of substantial farm losses exist if liming programs are not commenced before critical surface and subsurface pH levels are reached. However, due to the rapid increase in lime use in agricultural, mining and construction industries, significant pressure has been placed on existing and potential limestone stocks. Lime is currently quarried at about 30 coastal sites between Geraldton and Esperance, with many situated in areas of conservation value. These sites are under significant threat from increased lime mining activity as demand increases, and questions are being raised about the sustainability of liming.

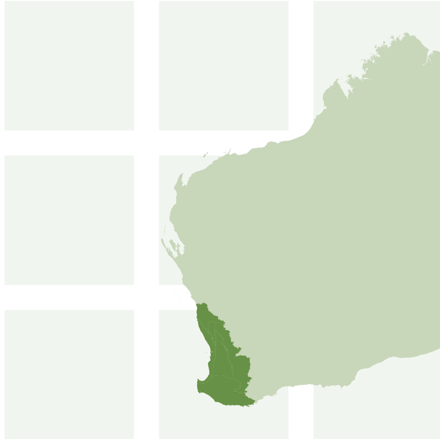
SUGGESTED RESPONSES

3.7 Develop and implement a Soil Acidification Management Strategy as a component of the proposed State Soil Protection Policy, covering all types of acid soils.

3.8 Finalise and implement the draft State Lime Supply Strategy incorporating sustainability principles.

3.9 Develop an agreed baseline of the extent and severity of soil acidification in WA.

3.4 LAND CONTAMINATION



INDICATIVE EXTENT OF ISSUE

PRIORITY RATING: 4

KEY FINDINGS

- As of March 2007, about 1350 contaminated sites have been reported in WA.
- Nearly 40% of reported contaminated sites are identified during land redevelopment.
- The *Contaminated Sites Act 2003* and regulations are now fully operational and have resulted in a dramatic increase in identified sites due to mandatory reporting.

Description

Land contamination is defined as land that has a pollutant (or pollutants) at above-background concentrations causing, or with the potential to cause, adverse impacts to human health, the environment or any environmental value. For this issue, 'pollutants' refers to chemicals such as heavy metals, pesticides, herbicides, oils, hydrocarbons and other toxic chemicals.

The toxicity and persistence of pollutants in soils, as well as their direct uptake by people, plants and animals, is the major concern with land contamination. The extent and severity of contamination will depend on pollutant type, land uses and industries, soil types and the effectiveness of pollution controls, if any exist. If the pollutant does not adhere to soil particles it may be mobilised by wind and water flow, or leached by soil water and transported by groundwater flow. For this reason, contaminated sites may cause both on-site and off-site environmental impacts. Contaminated sites are usually identified after the polluting activity or land use has ceased and the land is being redeveloped for another use. Some contaminated sites are identified once groundwater pollutant plumes are detected in inland waters or bore water.

Soil pollutants can affect human, plant and animal health if direct contact is made with contaminated soils or water, or if inhalation of chemical vapours and contaminated dust occurs. Impacts may vary in severity from reduced growth and reproduction to sickness, mutations and, in extreme cases, death. The effect of some toxic pollutants is increased by their ability to persist and build up in the environment over a very long period of time.

Objectives

The *Contaminated Sites Act 2003* identifies a specific objective to:

- protect human health, the environment and environmental values by providing for the identification, recording, management and remediation of contaminated sites in the State; and identifies a principle that:
- all reasonable and practicable measures should be taken to minimise the generation of waste and its discharge into the environment.

Condition

Indicator L13: Spatial extent and number of known contaminated sites, by sector.

The actual number of contaminated sites in WA is difficult to determine. In 1995 it was estimated there were 1500 sites, with about 80% thought to be on the Swan Coastal Plain as a result of extensive land development, and major industry and manufacturing operations. New regulations under the *Contaminated Sites Act 2003* have enabled better identification of contaminated sites in WA, through mandatory reporting of known or suspected contaminated sites. Although the Department of Environment and Conservation has a database of suspected contaminated sites, many require further investigation to clarify whether they are actually contaminated. As of March 2007, 1358 contaminated sites had been formally reported to the department. A significant number of additional sites is expected to be reported in 2007, to meet mandatory reporting requirements.

Known contaminated sites are mostly linked to past land uses for heavy industry, service stations, power stations, gasworks, landfill sites, mine sites, chemically intensive industries and some agricultural land uses (e.g. feedlots, market gardens). Service industries and the oil, petroleum and energy sectors currently account for over two-thirds of new contaminated sites identified (Figure L4.1). A high number of contaminated sites associated with the services sector can be attributed to land redevelopment. Remediation and treatment activities are normally required to ensure future land uses are not at risk of contamination.

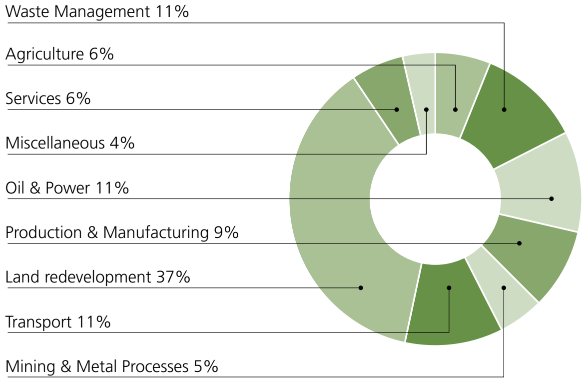


Figure L4.1: Proportion of identified Western Australian contaminated sites by sector.

Data source: Department of Environment and Conservation.

Indicator L14: Number of identified contaminated sites over time.

There has been a trend towards increasing identification of contaminated sites since the early 1990s (Figure L4.2). Most of this increase can be attributed to greater awareness and identification of contaminated sites in relation to land redevelopment. Since 1992, improved leak detection capability for underground storage tanks of petrol stations has also led to improved identification of contaminated sites. A peak in 2004 is due to the identification of about 180 individual sites as a result of the Northbridge Redevelopment Project in Perth. New regulations for the *Contaminated Sites Act 2003* became operational in December 2006, and is expected to result in a dramatic increase in the number of contaminated sites recorded in 2007.

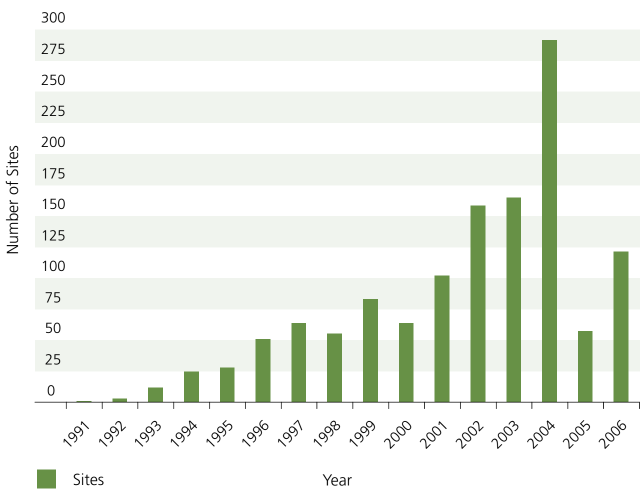


Figure L4.2: Number of contaminated sites reported to the Department of Environment and Conservation, 1992–2006.

Data source: Department of Environment and Conservation.

Pressures

The main causes of land contamination are poor or inadequate practices linked with the manufacture, use and disposal of chemicals by past or current industrial, agricultural or commercial activities. Point (local scale) contamination sources include chemical spillage, leakage of chemicals from landfill sites, storage drums, tanks, pipes and drains. Leakage of chemicals often occurs during industrial plant operation, storage or transportation. The main contaminants from industrial operations or waste that have potential to contaminate land include acids, alkalis, metals, surfactants, solvents and organic chemicals (such as phthalates, phenols, oils, aromatics, polycyclic aromatic hydrocarbons, polychlorinated biphenyls, halogenated aliphatics, pesticides, radionuclides and biological contaminants). Diffuse (broad scale) contamination sources usually include leaching of contaminants from widespread application of pesticides and fertilisers.

Deliberate dumping of waste by-products because it is cheaper and easier can be environmentally damaging and harmful to human health. It can also be especially difficult and costly to clean up and may result in offenders being prosecuted.

Mining activities, such as constructed tailings storage dams and some disused mine sites, have the potential to contaminate land if managed or constructed inappropriately. Many tailings deposits are not built as engineered structures, but simply through piling up of tailings slurries. Depending on the nature of the mining operation and extractive processes, these tailings may contain acidic or caustic material, heavy metals or cyanide, generally rendering the land unsuitable for any other future land use. Mine pits may become contaminated due to acidic water, potentially carrying high levels of dissolved heavy metals, infiltrating the pit. They are likely to remain contaminated in the absence of extensive rehabilitation measures.

Indicator L15: Number of licensed pest control operators and registered pest control firms.

Historical use and improper disposal of pesticides has been a leading cause of contaminated sites. Pesticide operators are licensed, and pest control businesses regulated, by the Department of Health to prevent further contamination occurring. As of March 2007, there were 1664 licensed operators and 686 pest control businesses in WA. The number of operators has grown significantly in recent years, in response to favourable economic conditions and the property boom. The rising number of operators indicates that pesticide and herbicide use is increasing. Synthetic pyrethroids and organophosphates are the pesticides now favoured by operators, and are considerably less toxic and persistent in the environment than pesticides used several decades ago (Department of Health, unpublished).

Indicator L16: Number of identified pollutant spills/ leakages per year.

Accidental spillage of hazardous chemicals, or biological or radioactive materials infrequently occurs following inappropriate storage, handling or transportation. Statistics indicate about 70 emergency events occur every year that involve hazardous materials (Fire and Emergency Services Authority, 2005). Many of these involve fires and chemical spills that may present some risk of land or water contamination.

Indicator L17: Number of sites where hazardous chemicals are stored.

There are currently about 6500 licensed sites in WA where hazardous chemicals are stored (Department of Consumer and Employment Protection, unpublished). While every attempt is made to store hazardous chemicals safely on licensed premises, inevitably there is a risk of spillage. Where spillages are significant or of a serious nature they may present a contamination issue if cleanup and remediation actions are not adequate.

Current responses

Contaminated Sites Act 2003: The purpose of the Act is to enable and facilitate identification, management and remediation of contaminated sites. It uses the 'polluter pays principle', which attaches liability initially to the polluter, then the landowner or occupier, and finally the State Government. The Department of Environment and Conservation is responsible for administering the Act and associated regulations.

Soil and groundwater remediation research: Projects are being undertaken by CSIRO to develop innovative technologies for the investigation, assessment and remediation of contaminated groundwater, water and soils.

Management guidelines for contaminated sites: The Department of Environment and Conservation has released a series of documents addressing identification, assessment, remediation methods, monitoring, community consultation, land use planning, and management and reporting in relation to contaminated sites. In addition, a number of guidelines have been developed to provide advice on the management of contaminating activities situated on, or near, groundwater protection areas.

National programs: There are a number of national programs such as the River Contaminants Program, the National Groundwater Research and Development Program and the National Pollutant Inventory which are directed at identifying and reducing pollutants being discharged to the environment.

Assessment of site contamination: The National Environment Protection (Assessment of Site Contamination) Measure 1999 forms the basis of many WA guidelines. This measure was developed by the Commonwealth Government to establish a consistent method for assessment of contaminated sites, so as to ensure sound environmental management practices for protection of human health and the environment (National Environment Protection Council, 1999).

Contaminated Sites Committee: is a statutory committee comprised of environmental and legal experts who are responsible for deciding appeals and for prioritising and remediating orphan or State-owned sites.

Contaminated site remediation: Land Corp is responsible for the remediation of orphan sites on behalf of the State Government. For other privately owned sites it is the responsibility of the polluter, land owner or occupier to clean up a contaminated site.

Planning conditions: The Western Australian Planning Commission and local government planning authorities are responsible for placing conditions on subdivision, rezoning, building and other planning applications where contamination requires investigation and/or remediation before development occurs.

Excavation of soil at a contaminated site (Department of Environment and Conservation)

Implications

Environmental implications of contamination may be short-lived or persistent, depending on the nature of the pollutant and the extent of its spread through the environment. Persistent chemicals such as heavy metals, pesticides, herbicides and some biological and radioactive agents pose the greatest risk to people, flora and fauna. The environmental repercussions of land contamination are extremely serious and may lead to a variety of complications, from sickness, to cancer and mutations, to widespread death of flora and fauna. Health effects of pollutants may be acute (short-lasting) or chronic (long-lasting), and be localised (in the vicinity of contaminated site) or widespread, affecting nearby populations (epidemic). Severe contamination may also render some land uninhabitable and severely constrain land use options for decades to centuries.

Remediation of contaminated sites is generally expensive but the economic costs of land contamination far outweigh the cost of remediation. For example, site cleanup costs incurred by government for the former East Perth Gas Works were $17.5 million, and for the former fertiliser plant at Minim Cove in Mosman Park was $16 million. Even relatively simple situations can be costly, such as the cleanup of drums containing oil and the herbicide 2,4,5-T at several bush sites near Dwellingup, which was estimated to cost $500 000. Contamination of land can also contribute to decreased property values and affect future potential land use capability. For example, the old Causeway Bus Depot site fell in value by nearly $9 million because of evidence of land contamination (Auditor General for Western Australia, 2002). The social ramifications of land contamination are significant. Discovery of a contaminated site in, or close to, residential areas may cause considerable community concern and distress, irrespective of the risk of potential exposure to the contaminant (e.g. the Brookdale incident of 2002).

SUGGESTED RESPONSES

3.10 The *Contaminated Sites Act 2003* and supporting regulations are now fully operational. Continue to implement the Act and regulations including the verification of suspected contaminated sites and their remediation.

EMERGING ISSUE – LOSS OF SOIL HEALTH

Loss of soil health is classed as an emerging issue due to its potential to cause significant impacts to agricultural productivity, however there is currently inadequate information to report on this issue.

Soil health is essential to farmers for maintaining the viability of their business. Many farmers and pastoralists regularly test soils and plants to determine soil health and combine this information with satellite imagery to identify problem areas. Soil health encompasses several factors, including soil physical structure, chemical composition and biological content. Deterioration of one factor may not necessarily cause an immediate loss of soil health, but may contribute to a decline in other factors and a gradual reduction in soil health.

Loss of soil health may be associated with a drop in soil fertility, caused by a decrease in soil nutrients that are necessary for plant growth (e.g. nitrogen, phosphorus or potassium). Soil nutrient decline is caused by removal of nutrients in harvested crop products, hay, plantation timber, animal products, as well as through soil erosion, leaching, acidification, burning of crop residues, and other chemical processes. Nutrient losses must be replaced by inputs over time (such as compost or fertiliser addition, or the growing of nitrogen fixing plants) if the soil is to remain productive. Native vegetation is not affected as much as it has evolved to the naturally low nutrient levels typical of Western Australian soils.

Loss of soil health may also be associated with a decline in soil structure, which tends to be a less visible or recognised form of soil degradation. A decline in soil structure can occur when wet soil is exposed to stresses of machinery, tillage activities or stock trampling. Similarly, exposure of bare soil to heavy rainfall can cause dispersion, slaking and crusting of the soil surface, which can lead to increased runoff and erosion. A decline in soil structure may also be due to poor soil drainage and subsequent waterlogging and soil dispersion (characterised by high sodium content). Soil dispersion leads to reduced cohesion between soil particles, and results in increased surface runoff and erosion, and reduced water infiltration. Although it occurs naturally, high soil sodium content can be exacerbated by land salinisation (see '*Land salinisation*').

Lack of organic or biological material (material from plants or animals) affects nutrient content, soil structure and the presence of soil organisms. Soil organic matter content typically decreases following clearing and cultivation of land, with regular tillage contributing to significant losses. Tillage physically breaks soil into small aggregates and reduces binding by soil organisms (e.g. fungi). Initial years of farming may result in the loss of one-third to one-half of soil organic matter. Loss of soil organic matter and biological activity will result in increased erosion potential, decreased nutrient storage and availability; and reduced water retention, infiltration and water-holding capacity.

Measuring soil health is difficult because soils are dynamic and often change in response to land uses, management practices, soil treatments, weather conditions and climate change. However, a good understanding of the many factors that contribute to soil health can avert deterioration in soil condition. A loss of soil health results in declining agricultural, pastoral or forestry productivity, causing significant economic impacts. A desire for short-term economic gain and ever-increasing levels of production from land must not compromise long-term soil productivity and health. This will only serve to place an additional burden on land managers who have to undertake expensive soil treatments and rehabilitation activities. Other environmental implications arising from a decline in soil health include exacerbation of soil erosion and associated inland water sedimentation, contamination and eutrophication.

Inappropriate grazing practices can contribute to soil and landscape degradation (B.Lloyd)

OUTGOING ISSUE – WATERLOGGING

Waterlogging was identified as an issue in the *1998 State of the Environment Report* (Government of Western Australia, 1998), however it was not identified as a major environmental issue for this report. Other parts of this report (see '*Altered water regimes*') consider broad changes to water levels in the catchment, including the effects of waterlogging.

Waterlogging represents excess amounts of water in the plant root zone of soils. It occurs naturally in low-lying wetland areas and near waterways where plants are suitably adapted for such conditions. However, problems arise when land is cleared of native vegetation and water infiltration to the soil (either from rainfall or irrigation) begins to exceed evaporation or plant water use.

Plants are particularly susceptible to the effects of waterlogging, causing damage and death to plant roots. It reduces soil oxygen levels, causing a build up of gases toxic to plants and alters the nutrient levels around roots. On agricultural land it may reduce crop and pasture productivity, and reduce the available cropping area. Excessive waterlogging may also cause pooling of water at the surface (inundation) leading to increased surface runoff, flooding, soil structure decline and erosion. Runoff may also export salt, nutrients and sediment to lower areas in the catchment.

Waterlogging and salinisation are closely related and can be managed by using or removing excess water from the soil. This may be achieved through the planting of perennial vegetation, approved drainage works, or engineering options such as groundwater pumping (see '*Land salinisation*').

Areas most susceptible to waterlogging include agricultural areas along the Swan Coastal Plain, the Scott Coastal Plain (east of Augusta) and low-lying areas in Wheatbelt valleys (Figure L6.1). Although many of these areas are still susceptible, waterlogging is now perceived to be a lesser environmental problem. It is possible that reduced rainfall in the South West over the past few decades (see '*Climate change*') has reduced the extent and severity of waterlogged areas. In addition, many farmers in affected areas also believe the problem can now be adequately managed.

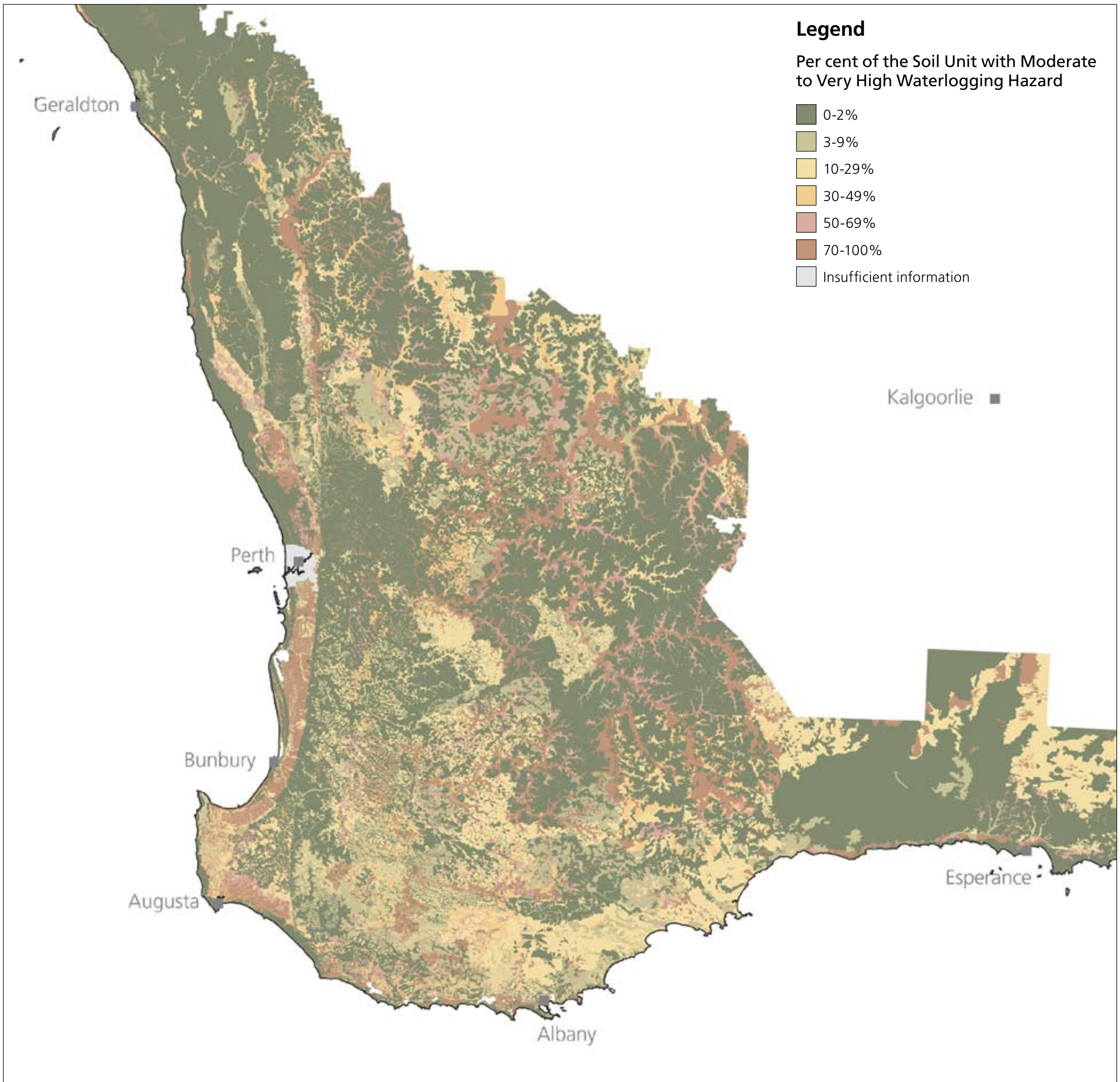


Figure L6.1: Risk of waterlogging inundation in the South West.

Data source: Department of Agriculture [ver. 2005]; Presentation: Department of Agriculture.

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