Environmental Factors Affecting Australia's Livestock Industries

A BRS report for Meat and Livestock Australia

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Department of AGRICULTURE FISHERIES & FORESTRY - AUSTRALIA

The Bureau of Rural Sciences (BRS) is the science agency within the Commonwealth Department of Agriculture, Fisheries and Forestry – Australia.

Postal address:
Bureau of Rural Sciences
PO Box E11
Kingston, ACT 2604

internet: http://www.affa.gov.au/output/ruralscience.html

Foreword

Australia's livestock industries operate in highly diverse environments, from extensive grazing in semi-arid and tropical rangelands to irrigated pastures and feedlots. The industry has a range of environmental impacts with immediate or delayed effects. Some impacts are historical, some are short-term and transient or reversible, others have long lag-times and are enduring. Both the industry and the community are increasingly focussed on the nature of these impacts and on means to manage them. This BRS report, commissioned by Meat and Livestock Australia, is an independent scientific assessment of current and emerging environmental issues for the industry.

Dr Peter O'Brien
Executive Director,

Authors

Dr Graham Yapp – Editing; Executive Summary, Introduction, text sections, Conclusions,

Dr Robert Munro – Coordination; Wind Erosion, Water Erosion, Weeds

Dr Michele Barson – Land Clearance and Biodiversity

Dr Colin Chartres – Soil Salinity, Soil Acidity, Soil Structural Decline

Dr Michael Hill – Greenhouse Gases

Dr Bernard Prendergast – Water and Groundwater

Executive summary

Environmental issues

This report discusses environmental issues and their effect on livestock industries. It considers environmental issues in a series of soil, water and vegetation related chapters.

Livestock industry development has had significant and prolonged impacts on Australia's environment. At the same time, the industry is affected by environmental issues and is adapting to meet pressure for change. The severity and scale of problems has changed over time. Some problems have been slow to emerge and are now being addressed as national priorities.

Land clearing

Clearance of vegetation for agricultural and pastoral development has changed the balance of vegetative cover and lies at the root of many environmental problems. Pasture improvement has been a 'driver' of land clearance. It accounted for 50% of land cover change between 1990 and 1995 and for 86% of total clearing in Queensland between 1995 and 1999. Clearing for pastures increased from 1950.

Greenhouse gases

Clearing has been a major source of greenhouse gas emissions ascribed to land use change. It also affects biodiversity, but detailed measures are not available. Controls have been introduced as a response to continuing and extensive clearing, notably in Queensland where the government has introduced a Vegetation Management Act. Vegetation management plans are providing guidelines for control of further clearing and other measures to reduce clearing and its effects are being prepared with industry consultation. Some nett greenhouse benefits may be obtained from control of woody weeds.

Livestock emissions

Proposed methods to reduce greenhouse gas emissions from livestock need careful assessment. Cyclical reductions in livestock numbers have reduced emissions but further reduction in animal numbers is an unlikely source for emission targets. Research continues into the reduction of methane emissions and other emissions that can be associated with the livestock industry. Improving the quality and management of feedstocks may reduce methane emissions. Nitrous oxide emissions from extensive dryland pastures are lower than emissions from irrigated pastures, and better management also can reduce nitrous oxide emissions. One strategy being developed is flexible trading of emission permits and the impacts of emissions trading may differ across the industry. The industry will have a major interest in how controls and permit trading systems are developed.

Soil carbon

The use of fire as a pasture management tool has a complex relationship to the greenhouse issue. The benefits of increases in soil carbon may be offset by increased gas emissions.

Overgrazing, often exacerbated by drought, has a major impact on soil carbon storage in rangelands.

Climate change Climate change predictions indicate the potential for some improvements in the productivity of rangelands, but increased variability and greater extremes of rainfall together with other negative impacts will drive adaptation of grazing practices.

Soil acidity The clearing of vegetation also is a direct cause of soil acidification. Leguminous crops and pastures, fertilisation, removal of products and burning-off all contribute to acidification. Increasing acidification is associated with aluminium toxicity to plants. Acidification depresses activity of microorganisms and causes physical and chemical changes. It progressively reduces pasture productivity and has also reduced species diversity. To date, acidification has not been shown to affect water resources in Australia.

Natural rates of acidification are low. Estimates of hazard show that some soils will degrade rapidly under annual pasture regimes. Acidification has mainly affected southern Australia but it can occur in the north. Very severe acidification has occurred under improved pastures in the south. Introduced species have contributed to nitrate leaching in the north. Sixty percent of soils in the intensive land use zone have a pH of less than 5.5. Addition of lime may be a cost-effective solution only for intensive grazing and current plant breeding programs are unlikely to provide a sustainable alternative solution for acidification.

Salinity Salinisation is Australia's most costly and serious environmental problem and clearing of native vegetation is its primary cause. Introduced crops and pastures have changed the water use regime and salinisation can emerge a long time after land clearing. Groundwater rises and salt accumulates where shallow rooted, introduced species cannot use the available water. The area of land affected is predicted to treble in the next 50 years. Increasing water quality problems result from saline groundwater discharge. Some groundwater supplies for stock and irrigation are at risk from increasing salinity. The National Land and Water Resources Audit has reported major increases in the salinity of rivers and streams.

Impacts on urban water users and infrastructure may be blamed on graziers. Concern about salinity will put pressure on the livestock industry to change land use. Salt load targets in the Murray-Darling Basin also will force land use change. Graziers in high-risk areas are likely to incur losses from rising groundwater and from measures to prevent it. They will need to receive better information and to sustain a strong commitment to adoption of best management practices.

Soil structure Grazing and cultivation for fodder crops have had a marked impact on soil structure. Soil structural degradation is due to changes that affect aggregation, water infiltration, shear and tensile strength, bulk density, porosity and water storage. Trampling is also a factor in structural decline. It is highly probable that structurally many soils were in significantly better structural condition prior to European settlement than they are today. Decline is often slow, but its impacts are wide ranging. The estimated affected area is nearly 26 million ha across all States.

Field evidence is increasing scientific understanding of the effects of structural decline. The role of low ground cover is important in the recovery from structural damage in sensitive environments. Adoption of 'best management practices' can minimise structural decline and its effects.

Water resources

Sustainability has replaced infrastructure development as the driver of water policy. The livestock industries are major users of Australia's water resources and they have had major impacts on landscapes and landscape function across Australia. The establishment of productive pastures after clearing of deep-rooted native species affects the water budget on the land surface.

Pastures consume approximately 35% of total water and stock and domestic supplies account for 8%. Water use by the livestock industries and other farming enterprises affects downstream users. Extensive grazing and irrigation for the livestock industry is a diffuse source of pollution. Livestock industries are often associated with the addition of fertilisers, pesticides, herbicides and other chemicals to the land. Overgrazing can result in increases in stream turbidity, salinity and faecal contamination. Turbidity is a worsening water quality issue across Australia. Contamination of surface waters, erosion of river banks and increases in stream turbidity are attributable to stock access.

Agriculture is usually the prime source of nutrients and pesticides causing algal blooms, but high stocking densities and irrigation frequency in the dairy and beef industries creates opportunity for algal toxins to accumulate. The problem of nutrients in riverine systems is exacerbated by several factors, including animal manure. Nutrients are a major surface water quality issue across Australia in more intensively developed areas including areas used for cropping, dairying and other livestock industries.

Surface water resources dominate the water use by the livestock industry. The livestock industry has had greatest impact on surface waters, stream habitat and downstream users in the Murray-Darling Basin and the Goldfields and South-West regions of Western Australia. The availability of surface water impacts the livestock industry over a substantial part of the country but groundwater supplies are generally sufficient.

Groundwater resources

The groundwater resource base will not limit the overall expansion of the livestock industry but over-allocation has occurred in some areas. Ten percent of the groundwater that is suitable for potable, stock and domestic use and for irrigated agriculture is currently used.

The most important groundwater supply is the Great Artesian Basin (GAB) and it is damaging to the industry to be associated with excessive water wastage and environmental degradation resulting from inefficient water use. The industry uses most of the water extracted from the GAB. Extensive water reticulation systems in the GAB are old, and numerous artesian bores are allowed to run freely which has meant that in excess of 90% of water extracted has been wasted. Groundwater pressures are declining over significant parts of the Great Artesian Basin. Environmental, biodiversity and sustainability issues related to water use in the Basin also have implications for inter-generational equity.

Mound springs in the GAB are strategically and ecologically important and have been subjected to grazing of various intensities, and to trampling and compaction of their margins with adverse effects. Falling groundwater pressure is primarily a result of water extractions by the pastoral industry. Recognition of groundwater dependent ecosystems as having high conservation value is developing, and the industry should look towards measures for their preservation as issues arise.

Contaminants

During the past decade groundwater quality assessment has included additional factors such as nutrient, toxic chemical, trace elements and microbiological loads. Broad area sources, such as grazing, dairying and animal manure applications have the potential to affect groundwater resources with widespread contaminant loads. Studies have shown that there are elevated nitrate concentrations in the groundwater across the nation in areas of grazing and dairying. On occasion, pathogenic viruses, bacteria, and protozoans of gastrointestinal origin may survive for sufficient time to be ingested by humans and livestock drinking the extracted groundwater.

Studies have shown that some residues increased as pasture height decreased, indicating soil ingestion as the major means of pesticide intake by grazing animals. Herbicides applied to control weeds in irrigated pasture lands have the potential to contaminate groundwater.

Contamination at cattle and sheep dip sites is very high and potential exists for migration of contaminants to the groundwater. Organochlorine pesticide residues are still present in soils and continue to impact environmental quality several years after the discontinuation of their use. Discharges from livestock industries using veterinary chemicals may contaminate both surface waters and groundwaters. Current impacts on the industry from some other contaminates are small but sources of contamination should be monitored. Protecting and preserving markets requires certainty that livestock products are free from residues that have been accumulated under previous management regimes.

Water policy

The freeing-up of water markets and the transfer of water allocations as a result of National Water Reform Agenda policies has caused considerable structural adjustment pressures within the livestock industry. Jurisdictional and institutional issues influence the widely varying regulatory policies for water development and use by the industry. The allocation of environmental flows has resulted in a significant reduction in water availability in some areas; the industry is more likely to feel the impacts of environmental allocations in the Murray Basin.

The greatest fraction of water consumption by the livestock industry occurs in the irrigation regions; it is in these areas that water availability is more likely to impact on the industry. The availability of water for the livestock industry in the irrigation sector is complicated by other beneficial uses for the water. The COAG water reform agenda has many aspects that are important to the allocation of water within the livestock industry. Under the National Action Plan (for salinity and water quality), there will be a substantial increase in water trading that will entail structural adjustment and affect the industry. Integrated surface water – ground water management plans and effective water trading regimes will be developed in the Murray-Darling Basin. The water reform agenda will continue and its impact on the livestock industry will increase.

Wind erosion

Wind erosion directly affects costs and productivity through soil depletion, impaired water availability and higher costs of production. It can have impacts on public health and increase public reactions to wind erosion that may lead to controls on land use. Wind erosion removes particles that may be rich in nutrients and organic matter. Very high losses occur in extreme events. Wind erosion is influenced by climate, characteristics of the soil and land surface, and by land management practices. While the incidence of dust storms is lessening, high risk remains. The risk of wind erosion can be minimised by good management practices.

Maintaining vegetation cover is critically important. Vegetation cover increases surface roughness and reduces erodibility. Managing the cover of annual vegetation is especially critical to protecting soil from wind. Organic matter in the soil also reduces susceptibility to wind erosion. Pasture and tree management are the critical elements in any strategy for reducing erosion risk. Sustainable grazing systems should have maintenance of suitable vegetation cover as a major aim, but vegetation management needs to be linked to better information on climate. Better information is needed for vegetation management strategies tailored to specific regions.

Water erosion

Water erosion takes several forms. Sheet and rill erosion varies according to rainfall erosivity, vegetative cover, soil conditions and management practices. Water erosion removes fertile fractions of the soil resource and erosion generally exceeds the rate of soil formation across Australia.

The energy of rainfall (erosivity) is a key determinant of soil loss. The erodibility of soil is influenced by land management practices. Vegetation management to increase surface protection and roughness is a key to reducing soil loss. Pasture and tree management and ground cover maintenance are critically important because bare surfaces are extremely vulnerable to erosion. Protection of riparian zones is important and more information is needed to guide land management.

Impacts of water erosion on water quality are well understood and other environmental impacts are widely recognised. At the property level, erosion lowers soil and pasture productivity, increases input costs, damages farm water supplies and increases the risk of other problems. Water erosion affects productivity and can raise consumer and other public concerns. Issues include damage to infrastructure, increased costs for protection and maintenance, poor water quality, reduced biodiversity and inferior quality of products. The development and adoption of best management practices to minimise water erosion is critical to sustainability of the industry and will ensure that community attitudes remain favourable. Land use needs to be matched to slope, soil type and the rainfall regime. Responses to water erosion may include increased regulation of the industry.

Weeds

A high proportion of Australia's plants has developed in isolation and is vulnerable to introduced and invasive species. The rate of invasion varies, but is usually initiated by a disturbance to the native vegetation. The course of invasions is hard to predict and more research is needed. Single species invasions are characteristic of northern Australia; multiple species of the south. Rangelands are susceptible to weed problems, including native species that are considered to be weeds. Several types of weed are now serious problems in high rainfall areas of the coasts and uplands and can have serious impacts on the industry.

Weed research has been concentrated on agriculture, horticulture and forestry. Other than biodiversity, the effects of weeds on ecosystems are poorly understood. Of about 30,000 exotic species in Australia, only a few have become serious weeds. The rate of spread of weeds depends on a combination of factors; these are well understood for only a few weeds.

Weeds have widespread effects on the productivity of agricultural and pastoral systems. Annual losses due to weeds have been estimated at $3.3 billion; a substantial component accruing to the livestock industries. Many weeds are the first 'colonisers' of disturbed environmentss and they can exclude grazing over large areas.

Fire and grazing can combine to ameliorate or, equally, to exacerbate weed problems and good burning strategies are needed in pasture management. Research and data collection is needed to improve understanding of the long-term effects of fire as a management tool. Working with nature is more likely to be a successful weed control strategy and yield better results than will be provided by attempts to eradicate weeds.

Some industry practices contribute to weed invasions and pastoralist, conservationist and community interests could become polarised.

Implications

The livestock industry must recognise community views that include a perception that the industry is the cause of many environmental problems. Community and export market concerns could increase pressure for direct government involvement and control by regulation. Response strategies for the industry will need to be based on assessments of the balance between risk of environmental damage and the potential loss of productivity from changing management practices. The key will be to find a balanced path between changes in environmental conditions and the industry's own inevitable impacts on the environment. Enlightened management can counter many unfavourable perceptions of the livestock industry.

MLA may need to address a significant requirement for social science research and improved public information resources. MLA needs to be able to establish and argue that the industry is addressing environmental goals. The industry will need to improve its capacity to respond rapidly and effectively to public pressure. MLA should focus on "hooking into" current research initiatives in order to maximise their relevance and value to the industry.

Contents

Chapter 1. Introduction

This report discusses environmental issues and their effect on the livestock industry

Meat and Livestock Australia (MLA) requires a review that provides concise data and information about the nature of current and emerging vegetation, land and water degradation problems and their effects, including greenhouse gas issues. To be supplemented with information on potential management responses, the review will be used in strategic planning for new programs.

The material presented in this report examines causes of environmental impacts and how these impacts have been expressed in the past and are now influencing the industry.

Livestock industry development has had significant and prolonged impacts on Australia's environment

The development and operation of livestock enterprises has had a significant and prolonged impact on the quality, diversity and condition of Australian environments. Settlement of the land and adjustment to the exigencies of Australia's climate and the relative poverty of its soil resources, has been marked by environmental problems that range from temporary, local and financially acceptable to permanent, widespread and economically disastrous.

The industry has adapted to meet environmental conditions

At the less serious end of this scale, problems have arisen and solutions have been found as the industry has been able to adapt to climatic variability, market fluctuations and the availability of new technologies, improved genetic material and advances in scientific knowledge.

The severity and scale of problems has changed over time

Causal factors at the seriously damaging end of the scale stem from the "pioneering" drive to clear and settle the land that was followed by the inappropriate transfer of European practices to the fragile and poorly understood Australian environment. While some results such as widespread gully erosion, sedimentation and accentuated flooding were quick to follow, other problems such as frequent and destructive dust storms developed more slowly. The severity of these impacts has been reduced with better understanding of their causes and increased readiness to change land use and land management. However, some problems have been even slower to emerge but are now developing at accelerating rates.

Some problems have been slow to emerge and are now being addressed as national priorities

From its beginning, the industry has faced major "on-site" impacts. It has weathered the effects of problems such as water and wind erosion and has been able to increase productivity through innovation and better animal husbandry. While the off-site effects from these causes have been serious, the suite of problems that is now emerging has an added dimension of national concern and this will be the powerful driving force for new industry strategies for environmental management.

The industry is affected by environmental issues and is adapting to meet pressure for change

These emerging problems are only now being accorded the status of major environmental issues that may require drastic change in the rural economy, placing pervasive and unavoidable external pressure for change on the livestock industry. Chief among these are widespread soil problems, especially salinity, acidification and structural decline, critical water problems including the deterioration of surface and groundwater quality, and problems of the biosphere, atmosphere and climate, especially related to decreasing biodiversity and increasing greenhouse gas emissions. The industry is a significant contributor to these problems but also is affected by their impact on the environment.

This report considers environmental issues in a series of soil, water and vegetation related chapters

This report compiles information on rural resource management issues that require responses from the livestock industry. It treats the main environmental issues in a series of individual chapters that summarise the current understanding of how the industry has affected the natural environment and follows this with information on how the industry has, in turn, been affected by deteriorating environmental conditions. The issues covered are land clearing; greenhouse gases; weeds; wind and water erosion; soil salinity, acidity and structural decline; and surface and groundwater quality and quantity. The individual assessments have provided the basis for suggestion of a number of specific problems and possible responses be addressed in strategic planning by Meat and Livestock Australia.

Chapter 2. Land clearance and biodiversity

Effects of broadacre livestock industries on the vegetated environment

Vegetation change since European settlement

Clearing and thinning for grazing and cropping have changed the balance of vegetative cover

Substantial modification of Australia's vegetation has occurred since European settlement. Clearing and extensive thinning of woody vegetation have meant that by the 1980s only five percent of the continent remained forested, and the area of woodland had decreased from 21 to 14 percent. Thinning of forests and woodlands, plus some invasion of grasslands by woody species, have resulted in a four percent increase in the area of open woodland. Although only about three percent of shrublands have been cleared (mostly mallee), about 20 percent have been thinned. Grasslands now cover almost 16 percent of the continent.

Clearing for pastures increased from 1950

Graetz (1998) reported data that indicate that most of these changes took place to support agricultural development. He suggests that early clearing was principally for cropping; clearing for pastures increased in importance from the 1950s on. Annual rates of clearing peaked in the 1970s, when extensive areas were cleared in southwestern Western Australia and Queensland for grain production, and in Queensland for pasture improvement.

Pasture improvement has been a 'driver' of land clearance

Preliminary estimates of rates of clearing for the 1980s were compiled for the first National Greenhouse Gas Inventory (Department of Environment, Sport and Territories 1994) and suggested that around 517,000 ha were cleared annually in the 1980s. A subsequent analysis of satellite data (Graetz 1998) showed around 520,000 ha were cleared annually over this period. While neither of these studies identified the causes of clearing, it was thought that much of the clearing, which was taking place in Queensland, was for pasture establishment or improvement.

Rates of land clearing associated with grazing industries

Clearing for grazing accounted for 50% of land cover change between 1990 and 1995 and was the major source of greenhouse gas emissions ascribed to land use change

A collaborative study undertaken by BRS and State agencies (Barson, Randall and Bordas 2000) of rates of change in woody vegetation showed that 929,280 ha were cleared for grazing over the period 1990/91-1995 (Table 2.1). (Woody vegetation was defined as all vegetation, native and exotic, with a height equal to or exceeding 2 metres and a crown density of 20 percent or more). Clearing for grazing accounted for more than 50 percent of the total land cover change, and for 77 percent of the clearing that contributes to greenhouse gas emissions identified in the land use change sector of the National Greenhouse Gas Inventory. Note that changes in tree cover associated with fire, forestry and plantation management activities are included in the total reported. These changes are generally regarded as temporary losses; these areas are regenerated or replanted.

Table 2.1. Decrease (ha) in woody vegetation by cause of change for study period

State	Agriculture*	Grazing	Other**	Forest management	Plantation management	On-Farm tree planting	Fire
A.C.T.#	0	0	0	210	4,390	NR	0
New South Wales #	51,860	NR	8,070	16,130	7,580	NR	123,040
Northern Territory	5,870	1,070	9,550	NR	20	NR	NR
Queensland #	40,510	924,410	27,380	3,970	12,300	NR	140
South Australia	6,040	NR	460	10	8,030	700	66,320
Tasmania	230	3,800	440	27,270	8,280	1,060	1,310
Victoria	9,240	NR	3,480	30,280	21,640	NR	25,120
Western Australia	99,930	NR	20,280	12,290	5,590	NR	198,140
Total	**213,680**	**929,280**	**69,660**	**90,160**	**67,830**	**1,760**	**414,070**

*Includes orchard management, ** includes urbanisation and infrastructure development, # data for 1991-1995, NR no examples recorded

Figure 2.1 shows the distribution of land cover change due to clearing for agriculture, grazing and other (development) activities

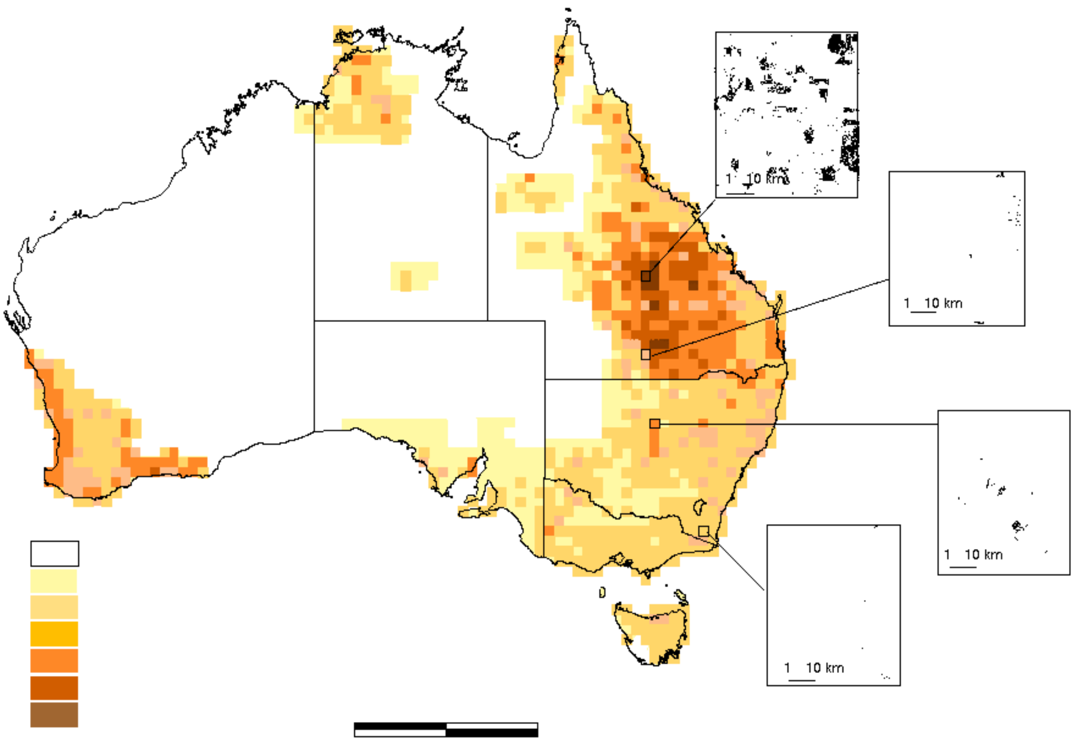

Figure 2.1. Distribution of clearing (ha) of woody vegetation 1990/91 -1995 for agriculture, grazing and development.

Figure 2.2 shows the location of clearing activities for grazing in Queensland 1991-1995.

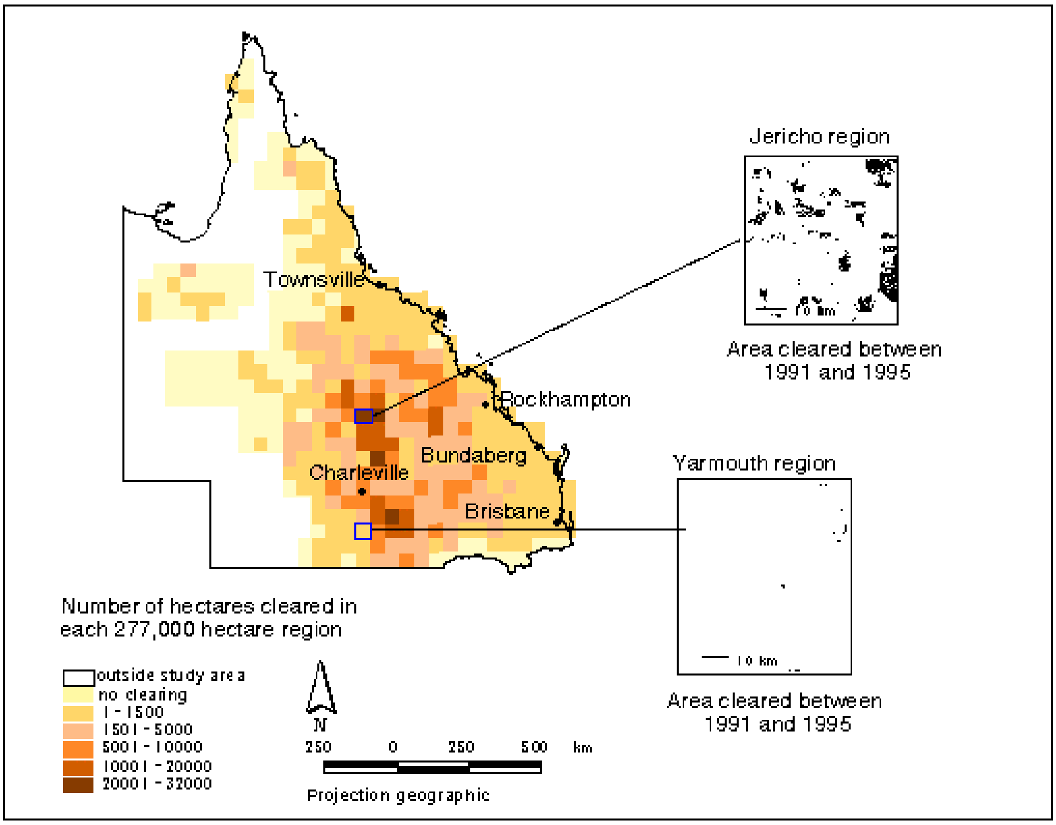

Figure 2.2. Decrease in woody vegetation - clearing for grazing in Queensland.

Clearing for grazing accounted for 86% of total clearing in Queensland between 1995 and 1999, but much less in other States and Territories

Calculation of annual rates of change also shows that clearing undertaken for grazing contributed about 80 percent of the loss of tree cover each year (246,100 ha) over the period 1990/91-1995 Continued monitoring of tree clearing in Queensland undertaken by the Department of Natural Resources (Queensland Department of Natural Resources 1999, 2000) has shown that clearing for grazing has continued to make a major contribution to vegetation loss in Queensland. Over the periods 1995-97 and 1997-1999, analyses of satellite data combined with other information showed that 292,600 and 363,800 hectares respectively were cleared for grazing. Over these periods clearing for grazing accounted for about 86 percent of Queensland's total clearing. Accurate data on rates of clearing for other States and Territories post 1995 are not available. It is thought that relatively little of the clearing occurring in these States is likely to be associated with grazing industries.

Data for 1991-95 show the scale of woody regrowth on land in

The problems of managing woody regrowth on land cleared for cattle grazing are well known (Burrows, Carter, Scanlan and Anderson 1990). Where this clearing is not followed by ploughing, woody vegetation may regrow within a few years of clearing. Rates of re-

Queensland that has been cleared for grazing

establishment probably depend on the type of vegetation cleared, rainfall in the years following clearing, and the intensity of land management. Regrowth is more difficult to measure than clearing, because its establishment and rate of growth can be very uneven. Recent increases in woody vegetation due to regrowth are closely associated with grazing industries in Queensland (Table 2.2).

Table 2.2 Increase (ha) in woody vegetation by cause of change for study period

State	Agriculture*	Grazing**	Other***	Forest management	Plantation management	On-farm tree planting	Fire****
A.C.T.#	0	0	0	0	1,790	0	70
New South Wales#	1 140	30	90	5,670	31,810	140	13,690
Northern Territory	420	NR	NR	NR	150	NR	NR
Queensland#	0	113,090	0	1,180	12,960	NR	NR
South Australia	15,140	NR	0	NR	19,190	1,370	183,410
Tasmania	120	0	60	1,380	22,560	220	NR
Victoria	NR	NR	3,370	13,400	33,350	NR	206,970
Western Australia	95,720	0	10,860	6,900	38,950	11,480	76,570
Total	**112,540**	**113,120**	**14,380**	**28,530**	**160,760**	**13,210**	**480,710**

* Includes orchard management, regrowth on land cleared for cropping then abandoned, ** includes regrowth in grazed woodlands, *** includes development, **** regrowth after bush fires, NR not recorded, # 1991-95 data

Land clearing affects biodiversity, but detailed measures are not available

Impact of land clearing on biodiversity

Remote sensing studies undertaken to date focus on the clearing of trees because changes in this type of vegetation can be detected with a high level of confidence (see Barson, Randall and Bordas 2000). Agricultural development has also led to losses of grasslands, heathlands, shrublands and sparse woodlands. Detailed estimates of the losses of these vegetation communities are not available.

Land clearing has been identified as the major threat to biodiversity in Australia (Department of Environment, Sport and Territories 1995) principally through fragmentation of communities and habitat loss and the impact of these on plant and animal species. A number of studies of species and habitat losses have been undertaken (see Boulter, Wilson, Westrup, Anderson, Turner and Scanlan 2000 for a recent review). These studies have been local or regional in extent and often focussed on individual species or groups of species.

There is currently insufficient data on the distribution of plants and animals and their status (whether they are rare or endangered) to undertake a comprehensive study of the impact of recent clearing on biodiversity. An analysis of the extent of clearing 1990/91 –1995 by Interim Biogeographic Region Australia (IBRA) provides an overview. IBRA regions are an environmental regionalisation

Clearing continued throughout the 90s in some regions where only limited areas have been set aside in reserves for protection of biodiversity

developed to help assess the adequacy of Australia's conservation reserve network (Thackway and Cresswell 1995).

Figure 2.3 shows Interim Biogeographic Regions where clearing for cropping, grazing and development were greater than 1,000 ha for the period 1990/91 - 1995. Clearing at this rate occurred in the Mitchell Grass Downs, where less than one percent of the region has been reserved, ie, included in National Parks and various types of reserves (Thackway and Cresswell 1995). Clearing also occurred in the Avon Wheatbelt, Brigalow Belt North and Brigalow Belt South, Cobar Peneplain, Daly Basin, Darling Riverine Plains, Desert Uplands, Einasleigh Uplands, Gulf Plains, Mulga Lands, and Nandewar regions with 1-5 percent of the region reserved. Clearing has also been undertaken in the Ben Lomond, Central Mackay Coast, Eyre and York Blocks, southeastern Queensland, and the Victorian Midlands regions where 5-10 percent of the land is reserved.

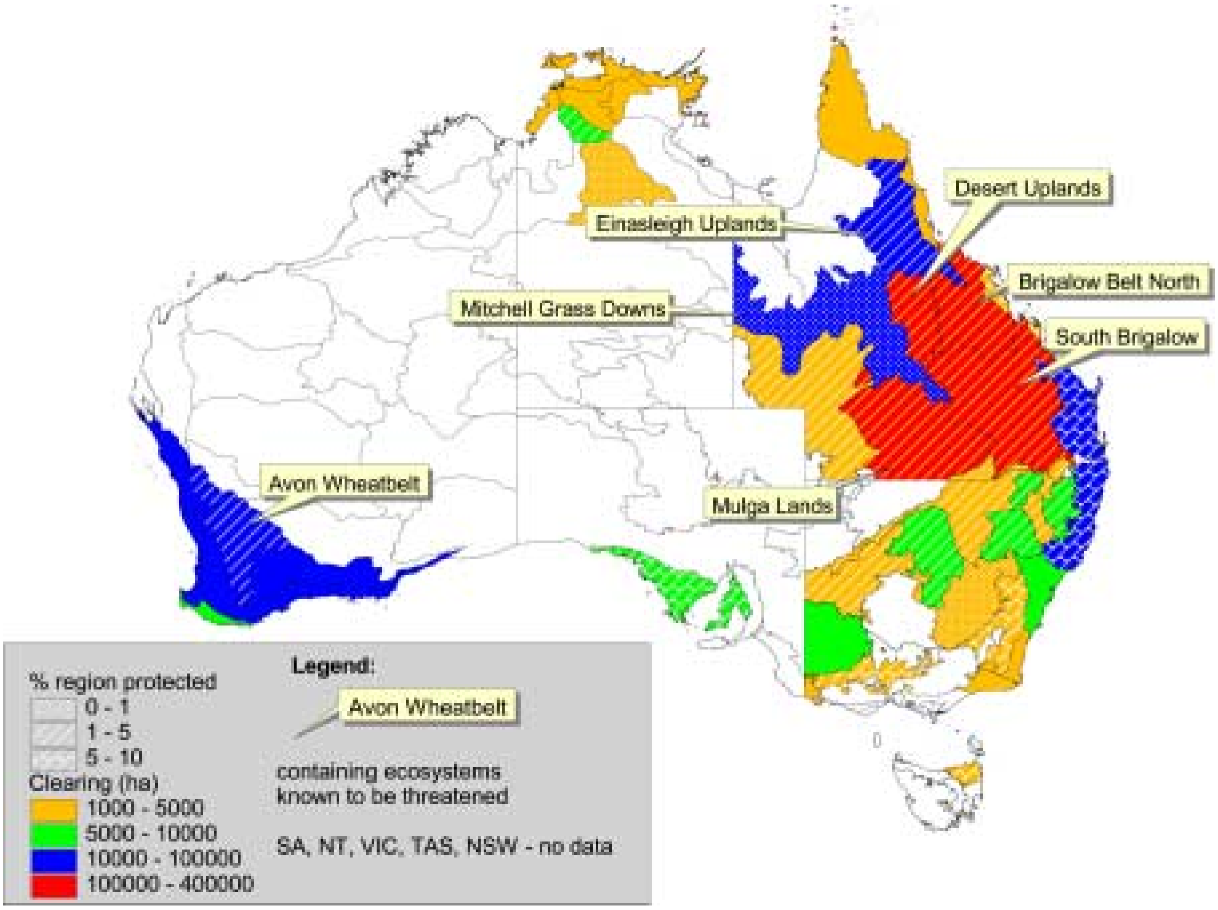

Figure 2.3. Extent of clearing 1990/91 – 1995 by Interim Biogeographic Region.

The Brigalow Belt North and Brigalow Belt South, the Desert Uplands, Einasleigh Uplands, the Mitchell Grass Downs and the Mulga lands of Queensland and the Avon Wheatbelt in Western Australia contain significant areas of ecosystems known to be threatened – that is where less than 30 percent of pre-European vegetation remains (Sattler and Williams 1999; Hopkins, Coker, Beeston, Bowen and Harvey 1996). It should be noted that the conservation status of bioregional ecosystems for States other Queensland and Western Australia has yet to be assessed. Figure 2.3 shows Interim Biogeographic Regions, the amount of protected land in each region and the extent of clearing from 1990/91 to 1995.

From 1990-95 clearing had most impact on woodlands, low woodlands and open forest in Queensland

Types of vegetation cleared for agriculture 1990/91 -95

Table 2.3 shows that for the study area as a whole (Figure 2.1), Woodland (M2 – 47 percent), Open forest (M3 – 16 percent), Low woodland (L2 – 28 percent) and Tall shrubland (S2 – 7 percent) were the major types of native woody vegetation cleared for agriculture, grazing and development over 1990/91-1995.

Table 2.3. Types (ha) of native woody vegetation cleared for agriculture, grazing and development by vegetation type

Carnahan Vegetation type	NSW	NT	QLD	SA	TAS	VIC	WA	Study area
T4	0	0	0	0	0	0	0	0
T3	2,530	0	0	0	1,020	760	660	4,970
T2	0	0	0	0	0	0	0	0
M4	680	0	3,530	10	10	530	1,390	6,150
M3	20,870	1,790	147,650	300	3,430	4,210	16,090	194,340
M2	27,650	6,650	515,990	0	0	1,030	19,450	570,770
L4	0	0	1250	0	0	0	0	1,250
L3	0	90	3,820	0	0	360	0	4,270
L2	3,280	7,680	307,580	310	0	560	24,240	343,650
S4	0	0	0	0	0	0	0	0
S3	0	0	10	0	0	70	5,040	5,120
S2	3,840	230	12,720	5,870	0	4,900	53,600	81,160
Total	**58,850**	**16,440**	**992,550**	**6,490**	**4,460**	**12,420**	**120,470**	**1,211,680**

In New South Wales most clearing (82 percent) was of Open forest (M3) and Woodland (M2). In the Northern Territory clearing was predominantly of Woodland (M2 – 40 percent), Low woodland (L2 – 47 percent) and Open forest (M3 – 11 percent). In Queensland the major types of vegetation cleared were Woodland (M2 – 52 percent), Open forest (M3 –15 percent), and Low woodland (L2 – 31 percent). More than 90 percent of clearing in South Australia was of Tall shrubland (S2).

Clearing in Tasmania was mostly of Open forest (M3 –77 percent) and Tall open forest (T3 – 23 percent). Open forest (M3 – 43 percent), Tall open forest (T3 – 22 percent), Tall shrubland (S2 – 15 percent), and Woodland (M2 – 11 percent) were the major types of vegetation cleared in Victoria. In Western Australia clearing was mostly of Tall shrubland (S2 – 35 percent), with Woodland (M2) and Open forest (M3) contributing a further 41 percent.

Effects of environmental issues on broadacre livestock industries

Land clearance and biodiversity

Controls have been introduced as a response to continuing and extensive clearing

By the mid 1980s to mid 1990s, concern about the rate of disappearance of native vegetation and associated land degradation problems resulted in the establishment of legislative or regulatory controls on land clearing in most States and Territories. At present, the only areas not covered by such controls are Tasmania and freehold lands in the Northern Territory.

Queensland introduced a Vegetation Management Act

In 2000, the Queensland government proclaimed the Vegetation Management Act 2000 to provide a statewide framework for the protection of native vegetation on freehold and leasehold land. The purpose of the Act is to preserve remnant endangered regional ecosystems (where less than 10% of preclearing extent remains, or 10-30% if the total remnant area is < 10,0000 ha), vegetation in areas of high nature conservation value and vegetation in areas vulnerable to land degradation. The Act has been designed to ensure that clearing does not cause land degradation, to maintain or increase biodiversity, to maintain ecological processes and to allow for ecologically sustainable land use.

Thresholds for vegetation retention under the Act include retention of at least 30 percent of the total original vegetation in each bioregion (see Figure 2.3), and no negative change in the conservation status of a regional ecosystem. However, there are no individual property retention levels.

Vegetation management plans are providing guidelines for control of further clearing

Under the Act the Minister has an obligation to prepare regional vegetation management plans. These will describe how the vegetation will be managed for the long term benefit of the region and link with other existing plans such as catchment plans and regional strategies. They will include local guidelines for assessing clearing applications. Department of Natural Resources' regional vegetation coordinators will facilitate community involvement in regional vegetation management planning.

Other measures to reduce clearing and its effects are being prepared with industry consultation

In addition, Commonwealth and Queensland government officials have been discussing a scheme aimed at providing a significant greenhouse outcome beyond the likely impact of the State's Vegetation Management Act, including, subject to farmers' support, a cap on clearing permits and the trading of permits. Additionally, the Prime Minister has indicated that within the Salinity and Water Quality Action Plan, the Commonwealth is prepared to assist in compensating for property rights (which potentially could include clearing) lost as a result of the Action Plan. There is no offer of compensation outside the Action Plan.

The industry will have a major interest in how controls and permit trading systems are developed

It is clear that the Queensland Vegetation Act will substantially reduce rates of land clearing undertaken by the grazing industry. Approximately one million hectares (about 0.5% of Queensland) are classified as endangered regional ecosystems. Of this about 0.5 million ha occur on freehold land and 370,000 ha on leasehold land (Boulter et al 2000). The potential impact of any additional controls resulting from agreement to a cap on clearing or the introduction of a clearing permit trading system on the grazing industries is not yet known. This would provide a good research topic for MLA.

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Chapter 3 Enhanced Greenhouse and atmosphere effects

Effects of broadacre livestock industries on greenhouse gas emissions

The nature and importance of livestock industry impacts on the atmosphere

The human-induced increase in concentration of greenhouse gases in the atmosphere is expected to result in increased global average temperatures and changes in the climate.

Greenhouse gas emissions are expected to change global climate

The major greenhouse gases produced by human activity are carbon dioxide (CO2), methane, nitrous oxide, ozone, nitrogen oxides, halocarbons and sulphur hexafluoride. The global warming potential of these gases is rated in terms of CO2-equivalents such that methane is 21 times as potent, nitrous oxide is 310 times and the various fluoride-based compounds are many thousands of times as potent as CO2.

Around 20% of Australian emissions can be attributed to rural industries

Agriculture, excluding land clearing, produced around 20% of the total net national greenhouse gas emissions in the 1998 National Greenhouse Gas Inventory (NGGI, 2000). The major sources are methane from enteric fermentation by livestock and nitrous oxide from cultivation, fertilisation and faecal and urine deposition.

Livestock production systems are major direct and indirect sources of greenhouse gas emissions. The major sources of emissions are:

Livestock industries contribute significant volumes of potent greenhouse gases

- Direct methane emissions from enteric fermentation by beef cattle (60%), sheep (27%) and dairy cattle (11%).
- Methane emissions from manure management in pig, dairy and poultry industries.
- Nitrous oxide emissions from feedlot cattle and poultry.
- Nitrous oxide emissions from faecal and urine deposition by livestock.
- Emissions of nitrous oxide through denitrification resulting from fertilisation and nitrogen fixation by legumes in intensive pasture systems.
- Oxidation of soil carbon through degradation and overgrazing of rangelands.
- Prescribed burning of rangelands.
- Land clearing for expansion of livestock industries, through burning and decomposition of organic matter, yielding CO_2, methane and nitrous oxide.
- Indirect emissions from power consumption and diesel usage by more intensive grazing enterprises

Cyclical reductions in livestock numbers have reduced emissions

Direct emissions of methane account for about two-thirds of agricultural greenhouse gas emissions for Australia and around 13% of total net emissions. Emissions from livestock have declined by about 5% between 1990 and 1998 due to the large reduction in sheep numbers (NGGI, 1998). However, this emphasises the sensitivity of greenhouse gas emissions from the livestock industry to animal population size.

The Kyoto protocol calls for Australia to meet an agreed target of 108% of 1990 emissions for the period 2008-2012. The questions of how the livestock industries might address their potential responsibilities, opportunities and liabilities under this agreement have been explored in a number of recent workshops and symposia (Anonymous, 1994; Thomas *et al.*, 1999; Reyenga and Howden, 1999; Keenan *et al.*, 2000).

Proposed methods to reduce emissions from livestock need careful assessment

There is a range of approaches which might be applied by the livestock industry to reduce emissions and/or increase sequestration of carbon in vegetation or soils. However, many of these approaches need to be carefully assessed as the net impact is severely affected by potential adoption rates, and some practices which sequester more carbon may also result in increased emissions through, for example, increases in animal numbers. The net greenhouse gas balance must be carefully estimated or measured to provide definitive assessments of the greenhouse benefits of any measures. In addition, there may be economic or social barriers and disincentives which reduce the likelihood of adoption of some measures.

Emissions Control

Reduction in Animal Numbers

Further reduction in animal numbers is an unlikely source for emission targets

With existing technology, it has been estimated that Australia would require a reduction in dairy cows of 200,000 to reduce methane emissions by 10% (Eckard *et al*., 2000). It is more likely that both beef and dairy cattle populations will increase with further intensification and more efficient utilisation. Therefore other approaches will be required.

Reduction in emissions per animal

Management of the feed base to improve feed quality

Methane emissions may be reduced by improving the quality and management of feedstocks

It is recognised that methane production is higher on poorer quality feeds since feed conversion rates are poorer. There is therefore potential to reduce methane emissions by better management and supplementation of the feed base to optimise quality (Hegarty, 1999). Pasture management to maintain pasture in a growth state to maximise nitrogen uptake, minimise pasture senescence and prevent accumulation of nitrogen rich organic matter in wet anoxic sites will also improve livestock production and minimise greenhouse gas emissions from pastures and animals.

A systematic evaluation of the benefits of new introduced species is

Introduction of exotic pasture species into tropical areas has potential to greatly improve feed quality, but there are negative environmental effects through weediness of some species and depletion of native *needed*

plant biodiversity. Technology and management to improve summer feed quality in Mediterranean environments may also result in some reduction to seasonal methane emissions. There is a need for examination of the overall benefits including production, economic, social and environmental, as well as emission benefits within a systems context.

Rumen Modification

Research continues into the reduction of methane emissions from livestock

Various approaches to reducing methane production in the rumen including removal of protozoa or inhibition of methanogenesis by bacteria are under investigation. A CSIRO project is investigating development of a vaccine to reduce methane emissions. These approaches may reduce methane emissions from individual animals, but the overall impact on greenhouse gas balances will be determined by average effectiveness across the animal population, feed quality and seasonal effects and the extent of adoption

Management of nitrogen fertilisation and legume use

Nitrous oxide emissions from extensive dryland pastures are lower than emissions from irrigated pastures

Denitrification is at its highest potential in fertilised, irrigated summer pastures. In most of southern Australia, low soil moisture in summer limits denitrification from dryland pastures. Legume-based pastures form the basis of the extensive livestock industry in the agricultural zone and are a major source of nitrous oxide through denitrification in wet, oxygen limited soils. Nitrous oxide emissions from extensive agriculture are potentially an important issue because of the high potency of nitrous oxide as a greenhouse gas. Emissions are small in extensive dryland perennial systems but may be more significant where cultivation ends the legume pasture phase of a crop rotation.

Application of nitrogenous fertiliser to coincide with high plant growth rates, and avoidance of anoxic soil conditions will ensure maximum incorporation into plant material, and minimise losses to run-off, volatilisation and denitrification.

Drainage to reduce waterlogging

Better management also can reduce NO emissions

Denitrification rates may be increased in waterlogged soils which also emit some methane. Reduction in flood irrigation of dairy pastures would improve water use and reduce waterlogging but would be subject to major social and economic constraints (Eckard *et al*., 2000).

Management of effluent spreading and waste storage

Analysis of effluent nitrogen content is recommended to ensure that quantities spread do not exceed the recommended application rate of nitrogen per growth period (Eckard *et al*., 2000). Reduction in the duration of waste digestion will reduce both methane and nitrous oxide emissions (*ibid*). Aerobic decomposition of effluent also minimises anaerobic production of methane and nitrous oxide.

Fire Management

This issue was briefly reviewed recently by Baker *et al*. (2000). Wildfires in northern Australia each winter result in major emissions of greenhouse gases. However, these for the most part, are not human-induced events. Fire is an essential tool for rangeland managers and has a role in controlling woody vegetation, removing dead material, stimulating new grass growth, and in the control of wildfires. Complex interactions with reproductive and survival ecology of different natural and modified vegetation types make the use of fire management for emission reduction or carbon sequestration difficult to assess. Prescribed burning early in the season can limit wildfire potential, but the extent of controlled burning required would be prodigious. Fire results in some fixation of stable carbon sources via charcoal and black carbon. Fires may reduce woody plants over time. This lowers carbon stocks, but these stocks could equally be lost in a large wildfire once fuel loads become large. Fire management has to be addressed in the context of individual grazed ecosystems, taking into account the response of natural vegetation to fire, incidence of wildfire, the presence of woody weeds and their sensitivity to fire or their requirement for fire to induce propagation. Fire management also needs to account for the livestock management regime and market targets, and the likely benefits of changed management in terms of carbon sequestration, economic outputs and social attitudes.

The use of fire as a pasture management tool has a complex relationship to the greenhouse gas issue

Carbon Storage

Increasing pasture production in the agricultural zone to improve soil carbon

Soil carbon levels depend on biomass, growth, cycling and organic matter inputs. Increasing the growth and turnover rates in pasture usually results in increased soil carbon. Such increases in production are usually associated with perennial systems with significant fertiliser inputs. The increased feed must be utilised by higher stocking rates. Hence increases in soil carbon may be offset by an increase in methane emissions and nitrous oxide emissions through denitrification.

The benefits of increases in soil carbon may be offset by increased greenhouse gas emissions

Farm Forestry and Tree Planting

There are significant synergies between carbon benefits from tree planting and other natural resource management issues. Targeted tree planting for salinity control may also provide a carbon credit, and count towards Australia's greenhouse gas balance provided plantations satisfy Kyoto rules about area and dimensions.

Grazing Management in Rangelands

Management of livestock

The largest carbon store in rangelands is in the soil. Degradation of rangelands leads to reduction in soil carbon. Research has shown that soil carbon is associated with perennial grass tussocks, and

Overgrazing, often exacerbated by drought, has a major impact on soil carbon storage in rangelands

reduction in tussock density leads to carbon losses. Degradation is mostly the result of overgrazing interacting with drought. There is much uncertainty about the sink potential of rangelands. Sinks by definition must be actively sequestering carbon, but the arid, fragile rangeland environments are highly sensitive to overgrazing and climatic cycles making their sink potential problematical. With better grazing management, a large amount of carbon may be sequestered in rangeland soils. One estimate by Ash *et al*. (1996) suggested that the potential carbon store for the entire Australian rangeland is 48 Gt. Climate and economic cycles represent a risk to this strategy of sequestration of carbon in soil as the effect of price increases is often to make high livestock numbers and land degradation the most profitable approach, with consequent serious increases in direct and indirect emissions.

Control of feral animals

Rabbits and feral grazing animals contribute to the total grazing pressure. Control of these species may be just as important as management of livestock.

Browse Shrubs and Woody Forages

Vegetation management to improve soil fertility and forage quality can have greenhouse benefits

A number of woody plants have forage attributes and could in plantations constitute countable carbon sinks. Leucaena could be planted over large areas of central Queensland as a cattle forage. Tagasaste has similar potential in the northern areas of the agricultural zone of WA. Saltbush has a role in reducing the water table in saline or potentially saline areas in WA, enabling pasture growth where salinity may have been a limiting factor. These species can improve the quality of the feed-base influencing methane emissions, as well as storing carbon directly in woody vegetation. Carbon credits could be obtained for plantations of such species provided they satisfy the criteria for accounting established internationally. The tree legumes may also have significant weed potential.

Management of Woody Weeds and Thickening

Some nett greenhouse benefits may be obtained from control of woody weeds

Thickening in woodlands may provide a steady measurable increase in carbon storage. However, where tree densities in woodlands begin to reduce grass growth and impact on animal production, there may be a conflict between greenhouse accounting goals and economic realities for livestock producers. There are a number of areas in the rangelands where exotic or native woody plants are invading and spreading. In western NSW, native shrubs have spread and thickened over large areas of the semi-arid woodlands. In Northern Australia, prickly acacia, giant sensitive plant and mesquite, for example, are significant woody weeds with the capacity to overrun large areas. Removal of these weeds is prudent and necessary to maintain pasture and animal productivity. Removal decreases carbon stored in vegetation but may have long term benefits for soil carbon storage if vigorous pastures are the replacement. However, removal of thickets may enable more stock with consequent increases in emissions.

Effects of greenhouse issues on the livestock industry

Climate Change

Global warming may result in an increase of 1.5 – 6.0º C in global average temperatures (latest Hadley Centre scenario). When combined with a doubling of atmospheric CO_2 concentrations, the outcomes for the livestock industries could be significant. Howden *et al*. (1999) carried out some comprehensive simulation studies on the impact of climate change on Australia's rangelands. Their main findings were:

Climate change predictions indicate the potential for some improvements in the productivity of rangelands, but increased variability and greater extremes of rainfall together with other negative impacts will drive adaptation of grazing practices

- Doubling CO_2 alone would have positive impacts on rangeland forage production and sustainability in many regions of Australia.
- Ground cover may improve, reducing runoff and erosion and increasing safe carrying capacities.
- High CO_2 levels may result in increased deep drainage under pasture and increase the risk of rising watertables and salinity in affected areas and this would be enhanced if rainfall increases.
- Reduced rainfall in combination with CO_2 rises results in some potential for decreased pasture and animal production, without taking any changes in frequency of El Nino events into account.
- Warmer conditions may lengthen the growing season, but forage quality may decline, and heat stress days for livestock may increase.
- Under all climate change scenarios, with existing grazing and burning practices, emissions would increase due to increased fuel loads and increased stocking rates.
- Global change impacts on farm income might be less than current effects of prices and management.

Significant adjustment and adaptation may be required, and there is a need for further analysis of the complex interactions between global change, and biophysical, social and economic effects and drivers.

Carbon Trading

The impacts of emissions trading may differ across the industry

There are large differences in emissions in CO_2 equivalents per dollar of gross domestic product (GDP) between the livestock and other sectors (Howden and Reyenga, 1999). There are also large differences in emissions per dollar of farm cash income or gross margin between different sectors of the livestock industries (Howden and Reyenga, 1999). Where these differences are unfavourable to the livestock industries, they could have a significant impact if emissions trading eventuates.

Emissions trading may have adverse impacts on the industry in some regions of low productivity

Although emissions trading is yet to be designed or implemented, "if a free-market approach were adopted, livestock industry emission permits could be purchased by other industries with lower emissions per unit economic return. Assuming no new technology to enable cost-effective emission reductions, this could significantly shrink the affected livestock industries, especially in regions of low productivity such as rangelands" (Howden and Reyenga, 1999).

On the other hand, with effective reductions in emissions, livestock industries could gain new income through the sale of emissions permits. It is therefore important that further research be supported to develop various potential methods for reducing methane emissions.

Synergies with Natural Resource Management

The livestock industry will gain advantage from close linkage to natural resource management programs

There is potential for a "win-win" situation when tree planting and grazing land management are used for ground water and salinity amelioration, improving the feedbase for better livestock production, reducing methane emissions and sequestering more carbon in agricultural grazing land and rangelands. Examination of regional landscape needs for tree cover in integrated natural resource management can provide a rational basis for assessing areas that require tree planting. It will also identify areas where land clearing for industry expansion and intensification can lead to a higher level of sustainable production and optimal rates of production relative to greenhouse gas emissions. The livestock industry has the opportunity to benefit from research that supports an integrated approach to industry development and environmental management.

Conclusions

Given the significance of livestock emissions, there are social and political advantages to be gained by appearing to understand the greenhouse issues facing the country, and being prepared to act voluntarily to gain the multiple benefits from improved grazing land and landscape management and reduced emissions per animal.

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Chapter 4. Soil Acidification

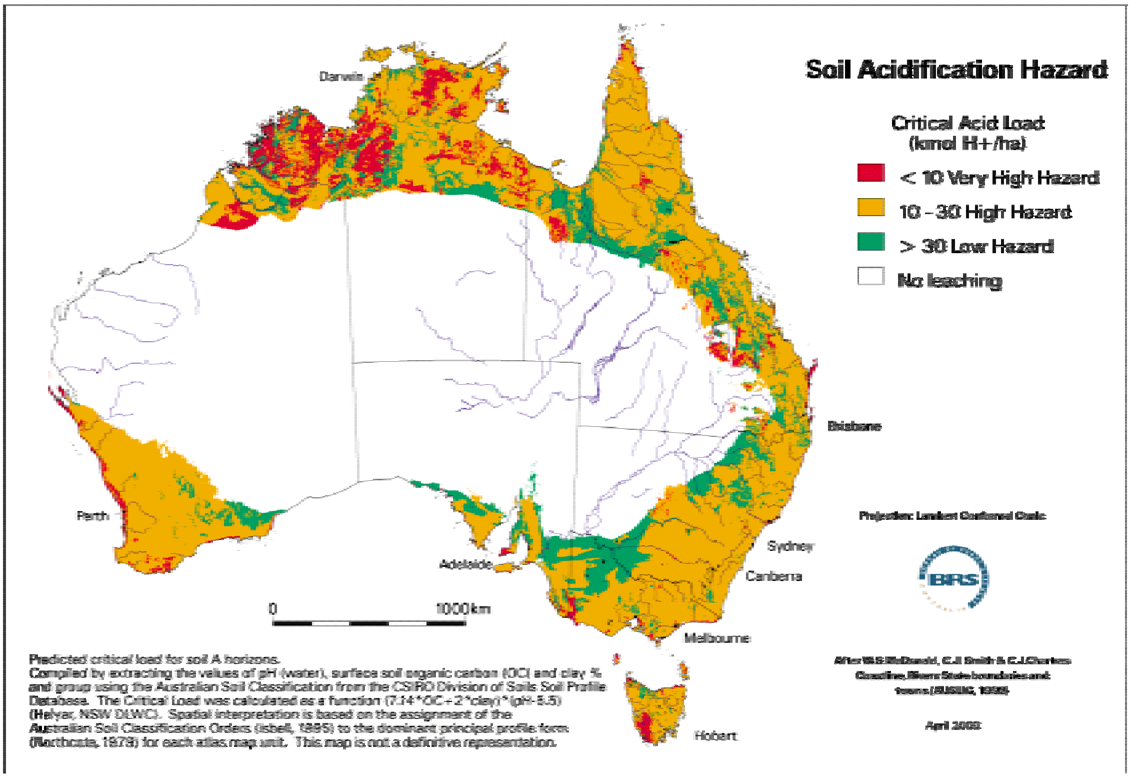
Effects of broadacre livestock industries on soil acidification

The clearing of vegetation is a direct cause of soil acidification

Impact of the grazing industry on acidification

Soil acidification in Australia is a direct consequence of the changes made to vegetative land cover by broadacre livestock industries and land cultivation and associated management practices. In Australia, unlike North America and Western Europe, soil acidification is almost totally caused by agricultural land use practices, with acid rain being restricted to a few zones adjacent to major power generating facilities and smelting operations. Acidification impacts in Australia are generally restricted to areas where there is leaching either below the root zone, or at least from upper soil layers to lower layers. Areas where acidification is, or may be a future problem are shown on Figure 4.1. Soil acidification is clearly exacerbated in areas where clearance of native vegetation has changed the hydrologic cycle to enable more leaching.

Figure 4.1 Soil Acidification Hazard.



Agricultural land management practices known to be responsible for acidification include:

- Use of leguminous crops and pastures (with subsequent nitrate leaching)
- Use of acidifying fertilisers
- Product removal (e.g. wool, meat, hay, cereals)

Leguminous crops and pastures, fertilisation, removal of products and burning-off all contributes to acidification

The severity of the above processes depend upon a number of factors including intensity of land use, land use practices e.g. tillage, fertiliser types used, tillage practices, and rainfall/evaporation regimes. Actual acidification is a consequence of the extent to which the soil carbon and nitrogen cycles are affected by these factors. For example, removing timber from an area causes a major loss of organic anions from the system and is thus an acidifying process (Helyar and Porter, 1989). Burning cleared timber on site causes a return of organic anions to the soil and thus raises pH (pH is usually measured in 1:5 soil to water {$pH_{(water)}$} or 1:5 soil to 0.01M$CaCl_2$ {$pH_{(Ca)}$}; $pH_{(Ca)}$ values can be up to 0.5 units below $pH_{(water)}$ for the same sample).

Nitrate leaching

The mineralisation of atmospherically fixed nitrogen under leguminous pastures and its leaching below the root zone also causes acidification because the NO_3 anions are leached with calcium, magnesium or potassium cations. The latter are replaced on the soil exchange complex by Al^{3+}or H^+.

Use of acidifying fertilisers

The use of fertilisers, such as diammonium phosphate and ammonium sulphate, can also cause acidification. In simple terms, this is because the oxidation of ammonium to nitrate releases a hydrogen ion. It should be noted that superphosphate does not have a significant acidification impact.

Product removal

While the seasonal removal of wool, meat and cereals also causes a net acidification, this is generally small compared with the other processes. Over time, product removal may be quite a significant process. Removal of lucerne hay can have a marked annual impact on acidification because of the large amount of organic anions lost from the site.

The acidification process

Increasing acidification is associated with aluminium toxicity to plants

As acidification occurs, a number of changes that will impact plant productivity are noted in the soil. Firstly, any free carbonates and the bases (Ca, Mg, and K) are “stripped” from the upper soil layers. These bases are replaced by hydrogen and aluminium ions. At $pH_{(water)}$ levels less than approximately 5.0, aluminium is generally present in the soil as Al^{3+} and is phytotoxic. As pH levels further

Acidification depresses activity of microorganisms and causes physical and chemical changes

decline, below 5.0, not only do sensitive species have difficulty growing, but soil microbiological processes also go into decline, phosphate is locked up in insoluble and therefore unavailable forms and soil structure also begins to deteriorate. Consequently, the soil becomes a much less favourable rooting environment, and in some cases, runoff increases causing erosion and sediment transport into water bodies. If pH levels are allowed to decline unchecked, they usually stabilise at $pH_{(Ca)}$3.9 –4.0 at which the soil tends to buffer against further pH decline via the dissolution of its clay mineral components. This process is highly degradational.

Rates and impact of acidification on the environment

Natural rates of acidification are low

Helyar et al. (1990) reported that actual rates of acidification for southern Australian dryland farming systems of NSW and adjacent areas ranged from near zero to between 3-5 kmol H^+/ha/yr. In contrast hay production from irrigated alfalfa, can be responsible for the addition of 10-20 kmol H^+/ha/yr. From a land management perspective, 50 kg of lime ($CaCO_3$) are required to neutralise 1 kmol H^+/ha. In comparison, acid addition rates to natural ecosystems in Australia are very low (< 0.5 kmol H^+/ha/yr).

Acidification has mainly affected southern Australia but it can occur in the north

The impact of agricultural land use including pastoralism has, so far, had a different effect on southern Australia compared to northern Australia. While autumn and winter climatic conditions may permit more leaching of nitrate below the root zone in southern farming systems, the occurrence of summer rainfall in northern Australia generally means that most species are active and able to utilise the rain as it falls and reduce leaching. However, the more extreme rainfall events that occur in northern Australia will certainly enable occasional leaching. Consequently, given the appropriate environmental and land use/management factors, there is no reason to presume that acidification will not occur in northern Australia (Williams and Chartres, 1991).

Introduced species have contributed to nitrate leaching in the north

In tropical northern Australia, some indications that acidification is taking place have already been observed under *Stylosanthes* pastures (Noble, 1997, Noble et al. 1998). Similarly, Jones et al. (1991) have recorded substantial nitrate leaching under a ley pasture/cropping system near Townsville. However, rates of acidification under most livestock production systems are substantially less than under pastoral activities in southern Australia.

Very severe acidification has occurred under improved pastures in the south

In southern Australia, pasture improvement, and in particular, the use of legumes including subterranean clover and alfalfa combined with product removal (hay, meat, wool) have led to large areas experiencing substantial declines in soil pH. pH declines as high as 2 units (e.g. from pH 6 to pH 4) over 50 year time periods have been measured across a number of pasture and cropping systems, although declines of 1 unit are more common.

Estimates of hazard show that some soils will degrade rapidly under annual

Figure 4.1 is a small-scale map indicating acidification hazard for areas with rainfall greater than evaporation. The map is based on the critical load concept. *Critical loads are estimates of the quantities of pollutants that the environment can absorb without ecological harm, or the pollution load the environment can withstand.* For many pastoral areas of southern and northern Australia the map suggests *pasture regimes*

that at annual acid addition rates of between 0.5-5 kmol H^+/ha many soils will be degraded by acidification in relatively short time spans (6 – 60 years). In fact the studies of Williams and Donald (1957) on the southern Tablelands of NSW confirm that annual pasture systems on poorly buffered soils have acidified at rates consistent with critical load calculations.

Effects of acidification on the livestock industries

Acidification progressively reduces pasture productivity

Acidification has also reduced species diversity

Acidification has been described as an agricultural "timebomb" in that its effects are often insidious on a year to year basis. However, over decades it can seriously reduce pasture productivity and in some instances, once threshold pH values are reached, sensitive species will no longer grow. While subterranean clover is a relatively tolerant species, barrel medic commonly grown in drier southern districts fails to thrive when pH (water) values decrease below 5.5. This is considered to be because pH levels below pH 5.5-5.0 reduce the numbers nitrogen fixation in barrel medic (Brockwell et al. 1991). In the hilly country of southern NSW and Victoria, soil acidification has also had a major impact by reducing the variability of species in pastures and the growth and productivity of these pastures. In northern Australia, although significant pH decreases have been noted under *Stylosanthes* pastures, as yet no decline in animal production has been noted (Noble, 1997).of *Rhizobium meliloti*, the symbiotic bacterium responsible for nitrogen fixation in barrel medic (Brockwell et al. 1991). In the hilly country of southern NSW and Victoria, soil acidification has also had a major impact on reducing the variability of species in pastures and the growth and productivity of these pastures. In northern Australia, although significant pH decreases have been noted under *Stylosanthes* pastures, as yet no decline in animal production has been noted (Noble, 1997).

Sixty percent of soils in the intensive land use zone have a pH of less than 5.5

Recent results from the National Land and Water Resources Audit (D. Reuter, CSIRO pers.comm.) indicate that 61% of soils in the intensive land use zone have $pH_{(Ca)}$ less than 5.5 and 16% less than $pH_{(Ca)}$ 4.8 with NSW, Victoria and Western Australia the most effected states. A $pH_{(Ca)}$ of <4.8 is certainly of concern with respect to the cultivation of sensitive pastures and fodder crops. Consequently, production losses are to be expected in areas where pH levels are trending downwards from $pH_{(Ca)}$ 4.5. It should also be of concern that in native pasture systems, biodiversity losses may also occur with acidifying soils.

To date, acidification has not been shown to affect water resources in Australia

As yet, there have been no validated instances of soil acidification having a flow-on effect on water resources as has been the case in environments impacted by acid rain elsewhere in the world. However, as the process is allowed to continue, it is to be anticipated that in some poorly buffered soils with rapid water transmission to throughflow and hence to streams and groundwater, water pH and associated chemical properties may be impacted.

Current plant breeding programs may not be a

Pastoral and cropping industries have generally tackled acidification by the support of traditional plant breeding programs focused on the development of acid tolerant cultivars and on the search for the genes that control aluminium uptake. While these programs may provide *sustainable answer to acidification*

temporary respite from the impacts of acidification on production, environmentally they may not be acceptable in the long term as collateral impacts of acidification affect biodiversity and water bodies.

Addition of lime may not be a cost effective solution other than for intensive grazing

A common management approach is to incorporate lime into the cropping phase of pasture/crop rotations. While this treatment will be economically viable for intensive animal production systems, unfortunately for the broadscale livestock industries, recent studies (LWRRDC, 1995) have demonstrated that liming is often not economic due to the cost of the raw materials and the cost of spreading it in difficult terrain.

As suggested by Williams and Chartres (1991) more research is needed into broadacre pasture systems that maintain water and nutrient fluxes in soils and landscapes as close to those that occur under natural ecosystems, if we are to minimise acidification and maintain productivity and profitability of broadacre livestock production.

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Chapter 5. Soil Salinisation

Effects of broadacre livestock industries on salinisation

Causes of salinisation

Salinisation is Australia's most costly and serious environmental problem and clearing of native vegetation is its primary cause

In terms of its costs and impacts on land, water, vegetation and infrastructure, salinisation is Australia's most costly and serious environmental problem. Like soil acidification, salinisation is the consequence of inappropriate land management practices across a range of agricultural industries. The causes of salinisation have clearly been demonstrated to be the clearing of native vegetation, its replacement by crops and pastures and the impact these have on the hydrological cycle.

Introduced crops and pasture shave changed the water use regime

Native ecosystems in Australia have adapted over millions of years to our climatic conditions and utilise the majority of rainfall where it falls. This adaptation has included an ability to survive and prosper under relatively low rainfall regimes as well as the ability to withstand drought. It is therefore somewhat ironic that introduced crops and pastures often suffer from a lack of water while allowing a greater proportion of rainfall to runoff, or drain to groundwater, than occurs under native ecosystems. It is critical to note that because of the slow speeds at which groundwater travels, the time lags between clearing and the development of a salinity problem may be considerable.

Salinisation can emerge a long time after land clearing

The National Land and Water Resources Audit Salinity Report classifies groundwater systems into local, intermediate and regional. While response times in local systems may be on a scale of years to decades, in the extensive regional systems common in Australia, responses of the groundwater system to changes in land use (either beneficial or negative) may take in the order of centuries to millenia.

Groundwater rises and salt accumulation occurs where shallow rooted, introduced species cannot use the available water

Where introduced crop/pasture systems cannot utilise water because of shallow rooting depths, the water drains to the groundwater table, which then gradually rises. In many areas the water table then intersects the land surface and seepage occurs, allowing evaporation of water and accumulation of salts. Where the water table remains below the surface it may often allow salt concentration in the soil via upward capillary rise of water and subsequent evaporation. Elsewhere, rising groundwater tables may mobilise salts stored in the landscape and transport them laterally into rivers and streams. The salts themselves are generally sodium chloride dominated, but in some areas sulphates are also abundant. Waterlogging is often associated with salinisation and is a major problem in terms of both stock management and cultivation.

Past and Previous land clearing

Land clearing in Australia commenced shortly after European colonisation and has gone on inexorably ever since. While most states now have relatively strong laws governing new clearing, clearing of native vegetation in Queensland is still a major

There is evidence of a very strong correlation between land clearing and salinisation

contentious issue. Between settlement and the 1980s Australia's forest cover reduced from nine to five per cent and woodlands from 21% to 14%. Graetz (1998) shows data that indicate that nearly all these land cover changes took place to support agricultural development; initially for cropping, but from the 1950s for grazing. Recent BRS studies (Barson, 2000, and see Figure 2.1 in Chapter 2 of this report) indicate that annually just less than 518,000 ha were cleared for agriculture nationally between 1983-93. Of this total, 300,000 ha were in Queensland. Recent investigations (Dent, unpublished data) indicate a very strong correlation between land clearing and salinity risk in the sub-humid areas of Australia.

Impact of salinisation on plants and water supplies

Salt tolerance varies between plant species

In soils, salts reduce crop and pasture growth by direct phytotoxic effects on plant cells and by raising the osmotic pressure in the soil solution, thus reducing water uptake by plants. However, different plant species have widely differing tolerances to salinity. Some species such as field beans and red clover have 50% yield reductions at soil saturation extract electrical conductivities (EC_e) of 4,000 µS/cm. Others such as barley, Rhodes grass, and Fescue grass tolerate EC_e values of approximately 10,000 to 16,000 µS/cm (Richards, 1954).

Increasing water quality problems result from saline groundwater discharge

River salinities and salt loads are affected by saline groundwater discharge. As indicated previously, the rates of groundwater discharge and their salinity depend very much on land use, although there are very significant time lags in many large groundwater systems. Currently, the World Health Organisation limit for drinking water quality is 800 µS/cm (see Table 5.1) and the Australian Water Quality standard is 1000 µS/cm. Recent studies by the Murray Darling Basin Commission have indicated that a number of the basin's major streams are predicted to increase in salinity and their total salt load over the next 50 years to the extent that the drinking water standard guidelines will be exceeded in several streams.

Some groundwater supplies for stock and irrigation are at risk from increasing salinity

In a groundwater context, if rising groundwater tables intersect salts stored in the landscape, this can also increase their salinity. In Australia, approximately 20% of water requirements are met from groundwater. This water is used for domestic and industrial supply, irrigation and stock water. In semi-arid and arid regions up to 100% of the water supply may be from groundwater. While salinisation is unlikely to impact on the groundwaters of the Great Artesian Basin, which are largely "fossil", increasing groundwater salinity may occur across a wide range of other environments.

Distribution of salinisation and salinisation risk

The area of land affected is predicted to treble in the next 50 years

Recently published information by the National Land and Water Resources Audit (NLWRA, 2001) demonstrates that the current area (1998/2000) of salinised land is 5,658,000 ha (Table 5.2). This is predicted to rise to 17,000,000 by 2050. Western Australia is the most severely impacted state, although the predicted rate of increase is greatest for Victoria. However, discrepancies in methods used to estimate future salinity risk between the various states mean that

The BRS has mapped salinity hazard for 80 million hectares

comparisons between states are difficult. The Bureau of Rural Sciences also has published figures that indicate areas where salinisation is a hazard. Hazard was determined by looking for areas with a rainfall to evaporation surplus, slopes less than 6% and soils/regolith containing significant salt stores. The total area identified with some degree of salt hazard was in excess of 80 million ha, although it is not expected that salinisation will occur over all of this area.

Table 5.1 Maximum water salinity before production declines for various uses (after Williamson, 1998, Taylor, 1991)

Stock type	EC µS/cm	Total soluble salts mg/L
Sheep	15,700	10,000
Beef cattle	11,400	7,300
Dairy cattle	5,400	3,450
Horses	7,800	5,000
Pigs	4,100	2,600
Poultry	4,100	2,600

Table 5.2. Current and predicted areas with high potential to develop dryland salinity in Australia (ha)

State/territory (1)	1998/2000	2050
New South Wales	181,000	1,300,000
Victoria	670,000	3,110,000
Queensland	n/a	3,100,000
South Australia	390,000	600,000
Western Australia	4,363,000	8,800,000
Tasmania	54,000	90,000
Total	**5,658,000**	**17,000,000**

(1) The NT and ACT were not included as the dryland salinity problem was considered to be very minor.

Impacts on urban water users and infrastructure may be blamed on graziers

However, it is of concern that many relatively high productivity grazing lands occur in the areas where a hazard is defined. Areas with irrigation developments are also shown on Figure 5.1. These along with other water users (towns, industry, environment) are also at significant risk if current salinity predictions occur. Given the significant use of many of the catchment areas upstream of these users is by the grazing industry, it is apparent that deleterious changes in water quality may be blamed on graziers.

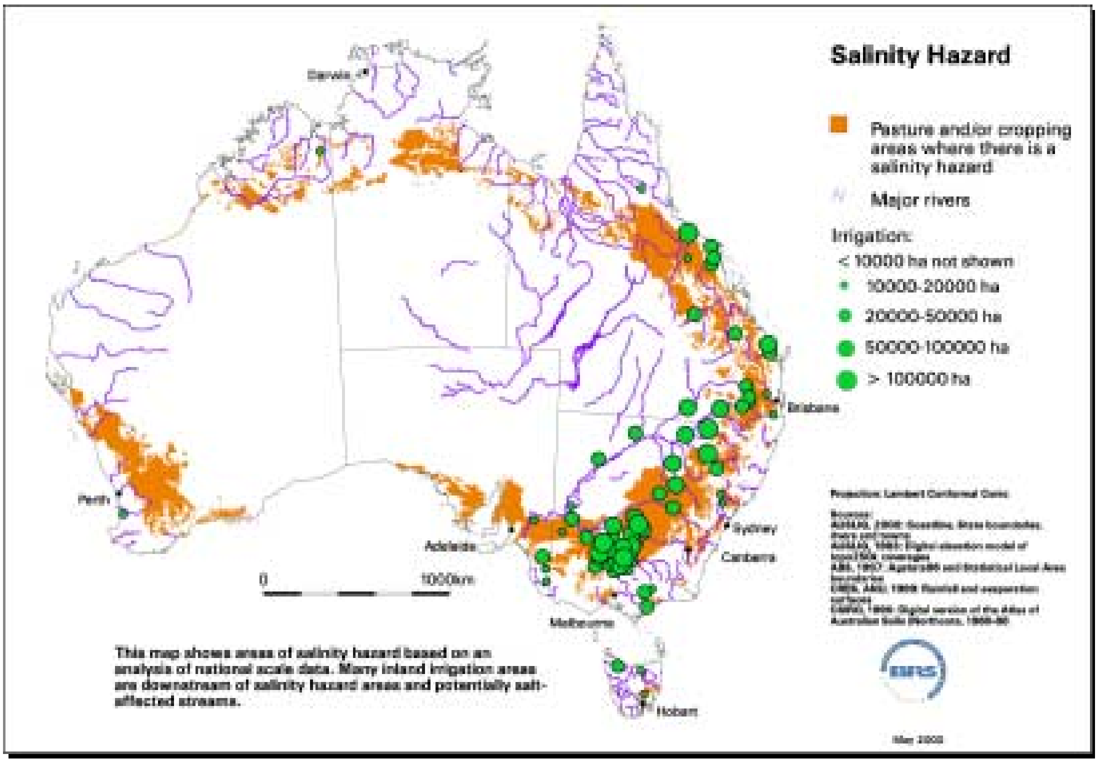
Regionally, the NLWRA Salinity Report indicates that:

The National Land and Water Resources Audit has reported major increases in the salinity of rivers and streams

- The length of stream affected by salinity may double in WA over the next 50 years
- In Victoria a possible three fold increase in the length or perimeter of reservoir, lake or wetlands located in areas of shallow watertable is predicted over the next 50 years, with expected increase of saline discharge into these waterbodies.
- An increase of 25% in median salinities in the River Murray at Morgan, SA.

In the Murray Darling Basin, the Macquarie, Namoi, Bogan, Lachlan and Castlereagh rivers will exceed the 800 µS/cm threshold for water quality within the next 50 years. Some areas will also exceed the 1500 µS/cm threshold for irrigation water within 100 years.

Figure 5.1 Salinity Hazard



Concern about salinity will put pressure on the livestock industry to change land use

Salt load targets in the Murray-Darling Basin will force land use change

Graziers in high risk areas will incur losses from rising groundwater and from measures to prevent it

Graziers will need better information and strong commitment to adoption of best management practices

The impact of salinisation on the livestock industry

Salinisation will impact the livestock industry in a number of different ways. Primarily, at the national level, there will be a growing pressure because of environmental concern that the industry, along with other agricultural enterprises, is a major contributor to dryland salinity and river salinisation. Regionally, the livestock industry will be expected to contribute to land use changes that minimise salt export into major at-risk catchments. For example, in the Murray Darling Basin salinity and salt load targets are being set for the major rivers, which will require some significant regional changes to current land use. Locally, some graziers will be confronted with loss of previously higher quality stream and groundwater resources for their stock. In some cases individuals will be faced with losses of significant proportions of their grazing lands as saline groundwaters rise and eventually reduce pasture production. However, these issues will only impact on graziers in those areas defined by the National Land and Water Resources Audit as under high risk of salinisation, or contributing to salinisation risks downstream. Work to be carried out under the Prime Minister's National Salinity and Water Quality Action Plan over the next 5-7 years will further refine the areas at greatest risk and catchment management authorities and communities will then be expected to contribute to solutions.

Key issues for graziers in high risk areas will include:

- Understanding local hydrological cycles and their impact on stream salinity and dryland salinisation;
- Considering and implementing best management practices that reduce leakage to groundwater e.g alley cropping, tree planting/plantation forestry, use of high water use efficiency and deep rooted pasture species; and
- Land retirement

While much can be achieved on the basis of recent research and development and innovative management practices, it is important to note that, if we are to overcome the rising trend of river salinity and increasing areas of dryland salinity, there are bound to be some winners and some losers as catchment land uses are redesigned to minimise the problem. Nationally, we have to move away from treating the symptoms of salinity, to an approach that understands the cause and treats it accordingly.

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Chapter 6. Soil Structure

Effects of broadacre livestock industries on soil structure

It is highly probable that structurally many soils were in significantly better structural condition prior to European settlement than they are today.

Soil structural degradation is due to changes that affect aggregation, water infiltration, shear and tensile strength, bulk density, porosity and water storage.

While, prior to European settlement, many Australian soils were chemically infertile, it is highly probable that structurally many were in significantly better condition than they are today. Soil structural degradation can be defined as detrimental changes to aggregation, water infiltration, shear and tensile strength, bulk density, porosity and water storage. It varies considerably across soil types and with land use practices and can be measured in terms of crusts, hardpans, visible morphological changes to structural units, pores, channels and consistency. The impact that these properties have on water entry, water and air permeability and root penetration are important in terms of plant production and environmental issues. For example, the structural degradation of soil A horizons can lead to marked increases in runoff, soil erosion and siltation of watercourses.

Grazing and cultivation for fodder crops have had a marked impact on soil structure

It is unquestionable that agricultural practices involved in cultivation of fodder crops and grazing have a marked impact on soil structure. Cultivation leads to the loss of surface structure, surface crust development, the development of ploughpans, and oxidation and loss of organic carbon (a key agent that promotes aggregation of soil particles).

Trampling is also a factor in structural decline

Hoofed animals are also know to have a major impact on sorptivity and water infiltration into soils (Marshall, 1974), and Bonnell and Williams (1989) have also shown that the spatial variability caused by animal trampling also impacts on water infiltration.

Extent and impact of the problem

The estimated affected area is nearly 26 million ha across all States

Reeves et al (1998) reported that there are recorded instances of soil structural degradation in every state and territory. In 1991 soil structural degradation was estimated (Lindsay Nothrop, pers. comm and DPIE, 1991) to impact a total of 25.6 m ha (Table 6.1). New data being collated by the National Land and Water Resources Audit was unavailable at the time of writing.

Table 6.1. Estimates of soil structural degradation by state and land use
(after DPIE, 1991 and Nothrop DPIE, pers.comm.)

	NSW ‘000 ha	Qld ‘000 ha	Vic ‘000 ha	Tas ‘000 ha	SA ‘000 ha	WA ‘000 ha	NT ‘000 ha	Australia million ha
Extensive cropping	3,293.1	1719.4	1.418.7	12.3	1680.4	4180.8	0.0	12.4
Intensive cropping	486.6	110.1	274.9	13.0	69.1	2.9	0.0	0.9
Grazing	3816.1	0.0	2613.1	0.0	1802.8	4101.6	0.0	12.3

Field evidence is increasing understanding of the effects of structural decline

The data in Table 6.1 demonstrate the differences in understanding and recording of structural degradation between different jurisdictions. For example, based on published evidence in Queensland and the Northern Territory, it is clear that grazing has caused structural degradation in these areas. For example, a number of specific experiments that document recovery after grazing, exclosures, or fenceline contrasts (Bridge et al.1983, Mott et al, 1979, Graetz and Tongway, 1980). Braunack and Walker (1985) demonstrated that 100 years of heavy grazing around Wycanna in southern Queensland led to the invasion of inedible woody plants, a process also recorded elsewhere in the semi-arid regions. Burch (1986), Bonell and Williams (1986), and Williams and Bonell (1986) demonstrated that surface crusting and runoff increase while water infiltration and hydraulic conductivity decrease. The findings of these two studies cast serious doubt on the utility of tree clearing in the semi-arid woodlands, given the fact that up to 30% of rainfall may runoff after tree clearing and thus be lost to the areas capacity for plant growth. Recently, Greene et al. (1998) also demonstrated that overgrazing and the development of a surface crust may have changed the hydrology of vegetated dunefields in western NSW in such a way that led to the recruitment of unpalatable shrubs in the most heavily grazed areas.

The role of low ground cover is important in the recovery from structural damage in sensitive environments

Mücher et al. (1988), Greene and Tongway (1989) and Chartres and Mücher (1989) illustrated the nature and consequences of overgrazing on ecologically sensitive environments and red earth soils in central NSW. These studies also demonstrated the role of mosses, lichens and liverworts (cryptogamic plants) in helping such environments recover.

Adoption of 'best management practices' can minimise structural decline and its effects

The studies described above indicate that the grazing industry has a marked impact on the environment. However, a range of best management practices that ensure that stock do not overgraze sensitive areas, fencing of watercourses and the provision of adequate watering points, all help minimise soil structural degradation and consequent runoff and erosion. While the major loser from the impacts of structural decline has been the grazing industry itself, there is currently a growing environmental concern that the industry may be contributing to sediments being delivered to major rivers that in turn impact on major national environmental assets such as the Barrier Reef. Williams and Chartres (1991) point out that it is reasonable for a grazing system to show fluctuations in soil conditions, but that the fluctuations need to be maintained within the limits that allow recovery in times of reduced stress. There is some evidence that this recovery is not taking place under current management of native pastures in our tropical rangelands (de Corte et al., 1991).

The impact of soil structural degradation on the livestock industry

Decline is often slow, but its impacts are wide ranging

Soil structural degradation is often a slow and insidious process so that changes occur gradually and may hardly be noticed. However, over a period of years and decades, the results of soil structural decline may decrease animal carrying capacity and productivity. In some instances, the poorer soil structural conditions have also been a complementary factor that has led to a change in rangeland species composition allowing, for example, the ingress of woody weeds.

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Chapter 7. Water resources

The nature and importance of livestock industry impacts on water resources

Sustainability has replaced infrastructure development as the driver of water policy

Introduction

Economic and development imperatives have dominated management of our water resources over the last century, but these imperatives have now been superseded by concern over the primary issues related to equity in allocation and use of water, ecologically sustainable development, and the efficiency of water use and its environmental implications. In recent years there has been a changing emphasis in water policy from infrastructure development to considerations of sustainability (AATSE and IEAUST 1999) and an increasing acceptance of the "polluter pays" concept in environmental management. These perceptions have lead to the establishment of the principles of ecologically sustainable development through the Intergovernmental Agreement on the Environment (1992), which is underpinned by four core principles:

- The precautionary principle, which states that lack of full scientific certainty should not be used as a reason for postponing measures to protect environmental degradation;
- The principle of intergenerational equity, which requires that the health, diversity and productivity of the environment is maintained or enhanced for future generations;
- The principle of conservation of biological diversity, which states that biological diversity and ecological integrity should be fundamental considerations;
- The principle of improved evaluation, pricing and incentive mechanisms.

The freeing-up water markets and the transfer of water allocations as a result of National Water Reform Agenda policies has caused considerable structural adjustment pressures within the livestock industries.

In 1994 the Council of Australian Governments (COAG) developed a National Water Reform Agenda which will have shaped the scope of water reforms since that time and will continue to drive reform over the next few years. The Agenda is a product of competition policy and ecologically sustainable development (AATSE and IEAUST 1999). As a result of undertakings in the Agenda, a National Framework for Improved Groundwater Management in Australia was developed (ARMCANZ 1996), along with a number of other technical papers prepared by the High Level Steering Group on Water. The freeing-up of water markets and the transfer of water allocations as a result of these policies have caused considerable structural adjustment pressures within the livestock industries. Other important developments relating to the management of water in Australia include the National Water Quality Management Strategy (Department of Primary Industries and Energy Australia 1997) and its series of 21 documents published since 1992, and various State of the Environment reports. Recently the Australian Water Resources Assessment 2000 has been completed (National Water Resources Audit, 2001).

The livestock industries are major users of Australia's water resources and they have had major impacts on landscapes and landscape function across Australia

The livestock industries are major users of Australia's water resources. Although these industries are often associated with less intensive agriculture practices (with the exception of feedlots and irrigation farms), they have had major impacts on landscapes and landscape function across Australia. The total use of water by the livestock industries can be estimated from the available data. The Australian Academy of Technological Sciences and Engineering (1999) estimated that total water use in Australia in 1995/96 was approximately 20,000 GL. This estimate differs slightly from the total water use of 21,700 GL in 1996/97 made by the Australian Bureau of Statistics (2000), and the value of 23,300 GL for 1996/97 made by the National Land and Water Resources Audit (2001). Pastures consume approximately 35% of total water. Stock and domestic supplies account for 8% (Australian Academy of Technological Sciences and Engineering 1999) giving a total of 43% plus grain feed for the total water consumed by livestock industries. Cropping consumes 27% of total water (AATSE and IEAUST 1999), so that the livestock industries (including dairying) could consume up to 45% of total water, or of the order of 9,000 GL/y.

Pastures consume approximately 35% of total water and stock and domestic supplies account for 8%

The resource base will not limit the overall expansion of the livestock industries but over-allocation has occurred in some areas

The total divertible water resource in Australia has been estimated for 1983-84 as 102,000 GL (Dept of Primary Industries and Energy 1987). Total water allocations in Australia in 1995/96 were 27,000 GL, with total use being approximately 20,000. Utilisation of 20,000 GL/y represents about 20% of the total divertible resource (AATSE and IEAUST 1999). These figures indicate that it is not the resource base that will limit the expansion of the livestock industry, and in fact further expansion of the water industry is expected in some areas. However, while there remains considerable potential for further developments in some areas such as the Kimberley in Western Australia, in other areas such as the Great Artesian Basin (GAB), aquifers in parts of coastal Queensland and smaller areas of the Murray Basin, over-allocation has occurred. In addition, greater emphasis in the future on environmental allocations and environmental impacts is likely to limit the expansion of the water industry. The spatial distribution of the resource is a further complicating issue for the livestock industry.

Impacts of the livestock industry on water resources.

For the purposes of this paper the impacts that the livestock industry has on water resources can be divided into two areas, those that result primarily from the infrastructure required to maintain the industry, and management aspects of individual enterprises associated with the industry. The impacts of infrastructure on water resources include:

1. Construction of storages and diversion from rivers for stock and domestic and irrigation supplies affects river flow regimes and riverine ecology;

2. Exploitation of groundwater resources for the livestock industries. This development precludes other beneficial uses.

The establishment of productive pastures after land clearing of deep-rooted native species affects the water budget on the land surface

3. Feedlots result in discharge of waste to waterways and groundwaters. These structures constitute *point* pollution sources for the environment as opposed to the *diffuse* sources of pollution emanating from extensive grazing and irrigation for the livestock industry;

4. Factories, abattoirs and support services impact on local hydrology, primarily through the discharge of waste streams to the environment. This infrastructure also adds point sources of pollution;

Extensive grazing and irrigation for the livestock industry is a diffuse source of pollution

5. The establishment of productive pastures after land clearing of deep-rooted native species affects the water budget on the land surface. These practices usually result in reduced infiltration at the soil surface, increased recharge to the groundwater and increased rainfall runoff, because pastures have often not evolved with the landscape to make maximum use of available water. The net effect of these hydrological changes has been widespread development of salinity problems in the Australian landscape. Soil erosion also sometimes develops because of the generation of greater overland flow velocities, especially when combined with the effects of fire, drought or overgrazing, which reduce vegetative cover. Erosion increases stream turbidity levels. Cropping can have similar impacts to pastures. Because introduced pastures often enable the land to support greater animal populations than previously, increased manure production results in greater discharge of nutrients to waterways. Stocking rates also affect erosion (see below);

6. Development of irrigation systems causes large changes to regional hydrology. Water is used for pastures, lucerne and crops directly for grazing, grain for cattle feed in feedlots, dairy cattle feed, and feed for other less economically important livestock.

Aspects of 2 and 5 will be discussed later in this paper, while other points listed above will be discussed only briefly here because their detailed treatment is beyond the scope of this paper.

Water use by the livestock industries and other farming enterprises affects downstream users

Jurisdictional and institutional issues influence the widely varying regulatory policies for water development and use by the industry

Beginning with point 1, it has been well established that water storage construction and the regulation of rivers and streams can have dramatic impacts on the downstream aquatic environment and water users. For example, in the Murray-Darling Basin the high level of diversions has resulted in substantial reduction in flow at the river mouth, and flow is summer dominant rather than winter dominant as would occur under natural conditions. Water released from large dams is colder than would normally be the case and lower temperatures persist for a greater time and distance downstream than would be the case without river storages. These aspects damage aquatic fauna and flora (Murray Darling Basin Ministerial Council 1995). In addition to these environmental impacts, water use by the livestock industries and other farming enterprises affects downstream users, including livestock producers. This issue is more important for (though not exclusive to) the management of surface waters than for groundwaters, because the lower velocity of groundwater means that its use has less immediate downstream impact. Jurisdictional and institutional issues can play a part. For example, the construction of off-stream storages in the Queensland part of the Murray-Darling system may not be subject to the same hydrologic design criteria and regulatory policy as off-stream storages in NSW, yet water harvesting in Queensland will affect water availability for NSW farmers. This highlights the importance of national level and multi jurisdictional bodies which can and do play an important role in reducing inequity and conflict (Crabb, 2001).

Discussion of the hydrological issues related to feedlots is beyond the scope of this report.

The primary concern under 3 above relates to point sources of surface water and groundwater pollution. The majority of feedlots are located in the Murray-Darling Basin, the south eastern corner of Queensland, and coastal New South Wales, Victoria and South Australia (see Figure 7.1), and waste disposal is subject to well developed design and environmental criteria. Discussion of the hydrological issues related to feedlots is beyond the scope of this report. Similarly, 4 above will not be a subject of this report. Item 6 will be discussed in various parts of the report.

The impacts that livestock industries have on water resources is also highly dependent on the nature of the industry and on-farm management practices. There is a variety of these aspects which affect water quality and the water resource, including:

Livestock industries are often associated with the addition of fertilisers, pesticides, herbicides and other chemicals to the land

- Livestock industries are often associated with the addition of fertilisers, pesticides, herbicides and other chemicals to the land, and some fraction of these chemicals inevitably finds its way to watercourses. The degree to which these practices result in water degradation depends on the nature of the chemicals and time and mode of application;

Overgrazing can result in increases in stream turbidity, salinity and faecal contamination

- Stocking rates determine the extent to which grazing animals cause denudation with resultant increased runoff and erosion. Overgrazing can result in increases in stream turbidity, salinity and faecal contamination which raises stream nutrient concentrations;

Stock access increases stream turbidity and faecal contamination

- Livestock sometimes have direct access to waterways and wetlands for watering purposes. Stock access increases stream turbidity and faecal contamination and can cause environmental degradation of wetlands and groundwater dependent ecosystems, and loss of biodiversity;
- Water and fertiliser management on irrigation farms. While, as stated above, irrigation causes a complete shift in the hydrologic budget, there is also enormous potential to change irrigation impacts through changed management practices (eg see Austin 1998). Detailed discussion of this topic is beyond the scope of this report.

Because the points listed above relate to on-farm management practices, there is considerable scope for their manipulation. With the exception of the fourth item they will be discussed in the body of this paper.

Distribution of livestock in Australia and the implications for local and regional hydrology.

The numbers of livestock provide some indication as to the impact these industries have on water resources and water consumption and sheep and cattle dominate the use of water resources

The distribution of cattle across Australia is shown in Figure 7.1, and the distribution of sheep in Figure 7.2. While there are numerous other types of livestock, sheep and cattle dominate the livestock industry. As expected, the density of livestock closely follows the distribution of rainfall, which is characterised by its spatial and temporal variability. The numbers of livestock provide some indication as to the impact these industries have on water resources and water consumption. There are approximately three million pigs in Australia owned by approximately 3,000 pig producers (National Farmers Federation 1997), while the numbers of cattle exceed 26 million and there are more than 120 million sheep (ABARE, 2000). The value of these industries to the Australian economy is given in Table 7.1. These figures indicate that within livestock enterprises, sheep and cattle dominate the use of water resources. However, while the volumes of water use are much lower in the feedlot, pig and poultry industries, these industries have specific local scale water issues associated with waste disposal and seepage of contaminants to groundwater. Feedlot, and to a lesser extent dairy and extensive grazing industries are supported through dryland and irrigated cropping, so that the impacts of these industries on water resources also occur as irrigation impacts.

Table 7.1 Major primary production commodity value scores. The scores in this Table are ABS 1998–99 data.

Industry	Wool	Sheep meat	Cattle meat	Dairy	Pig meat	Poultry meat	Eggs	Other livestock meat
Commodity Value Index (1998–99)	2.6	1.0	3.4	2.9	0.7	1.1	0.3	0.1

For the broadacre livestock industries (dominated by sheep and cattle) rainfall is the primary determinant of feed production and therefore carrying capacity. Half of Australia has a rainfall less that 300mm (see Figure 7.3) and 40% is too dry for agriculture. In inland Australia there is little permanent water and the extensive grazing in these areas is primarily dependent on groundwater resources (these have been developed since the late 19th century).

Impacts of the industry on surface waters

Surface water resources dominate the water use of the livestock industries

Surface water resources dominate the water use of the livestock industry. The distribution of average annual rainfall in Australia and approximate runoff percentages which produce this resource are given in Figure 7.3. This provides a good indication of where surface water diversions and storages are likely to provide water supplies for the livestock industries.

Livestock industry affects the water budget, and therefore surface water resources, in a number of ways:

- Reduced surface water volumes result because of consumptive use for drinking supplies, domestic and infrastructure supplies and irrigation of pastures and stock feed;
- Contamination of waters can occur through use of agrichemicals and fertilisers;
- Stock can contaminate surface waters, including through erosion induced turbidity, nutrient accessions, bacterial contamination from manure and physical damage to watercourses and wetlands;
- Contamination of surface waters by salinity can occur;
- The environmental values of surface waters can be degraded as a result of the impacts above.

Consumptive use of surface waters by the livestock industries includes water required for stock drinking and irrigation

Reduction of surface water volumes due to consumptive use by the livestock industries

Consumptive use of surface waters by the livestock industry includes water required for stock and irrigation. In Table 7.2 this is approximated by the water use listed under “rural” (which is stock and domestic and channel seepage losses) and a substantial part of the irrigation use as irrigated pasture, lucerne and stock feed. The degree to which allocations and water use have affected stream flow can be approximated by the extent that the divertible surface water resource is utilised.

The livestock industries have had greatest impact on surface waters, stream habitat and downstream users in the Murray-Darling Basin and the Goldfields and South-West regions of Western Australia

The Australian Academy of Technological Sciences and Engineering and IEAUST (1999) has estimated the percentage utilisation of the resource, although it is notable that their figures date back to estimates made in 1987. As expected, water utilisations are highest in the Murray-Darling Basin in New South Wales and Victoria (115 and 57% respectively) and in Adelaide and its hinterland (76%), the Western Australian goldfields (50%) and the south west of Western Australia (46%). These are the regions where the livestock industries have had greatest impact on surface waters, including for downstream users and probably on stream habitat. Up to date information will soon be available from the more recent Land and Water Resources Audit (2001). It is notable that in the Western Australian Water Assessment (Water and Rivers Commission 2000) the divertible yield for the south west region is 2,936 GL/y, with an estimated sustainable yield of 1608 GL/y, compared with the above estimate of divertible yield at 1390 GL/y (utilisation of 47%). It would be in the interests of the livestock industries to have these quantities clarified.

Table 7.2 Mean annual surface water use (GL) by summary (Level 1) use categories.

	Irrigation	Urban / industrial	Rural	Total
New South Wales	8 000	900	100	9 000
Victoria	4 021	860	285	5 166
Queensland	3 350	787	20	4 157
Western Australia	430	206	22	658
South Australia	465	269	12	746
Tasmania	266	179	5	450
Northern Territory	6	39	6	51
Australian Capital Territory	4	63	1	68
	16 542	**3 303**	**451**	**20 296**

Surface water contamination from agrichemicals and fertilisers

Agriculture is usually the prime source of nutrients and pesticides causing algal blooms, but high stocking densities irrigation frequency in the dairy and beef industries creates opportunity for algal toxins to accumulate

The surface water system is more prone to contamination by nutrients and chemicals used in different land uses in the catchment as it is, by definition, exposed for its full length. In addition, poor water quality can result from salinity, turbidity, heavy metals and bacterial contamination. Algal blooms are widespread in reservoirs and rivers of the Murray-Darling basin. The severity of the blooms varies from year to year depending on the climate. Enrichment of water with nutrients, especially phosphorus and nitrogen that stimulate the growth of algae, cause the development of blue-green algal blooms. Agriculture is usually the prime source of nutrients (particularly nitrogen and phosphorus) and pesticides. Major sources include farm fertiliser and pesticide applications, and intensive rural industries including feedlots, grazing, dairying, abattoirs, dairy sheds, wool scours and butter or cheese factories. With the necessity of high stocking densities and high irrigation frequency, particularly in the dairy and beef industries, there is sufficient opportunity for algal toxins to be accumulated.

Nitrate contamination extent and impacts

Nutrients from agricultural land use usually find their way into riverine systems when soil and soil nutrients are removed during erosion events. This problem is exacerbated by high levels of fertiliser application, by irrigation, and by animal manures which are

The problem of nutrients in riverine systems is *exacerbated by several factors, including animal manure*

transported from the field either suspended in solution or adsorbed to displaced soil particles. It has been estimated that in an average year, approximately 1800 tonnes of nitrogen and 360 tonnes of phosphorus are transported to riverine system each year from pasture land in Murray Darling Basin (MDBC 1992).

Nutrients are a major surface water quality issue across Australia in more intensively developed areas including cropping, dairying and other livestock industries

Nutrients are a major surface water quality issue in 43 (61%) of the 70 assessed basins across Australia (NLWRA 2000). The national summary of exceedance of surface water total nitrogen and phosphorus guideline values (see Figures 7.4 and 7.5) indicates that widespread exceedances occur across Australia. Areas of more intensively developed industries including cropping, dairying, feedlots, grazing, dairy sheds and piggeries in Murray-Darling, North-East Coast and South-East Coast of Australia had high concentrations of nitrogen and phosphorus in rivers and streams. High nutrient levels in rivers are also related to nutrients introduced from fertiliser and manure applied to crops, and from livestock waste.

Turbidity

Turbidity is a worsening water quality issue across Australia.

Turbidity is a major water quality issue in 41 (61%) of the 67 assessed basins in Australia (Figure 7.6). The most affected areas included most inland and lower rainfall basins of the North-East drainage division, the majority of the MDB and the most intensively developed basins of the southern South-East Coast drainage division. The variable rainfall and stream flow and highly erodible soils and streambanks combine to create naturally high turbidity levels in surface waters. Existing widespread exceedances and the predominantly increasing trends suggest that turbidity is a worsening water quality issue for Australia. While constrained by data availability, the majority of trend analyses found increasing turbidity trend across the basins. This is particularly true for basins in Murray-Darling drainage division and South-East Coast drainage division.

Pesticide contamination extent and impacts

In a pastoral and agricultural region of Victoria (around Horsham) trace levels of organochlorines and pyrethroid insecticides were detected in surface water (Bell 1989). In South Australia, a survey of pesticide residues in streams draining from a horticultural cropping and pastoral land in a catchment (Onkaparinga) was carried out during July 1984 to January 1987 (Thoma 1988). The survey showed that some water and sediment samples contained trace levels of pesticide residues.

Contamination of surface waters by stock

Contamination of surface waters, erosion of river banks and increases in stream turbidity are attributable to stock access

Contamination of surface waters through stock access is a well established phenomenon. Remediation is simple and involves fencing of open waterways and wetlands and installation of troughs. Stock trampling adds to erosion of river banks and increases in stream turbidity, and adds to the problems of soil erosion from cultivation and overgrazing. Nutrient levels can increase with the addition of stock manure.

The livestock industries have contributed to salinisation of rivers and streams through greater discharge of saline groundwater into waterways

Impacts of the livestock industries on stream salinity
The heightened levels of stream salinity have been well documented in Australia, and are treated separately in Chapter 5 of this report. In brief, the replacement of deep rooted native vegetation by shallow rooted pastures has resulted in increased groundwater recharge, rising watertables and subsequent discharge of this saline groundwater in the lower parts of the landscape. The problem is exacerbated by irrigation because of the increased additions of water. Salinisation of rivers and streams occurs both because of the higher salinity of runoff from salinised land and because of the greater discharge of saline groundwater into waterways due to the higher groundwater pressures. In Australia this has resulted in widespread changes to the landscape and primary contributions to stream degradation. The state of stream salinity increases across Australia is summarised in Figure 7.7.

Impacts on groundwater systems, including salinity

There are four primary means by which groundwaters are affected by livestock industries. These are:

- Groundwater extractions used for stock and domestic supplies and for irrigation;
- Contamination of aquifers by chemicals, nutrients and bacteria;
- Increased groundwater recharge caused by replacement of natural vegetation with pastures;
- Degradation of groundwater dependent ecosystems has occurred in a number of areas as a result of physical damage from grazing animals and groundwater pumping from upstream aquifers.

Ten percent of the groundwater that is suitable for potable, stock and domestic use and for irrigated agriculture is currently used

Groundwater extractions used for livestock industries
Australia has 25,780 GL of groundwater that can be extracted sustainably each year and is suitable for potable, stock and domestic use and irrigated agriculture. Ten percent (2,489 GL) is currently used (National Water Resources Audit, 2001). The groundwater extractions utilised through stock and domestic supplies in Australia as quantified by the Australian Water Resources Assessment 2000 are listed in table 7.3 below. The distribution of principal aquifers in Australia is illustrated in Figure 7.8.

It can be seen from the table that groundwater use, as with surface water, is dominated by irrigation, although rural use comprises a larger percentage of total groundwater use than it does for surface water (see table 7.3) because of the emphasis on groundwater use in rural and remote Australia. The total use of groundwater at 4,171 GL has increased by 58% since 1983/84 (National Water Resources Audit 2001), and is likely to be subjected to greater future use by the livestock industries.

Table 7.3 Mean annual groundwater use in Australia (GL)

	Irrigation	Urban / Industrial	Rural	In Situ	Total
New South Wales	643	160	205	0	1008
Victoria	431	127	54	10	622
Queensland	237	184	410	0	831
Western Australia	280	821	37	0	1138
South Australia	354	23	42	24*	419*
Tasmania	9	7	4	0	20
Northern Territory	47	48	33	0	128
Australian Capital Territory	2	0	3	0	5
	2003	**1370**	**788**	**34**	**4171**

Rural use of groundwater only exceeds irrigation in Queensland because of the large impact of the Great Artesian Basin (GAB). This sedimentary basin covers approximately 22% of Australia's land area and by 1918 some 1500 bores had been drilled to provide artesian and sub-artesian water supplies.

The pastoral industry uses most of the water extracted from the Great Artesian Basin

Of the 570 GL of water extracted annually from the GAB, the pastoral industries use 500GL and the irrigation industry uses 11 GL, comprising a total of 90% of the water extracted. Total production in the Basin has been estimated at $3.5 billion, almost 60% of which comes from the livestock industries and 35% from extraction of oil and gas, and uranium and copper at Olympic Dam (Mues and Hardcastle 1998).

Extensive water reticulation systems in the GAB are old, and numerous artesian bores are allowed to run freely which has meant that in excess of 90% of water extracted has been wasted

Much of the Basin's social fabric and human endeavour is dependent on this resource (Great Artesian Basin Consultative Council, 2000). Because the livestock industry over the Basin almost exclusively comprises rangeland sheep and cattle grazing, extensive water reticulation systems are required. These systems are old, and numerous artesian bores are allowed to run freely through corroded and unchecked bore headworks, with associated water distribution through inefficient bore drains. Poor infrastructure and seepage losses and evaporation in bore drains has meant that in excess of 90% of water extracted has been wasted. Although storage in the Basin has been estimated at 8,700 GL, replenishment of the system through groundwater recharge has been estimated at 1,090 GL and discharge from the Basin has been estimated at 1,000 GL including 430 GL of leakage into overlying aquifers. There is still some debate surrounding the accuracy of these figures.

Groundwater pressures are declining over significant parts of the Great Artesian Basin

environmental, biodiversity

Industry practices in the Basin have resulted in unsustainable groundwater water use and the associated excessive depletion of one of Australia's most important water resources. This is confirmed by the falling groundwater pressures over significant parts of the Basin. In addition, there are also significant environmental implications associated with loss of mound springs and wetlands which house endemic fauna and flora (Fencham 2000), the expansion of areas of *and sustainability issues related to water use in the Basin also have implications for intergenerational equity*

woody weeds and feral animals and pests associated with the bore drains (Bureau of Rural Sciences 2001). Saline water in bore drains results in increased soil sodicity, soil structural breakdown, erosion and subsequent additions to stream turbidity and salinity. These environmental, biodiversity and sustainability issues related to water use in the Basin also have implications for intergenerational equity.

In response to the inadequate investment to address these issues the government initiated the GAB sustainability initiative in 2000 with $31.8 million being allocated primarily for capping and piping works. The plan provides a framework for a target of 30% of bores to be rehabilitated within 5 years and 30% of bore drains replaced to reduce salt loads to streams. The plan aims to have all bores rehabilitated and all bore drains replaced after 15 years.

The current poor level of data availability and mapping of the important ecosystems within the Basin needs to be addressed so that groundwater programs can be monitored

The GAB strategic management plan also makes a commitment to restoration of natural groundwater dependent and water-remote ecosystems and a commitment to eliminate further loss of groundwater dependent ecosystems. Given the current poor level of data availability and mapping of the important ecosystems within the Basin, it is difficult to see how the success of these initiatives will be accurately quantified. Recently the GAB Consultative Council has organised a biodiversity workshop to further address these issues.

Problems associated with groundwater use include issues such as beneficial use, pricing and market reforms, groundwater surface management plans, environmental allocations and sustainable yield and over allocation

The most important basin utilised by the livestock industries in Australia is the Murray Basin. Water extractions from the basin are from the deeper groundwater system as well as numerous shallow alluvial systems. Problems include the full range of COAG issues, such as beneficial use, pricing and market reforms, groundwater surface management plans, environmental allocations and sustainable yield and over allocation.

While the MDB and the GAB are by far the most important groundwater basins for the livestock industries, it is clear from Table 7.3 that numerous other developed resources are utilised.

Increased groundwater recharge

The introduction of pastures for the livestock industries has lead to large areas of high watertables and extensive expansion of salinity problems

As stated in the introduction to this report, management of land cover is the major factor which determines the water budget on the surface and dictates the amount of water percolating past the rootzone to the groundwater below. Thus the introduction of pastures for the livestock industries has led to what is arguably the largest environmental problem facing the Australian landscape. Increased groundwater recharge under these pastures has lead to large areas of high watertables and extensive expansion of salinity problems (see Chapter 5). The areas expected to be affected by salinity are illustrated in Figure 7.9. It is notable that impacts on the industry in dryland areas are more likely to occur in the form of feed loss because of soil degradation. Stock are relatively tolerant of water salinity increases. Deterioration in water quality is problematical for the livestock industries in irrigation areas, where the water is used for pasture and lucerne production.

There is a considerable time lag between when surface vegetation is changed and when salinity problems develop; surface water flow systems respond much more quickly

An important aspect of the development of salinity in Australia is whether or not mitigation methods will effectively reverse the environmental degradation. There is a considerable time lag between when surface vegetation is changed and when salinity problems develop. This lag depends on the time that extra recharge takes to reach the watertable, and the hydraulic characteristics of the groundwater system that determine the rate of transmission of pressure changes and the rate of movement of groundwater to the surface in the lower parts of the landscape. Salinity problems not only take some finite time to develop after the change in vegetation, but also take some time to recede if vegetation is converted back to deep rooted species, especially where groundwater flow systems are regional, as opposed to local, in nature.

A strategic approach to catchment management and salinity mitigation will be necessary if impacts on the livestock industries are to be minimised

In contrast, the surface water flow systems respond much more quickly, so that the introduction of pastures could be expected to produce an immediate increase in runoff, and a fairly rapid decrease in runoff could be expected with the reintroduction of deep-rooted species. These processes suggest that once salinity problems develop, re-introduction of deep rooted species will not result in a fall in stream salinity, both because groundwater discharge will continue for some time, and because less dilution and lower stream discharge will result from lower rates of runoff. A strategic approach to catchment management and salinity mitigation will be necessary if impacts on the livestock industries are to be minimised.

Contamination of aquifers

During the past decade groundwater quality assessment has included additional factors such as nutrient, toxic chemical, trace elements and microbiological loads

Groundwater is a major source of drinking water for livestock over a large area of Australia. Consequently, the quality of the nation's groundwater resources is of growing concern to water managers and industry in all States. Natural processes and human activities jointly determine groundwater quality (ie. its acceptability as judged by domestic, livestock, industrial, agricultural or environmental criteria). Historically, in Australia, resource assessment has dominated groundwater investigations and groundwater quality has been synonymous with salinity and its relationship to irrigation-induced land salinisation. However, during the past decade, groundwater quality has increasingly come to be assessed by additional factors such as nutrient, toxic chemical, trace elements and microbiological loads, concomitant with increasing awareness of the vulnerability of groundwater resources to contamination.

Broad area sources, such as grazing, dairying and animal manure applications have the potential to affect groundwater resources with widespread contaminant loads

In Australia, broad area sources, such as grazing, dairying and animal manure applications have the potential to affect groundwater resources with widespread contaminant loads. While the current levels of contamination appear to be limited, international experience suggests that agricultural development worldwide has resulted in degradation of groundwater resources. The industry should therefore not be complacent about the potential for groundwater contamination to occur.

Nitrate contamination extent and impacts

Influence of land clearing/stocking on natural environments, grazing, dairying and farm/feedlot animal manure application can generate or mobilise the nitrate fraction and lead to contamination of groundwater (Bolger and Stevens 1999). Elevated nitrate concentrations in groundwater intended for potable or stock watering use represent a health risk to human and animal consumers. Ingestion of nitrate in drinking water can cause low oxygen levels in the blood, a potentially fatal condition (Fan and Steinberg, 1996). Studies in laboratory animals have not indicated that nitrates are directly carcinogenic, but there is evidence that they may react in the stomach with foods containing secondary amines to produce N-nitroso compounds which are known to be carcinogenic in animals (NHMRC/ARMCANZ 1996). Australian Drinking Water Guidelines (op cit 1996) recommended 11.3 mg/L NO_3-N and 0.9 mg/L NO_2-N as the guideline level for protecting infant health.

Studies have shown that there are elevated nitrate concentrations in the groundwater across the nation in areas of grazing and dairying

Studies have shown that there are elevated nitrate concentrations in the groundwater across the nation in areas of grazing and dairying (Watkins and Bauld 1999; Bolger and Stevens 1999). For example, a nitrate-N concentration > 10 mg/L was detected in groundwaters under grazing on irrigated and dryland dairy pastures in South-East South Australia (Schmidt et al 1998). Schmidt et al (1998) attributed elevated concentrations of nitrate in groundwater to urea from cattle urine in paddocks. Another study conducted in the Peel Valley near Tamworth in northern NSW showed elevated concentrations of nitrates (>10 mg/L nitrate-N) in shallow aquifers (Bolger and Stevens 1999). The predominant land uses such as grazing, dry and irrigated cropping, intensive animal husbandry (mostly piggeries and poultry farms) had contributed to the elevated nitrate-N concentrations. In a recent study, elevated nitrate concentrations were also measured in shallow aquifers in the Murray region of NSW (Watkins and Bauld 1999). The area had various land uses, including irrigated pasture, rice, cereal and grazing livestock.

Faecal coliform contamination extent and impacts

On occasion, pathogenic viruses, bacteria and protozoans of gastrointestinal origin may survive for sufficient time to be ingested by humans and livestock drinking the extracted groundwater

As with other natural habitats, the subsurface environment, including groundwater, has been found to contain a broad spectrum of microbial types similar to those found in surface soils and waters. These microbes encompass bacteria, fungi and protozoa. On occasion pathogenic viruses, bacteria and protozoans of gastrointestinal origin from domestic, dairying, agricultural and other anthropogenic activities, may infiltrate through soils, sediments and rocks to the underlying groundwaters. There they may survive for sufficient time to be ingested by humans and livestock drinking the extracted groundwater. Representatives of both indigenous and contaminant microbes have been recovered and enumerated from groundwaters across the nation. For example, one or more classes of faecal indicator bacteria were detected in 6 groundwaters in Goulburn catchment in Victoria (Watkins *et al*., 1999). The possible source of faecal contamination of groundwaters was attributed to livestock as all contaminated bores were within 100 m of dryland grazing, cattle yards, irrigated pastures or dairy sheds.

Pesticide contamination extent and impacts

Organochlorine (OCs) pesticides residues are still present in soils and continue to impact environmental quality several years after the discontinuation of their use

In the past, organochlorine (OC) pesticides were used extensively in Australia to control the pests of agricultural crops as well as of cattle, sheep, pigs and poultry. Although most OCs were banned in agriculture in late seventies, their residues are still present in the soils, and continue to impact environmental quality several years after the discontinuation of their use. For example, in 1987 organochlorine pesticides were detected in Australian export beef, as a result of their past usage. This led to the analysis of thousands of soils samples collected from farms designated "at risk". In Western Australia, for example, chlordane, DDT, dieldrin and heptachlor were detected in 18.4%, 39.6%, 39.0% and 18.8 %, respectively, of 11,248 samples analysed (EPAWA 1989).

Studies have found that some residues increased as pasture height decreased, indicating soil ingestion as the major means of pesticide intake by grazing animals

In NSW, residues of BHC, dieldrin and heptachlor that were found in beef cattle. This may have originated from grazing on land previously under horticulture and sugarcane (Wilson 1987). A sensitivity analysis carried out at the time by Harradine and McDougall (1987) suggested that heptachlor residues in cattle fat could have exceeded the maximum allowable concentration of 0.2 mg kg^{-1} within a month of grazing the OC treated land. They found that the residues increased as pasture height decreased, indicating soil ingestion as the major means of pesticide intake by grazing animals. An analysis of data on OC residues in meat products by Blackman (1992) showed that the proportion of animals with an MRL of 0.1 mg kg^{-1} in fat steadily declined from 1978 to 1991, leading to fewer than 1 in 5000 Australian cattle or sheep with residues above this value.

Herbicides applied to control weeds in irrigated pasture lands have the potential to contaminate groundwater

Schmidt *et al*. (1996) tested 129 bores in the south east of South Australia with a variety of land uses (dairying, potato cropping, horticulture, viticulture, grazing, pine forest and native vegetation) and found that 15% of samples showed the presence of pesticides at trace levels. The pesticides detected included dieldrin, lindane, chlorpyriphos and alachlor, all of which except chlorpyriphos have not been registered for use in agriculture for more than ten years. Also, herbicides applied to control weeds in irrigated pasture lands have the potential to contaminate groundwater. Triazine herbicides (atrazine, simazine) have been detected in groundwaters in Cobram region in Victoria (Ivkovic *et al*., 2001) and the possible source of this contamination was associated with weed control in pastures, orchards and irrigation channels.

Contamination at cattle and sheep dip sites is very high and potential exists for migration of contaminants to the groundwater

High levels of soil contamination with OCs and other pesticides have occurred at former cattle and sheep dip sites, where drenching of animals in pesticide solutions to control pests such as ticks on cattle were carried out. According to some estimates there are about 1600 such cattle dip sites in north-eastern NSW (Beard 1993). The level of contamination at cattle dip sites is indeed very high; as up to 100,000 mg DDT/kg soil have been found. This is many times above the threshold required to trigger investigations at these contaminated sites. Although these chemicals have not been found extensively in groundwater, there can be little doubt that potential exists for their migration to the groundwater.

Veterinary chemicals extents and impacts

Discharges from livestock industries using veterinary chemicals may contaminate both surface waters and groundwaters

In addition to pesticides, veterinary chemicals are widely used by livestock industries. The extent of contamination of surface and groundwater by these veterinary chemicals is unknown. However, some of the most rapidly growing areas of intensive rural industries in southern Queensland and northern NSW are close to recharge areas of the GAB, and many occur in close proximity to local alluvial aquifers. Discharges from livestock industries using veterinary chemicals may contaminate both surface and groundwaters. Insufficient is known about the effects of these chemicals on human health, and there is little information available on the removal of these chemicals by water treatment technologies.

Degradation of groundwater dependent ecosystems

In some areas of arid and semi-arid Australia, stock are watered from natural groundwater discharge zones. The mound springs of the GAB are the best known of these groundwater dependent ecosystems. The springs are unusually specialised aquatic habitats, analogous to biogeographic islands, and their isolation has resulted in an assemblage of flora and fauna that includes several endemic and relic species. In addition, the GAB mound springs have significant Aboriginal and European cultural heritage value.

Mound springs in the GAB are strategically and ecologically important and have been subjected to grazing of various intensity, trampling and compaction of their margins with adverse effects

The mound springs were of strategic importance during early European settlement of the south west GAB because they represented the only source of permanent water for stock in an arid environment. After artesian water was discovered, boreholes with associated bore drain reticulation systems enabled pastoralists to distribute water more widely through their properties and some of the grazing pressure was taken off the mound springs. Nevertheless, over the past 200 years the mound springs were subjected to grazing of various intensity, trampling and compaction of their margins which adversely affected their biodiversity. Also, organic pollution through the dropping of manure into the springs led to algal growth and reduced oxygenation of the spring waters. Fouling of the water occurred when cattle became bogged and died in the springs.

Falling groundwater pressure is primarily a result of water extractions by the pastoral industry

In addition to direct contamination of the springs by livestock, there has also been a steady drop in GAB water pressures over the last 100 years and these pressure reductions have also been transferred to the discharge zones causing some springs to dry up completely. Falling groundwater pressure is primarily a result of water extractions by the pastoral industry which uses about 90% of all water taken from the Basin. There are now about 1000 derelict springs in the GAB, with about 1500 remaining. It is expected that if some of the large water use efficiency gains achievable in the basin are realised, this rate of environmental damage will slow.

Recognition of groundwater dependent ecosystems as having high conservation value is developing, and the industry should look towards measures for their

The degradation of groundwater dependent ecosystems through stock access is not a problem unique to the GAB, and these areas of high conservation value have been affected by stock across Australia including along the coastal zones, in the arid interior and in the northern tropics. While the recognition of groundwater dependent ecosystems as having high conservation value is reasonably recent *preservation as issues arise*

(see Hatton and Evans 1999; Evans 2000), the livestock industries should look towards measures for their preservation as issues arise.

Other impacts, including runoff water conservation and environmental flows

The allocation of environmental flows has resulted in a significant reduction in water availability in some areas; the industry is more likely to feel the impacts of environmental allocations in the Murray Basin

Since the introduction of COAG water reforms in 1994 there have been widespread changes to water management in Australia. In additional to institutional arrangements and the introduction of water markets, the allocation of environmental flows has resulted in a significant reduction in water availability in some areas. The process of implementation of such allocations is somewhat haphazard because of jurisdictional and environmental factors. The industry is more likely to feel the impacts of the environmental allocations in the Murray Basin, particularly the irrigated parts of the Basin, than elsewhere. Recently there has been a move to allocate environmental water through minimal acceptable impacts on the aquatic ecosystem, rather than on a volumetric basis. For example, a bore installed in an aquifer close to an important wetland may have a higher environmental allocation (and therefore lower sustainable yield) that one in the same aquifer but more distant from the wetland, because the closer bore will have a greater impact on wetland water levels.

Effects of Environmental Issues on Broadacre Livestock Industries

The impacts of water resource issues on livestock distribution and productivity

Surface water availability and quality, including chemical residues

The availability of surface water impacts the livestock industries over a substantial part of the country but groundwater supplies are generally sufficient

As indicated in Figure 7.3 the availability of surface water in Australia impacts the livestock industries over a substantial part of the country. In these arid and semi-arid zones the industry is substantially dependent on groundwater supplies. Groundwater supplies are in general sufficient because of the severe limitations that climate imposes on feed production and therefore stocking rates. In addition the water quality requirements for livestock are not stringent and water salinity of up to 11,000 µS/cm for beef cattle and up to 15,000 µS/cm for sheep can be utilised before significant reductions in productivity occurs (Williamson 1998; Taylor 1991). Water of this quality is of little use for many other purposes, so that adequate groundwater supplies can usually be found. In productive higher rainfall areas, water supplies are more plentiful, and with the exception of the irrigated enterprises, water requirements of the industry are not high. Surface water availability for the non-irrigated industry is therefore not likely to result in problems.

Because by far the greatest fraction of water consumption by the livestock industries occurs in the irrigation regions, it is in these areas that water availability is more likely to impact on the industry. It can be seen from table 7.2 that the non-irrigation sectors consume

The greatest fraction of water consumption by the livestock industries occurs in the irrigation regions; it is in these areas that water availability is more likely to impact on the industry

only about twenty percent of Australia's total surface water use. However, in total the largest users of rural water are the dairy and beef cattle industries accounting for 44% of consumed water. Up to one third of water supplied in the Murray Darling Basin is use on mixed farming enterprises which are not profitable, with non-dairy farms showing substantial negative profits every year from 1990-1995 (ABARE). Dairy farms by contrast have been profitable and expanding in recent years.

The availability of water for the livestock industries in the irrigation sector is complicated by other beneficial uses for the water

The availability of water for the livestock industries in the irrigation sector is complicated by other beneficial uses for the water, by institutional arrangements and the commitment to COAG water market reforms. The states have the responsibility for providing the institutional framework in which water and catchment managers operate. The Federal Government exerts its influence through COAG and agreements with the States. The principal source of advice for COAG is SCARM, the Standing Committee for Agricultural and Resource Management. As documented earlier in this paper, it is the COAG water reform Agenda initiated in 1994 which is currently driving substantial changes in the water industry. Aspects of this agenda which are important to the allocation of water within the livestock industries include:

The COAG water reform agenda has many aspects that are important to the allocation of water within the livestock industries

- Prices to be based on consumption and not property taxes and set to cover all costs of supplying the water;
- Water rights to be separated from property rights. Currently the debate on this issue suggests that the benefits of fixing stock and domestic supplies to property rights should be retained;
- Markets to be set up to allow free trading of water;
- Reduction or elimination of cross-subsidies;
- Allocation of water for the environment;
- Integrated catchment management to be pursued as a framework for resource management.

Under the National Action Plan (for salinity and water quality), there will be a substantial increase in water trading that will entail structural adjustment and affect the livestock industries

The COAG water reforms are at various stages of implementation, with low levels of adoption in some areas. This process is due for completion in 2002, and with low levels of adoption of some of the reforms, new vehicles have been sought to enhance their adoption. The National Action Plan is likely to provide the impulse for ongoing reform in the water industry. There has however been substantial increase in water trading, resulting in significant economic gains. These gains have also come with significant social impacts through structural adjustment in irrigation areas.

Surface water consumption is dominated by the irrigation industry. It uses about 75% of total water supplied, with 90% of this water being used in NSW, QLD and Vic. Irrigated pastures for the livestock industry covers almost half the area of irrigated land. The area used is approximately 935,000 ha out of a total of 2,056,580 ha in 1997 (Water account for Aust., 2000). It is notable that agriculture has a much lower gross product per ML consumed than other competing industries such as forestry, fishing and manufacturing. This is unlikely to affect water supplies to rural industries however, because industrial and other uses are usually fully supplied. Irrigated pastures represent one of the lowest gross values of irrigated agriculture.

Impacts of nutrients and chemical residues

Protecting and preserving markets requires certainty that livestock products are free from residues that have been accumulated under previous management regimes

Australia's cattle industry is worth $3.3 billion per annum. Australia is exporting approximately 65% of total beef production each year, reaching 110 different countries. To preserve these valuable export markets, we must be able to guarantee that our products are free from nutrient and chemical residues. However, in earlier years organochlorine (OCs) pesticides such as chlordane, DDT, BHC, dieldrin and heptachlor were detected in Australian export beef as a result of their past usage to control the pests of agricultural crops as well as of cattle, sheep, pigs and poultry. Although the above chemicals have been detected in the export beef in the past, the levels have steadily declined and are well below the MRL of 0.1 mg kg^{-1} (Blackman 1992). More recently, endosulfan residues have been detected in export beef as a result of cattle being raised near crops on which endosulfan was sprayed. Drinking contaminated surface waters is a suspected origin of this contamination.

Direct use of nitrate contaminated groundwater for potable or stock watering represents a health risk to human or animal consumers, as stated earlier in this chapter.

Groundwater and artesian water supplies, institutional and jurisdictional arrangements

Institutional and jurisdictional issues are particularly relevant in the Murray Darling Basin and the Great Artesian Basin, the two most important groundwater basins in the country. Both lie across four State/Territory boundaries and therefore operate under four independent legislative frameworks, policies and resource management issues. Sometimes the existence of multiple institutional arrangements have slowed the implementation of COAG water reforms. Maximum economic and social benefits and minimal environmental impacts will result only if policies and practices are consistent across these basins. Consistency for equity is also important.

Groundwater supply

The most important groundwater supply is the GAB and it is damaging to the industry to be associated with excessive water wastage and environmental degradation resulting from inefficient water use

The supply of groundwater is critical for the livestock industry over large parts of Australia as indicated in Figure 7.3, because of low rainfall. The most important supply is the GAB, and it is this supply where there is poor management resulting in excessive water wastage by the livestock industries. While this issue is not likely to result in large production losses because of the large volume of water available (approximately 8,000 GL), it is damaging to the industry to be associated with environmental degradation resulting from inefficient water use. These environmental issues are only likely to receive greater attention and a higher profile in the future. As noted earlier, the capping and piping of bore water and the current strategy put in place by the GAB Consultative Council (2,000) in the Basin, will alleviate this problem.

In some parts of Australia, the quality of groundwater that has adverse impacts on the industry

Despite greater future emphasis on environmental allocations, it is unlikely that quantity of ground water supply will affect the industry over much of Australia. In many arid and semi arid areas (excluding the GAB) extraction rates are for stock and domestic supply are low and well below sustainable yields of aquifers. In some parts of Australia it is the quality of groundwater that has adverse impacts on the industry. However, where groundwater comprises the only source of stock and domestic water, stocking rates are low, so that water quality impacts are more likely to be of local importance rather than of industry significance. While recent gains have been made in the treatment of groundwater, the cost of treated water ($2-$3 per KL) is still too high for the industry. In some areas such as the Officer Basin (see Figure 7.8), some large scale treatment plants have been mooted, but it seems currently that such schemes are unlikely to impact the industry in the near future.

Integrated surface water groundwater management plans and effective water trading regimes will be developed in the Murray-Darling Basin

The supply of groundwater is more likely to affect the industry in the irrigated areas of the Murray Darling Basin, where there is significant over-allocation of water, and where integrated surface water groundwater management plans and effective water trading regimes are likely to be developed. While the expansion in the use of groundwater between 1983/84 and 1996/97 has been estimated at 56% (Land and Water Resources Audit), few bores are metered and currently there are no reliable data on specific use of this water by the livestock industries.

Groundwater contamination

The protection of groundwater and surface water is based on the principle that the existing or potential beneficial use of the water should not be impaired by any activity

The significance of contaminants in groundwater in Australia is identified by its impact on the beneficial use of the water. Groundwater protection classes can be found in the ANZECC guidelines (1992) which have relevant environmental values for ecosystem protection and agricultural water (irrigation and livestock watering). The protection of groundwater and surface water is based on the principle that the existing or potential beneficial use of the water should not be impaired by any activity. The beneficial use of the water is considered impaired if the total dissolved solids (TDS) or other constituents concentration is outside guidelines. Good water quality is an essential component of successful livestock production. Poor quality water may reduce production by, and interfere with the reproduction of livestock. In extreme cases stock may die.

In a recent study of coastal aquifers near Bowen (Baskaran *et al.*, 2001), exceedances of livestock water quality guidelines relating to TDS were found in 10 groundwaters out of 50 sampled, sulfate in 7 samples, boron in 4 samples, fluoride and molybdenum in one sample and selenium in 3 samples. The tolerable concentration of TDS for livestock varies depending on the type of stock and the mix of dissolved ions. A maximum concentration for TDS of 13,000 mg/L is acceptable to sheep, the most salt-tolerant of livestock. Concentrations of sulfate in excess of 1,000 mg/L can result in diarrhoea in young stock. Although higher concentrations may be tolerated in older stock, loss of production may result. Consumption of water with boron concentrations in excess of 5 mg/L can result in loss of appetite and weight.

Current impacts on the industry from some other contaminates are small but sources of contamination should be monitored

Fluoride concentrations in excess of 2 mg/L in livestock drinking water can result in tooth damage and bone lesions. Concentrations greater than 5 mg/L have been found to affect breeding efficiency in cattle. The toxicity of molybdenum is related to the dietary intake of copper and inorganic sulfate. Selenium is an essential element for animals, but can be toxic in higher concentrations, resulting in blindness and paralysis. As stated earlier, although current impacts on the industry are small, these sources of contamination should nevertheless be monitored.

Conclusions

The water reform agenda will continue and its impact on the livestock industry will increase

- The water reform agenda can be expected to continue, with ongoing emphasis on integrated groundwater-surface water management plans, sustainable yields, beneficial use, market reforms and environmental allocations;
- The freeing up of water markets is likely to exert greater pressure for structural adjustment on the livestock industries. These pressures will continue to be greatest on enterprises where profitability is lowest, including the mixed irrigated farming enterprises;

The industry will need to expand research into its environmental impacts on water and groundwater

- Adverse impacts on the aquatic environment from the livestock industries are substantial. Many of these impacts, such as destruction of groundwater dependent ecosystems and pollution of watercourses by stock, inefficient water use such as in the Great Artesian Basin, can be ameliorated. Ongoing investment by the industry will be required;

The development and adoption of best management practices is critical to sustainability of the industry and will ensure that community attitudes remain favourable

- There is a need for a more comprehensive analysis of data obtained for the Land and Water Resources Audit;
- The livestock industries sometimes impact on groundwater dependent ecosystems. While these habitats are generally not widespread, they are often associated with endemic fauna and flora and have high conservation value. As more information becomes available the livestock industries should engage management practices to conserve these areas;
- Some of the likely expansion of the water industry offers opportunity for expansion of the livestock industry;
- Land salinisation and increases in river salinity are the biggest natural resource management issue facing the livestock industries. Although land salinisation will result in direct economic loss to the industry, increases in water salinity will not directly affect productivity of extensive grazing areas;
- Agrichemicals from the livestock industries are unlikely to have substantial impacts on water resources, but nutrient discharge may be more problematical. Nevertheless, if the industry is to maintain a clean and green image, the possibility of pesticide contamination should be eliminated through additional studies.

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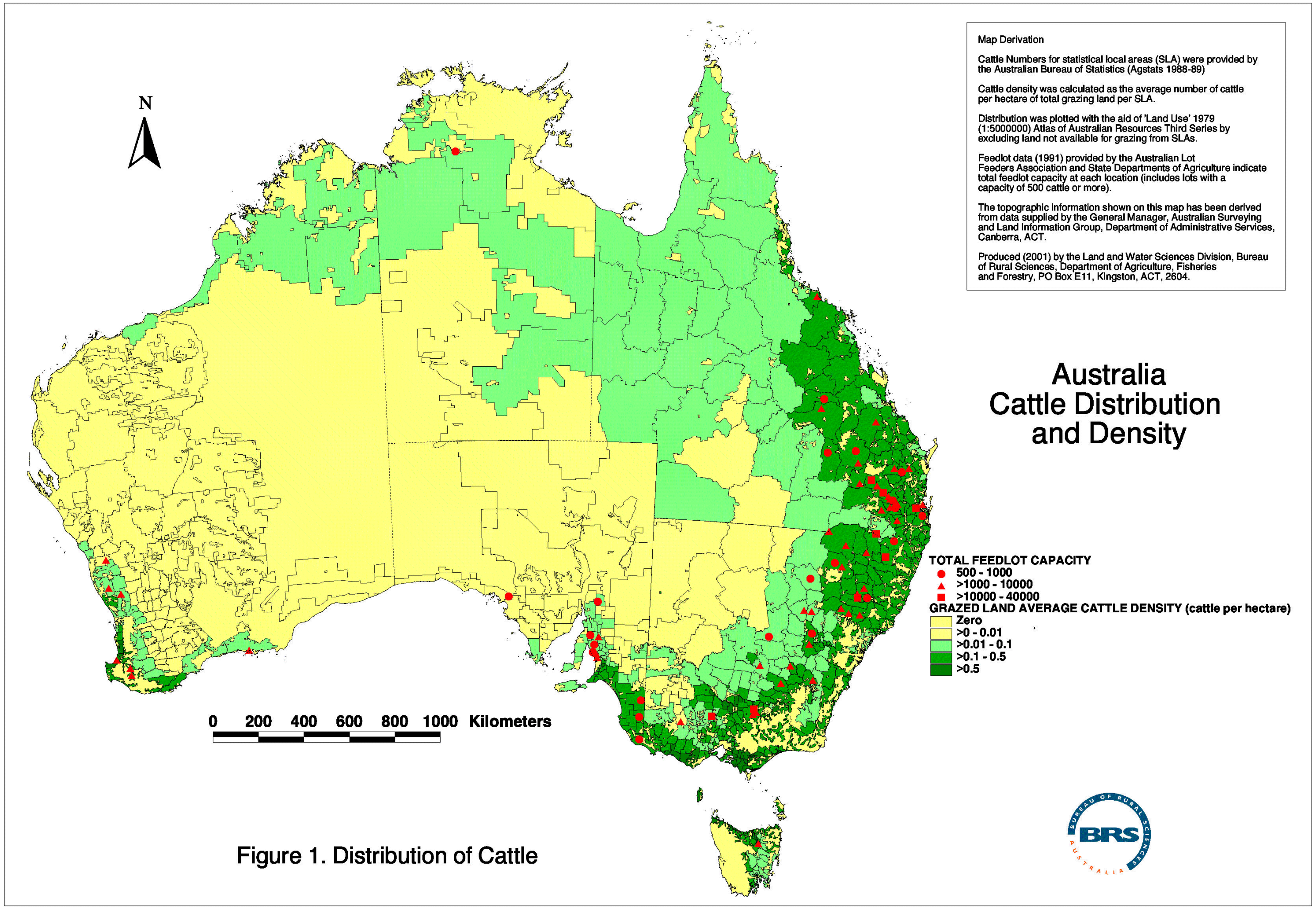


Figure 1. Distribution of Cattle

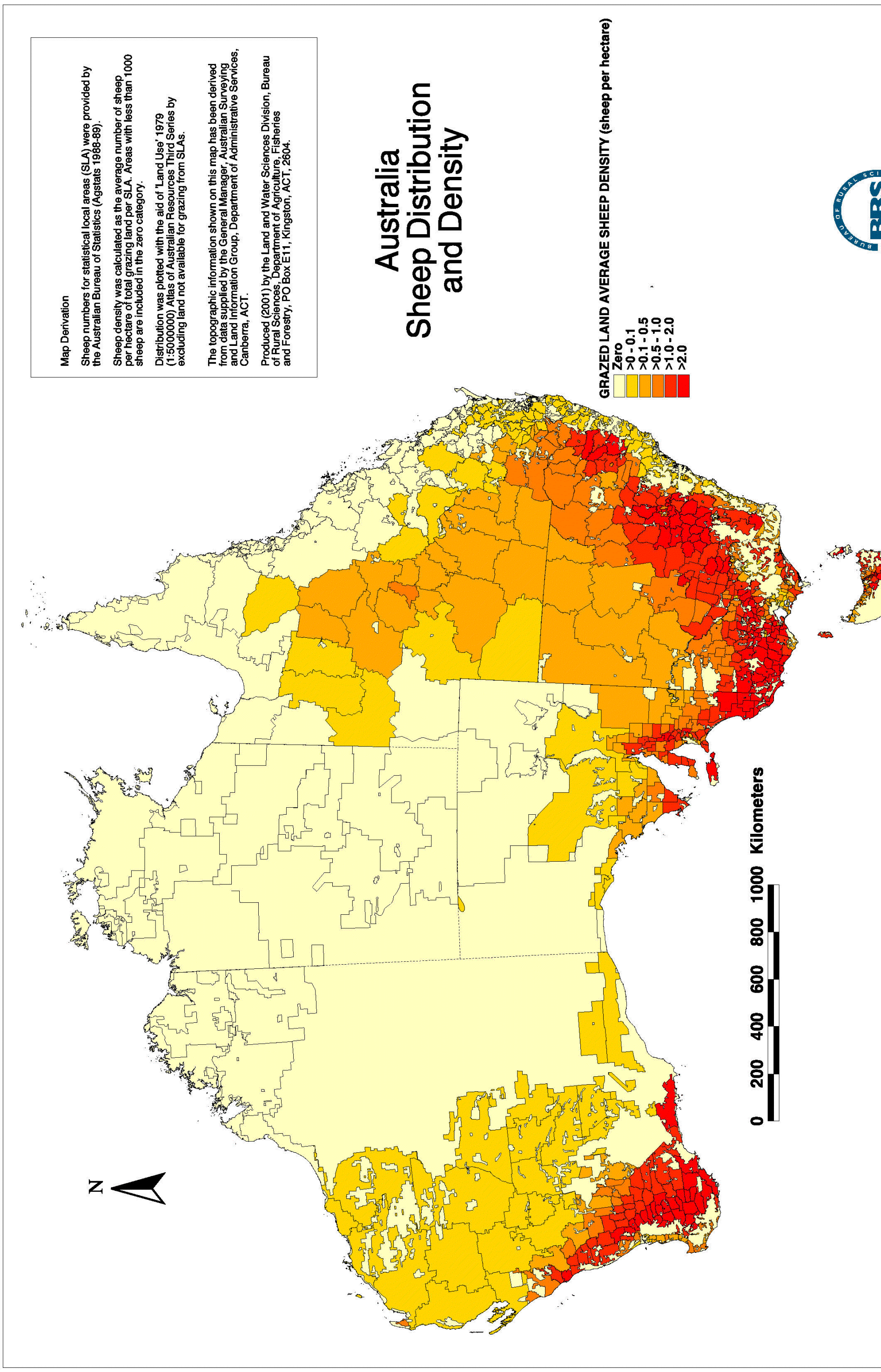


Figure 2. Distribution of Sheep

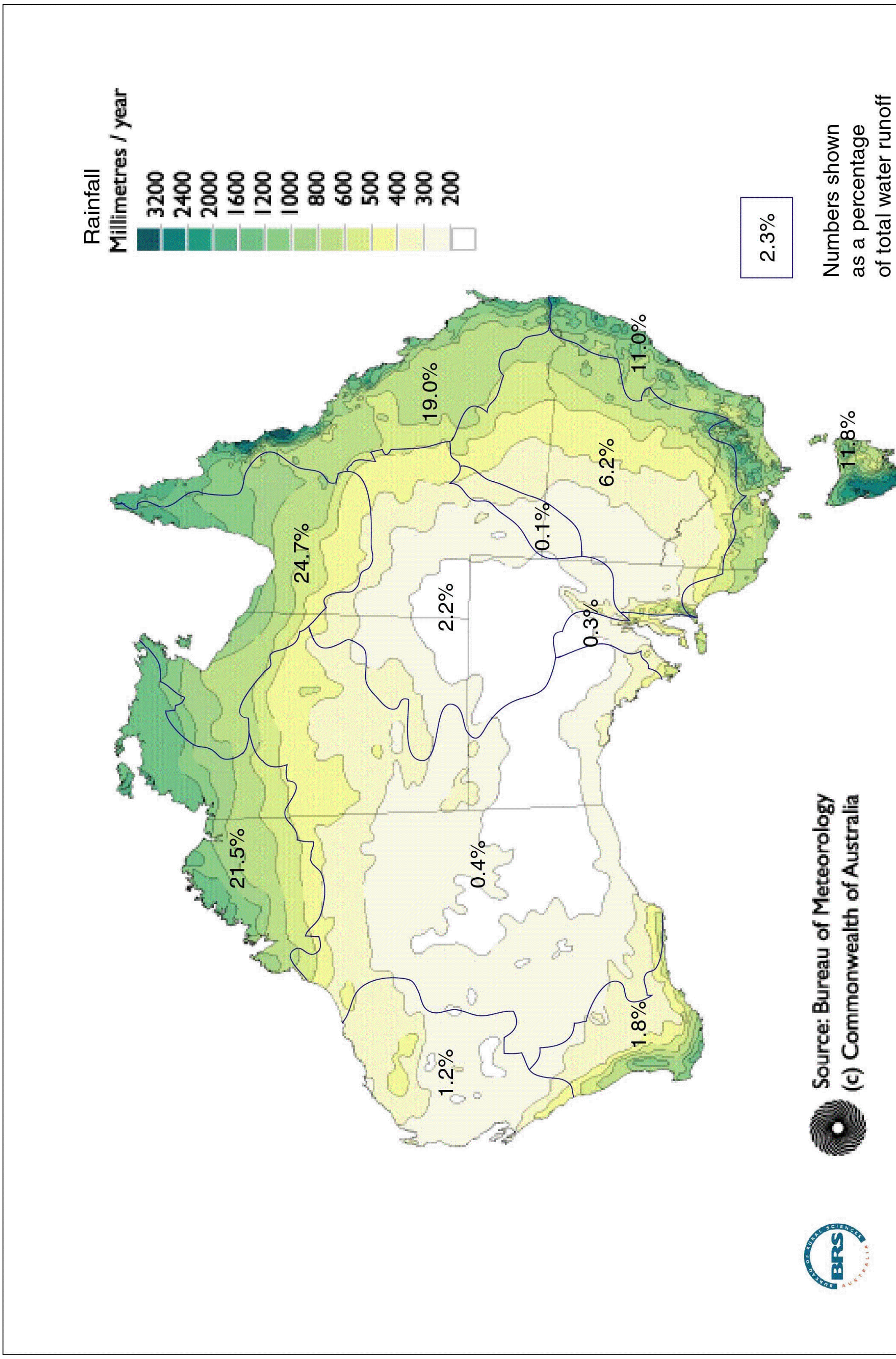


Figure 3. Availability of Surface Waters

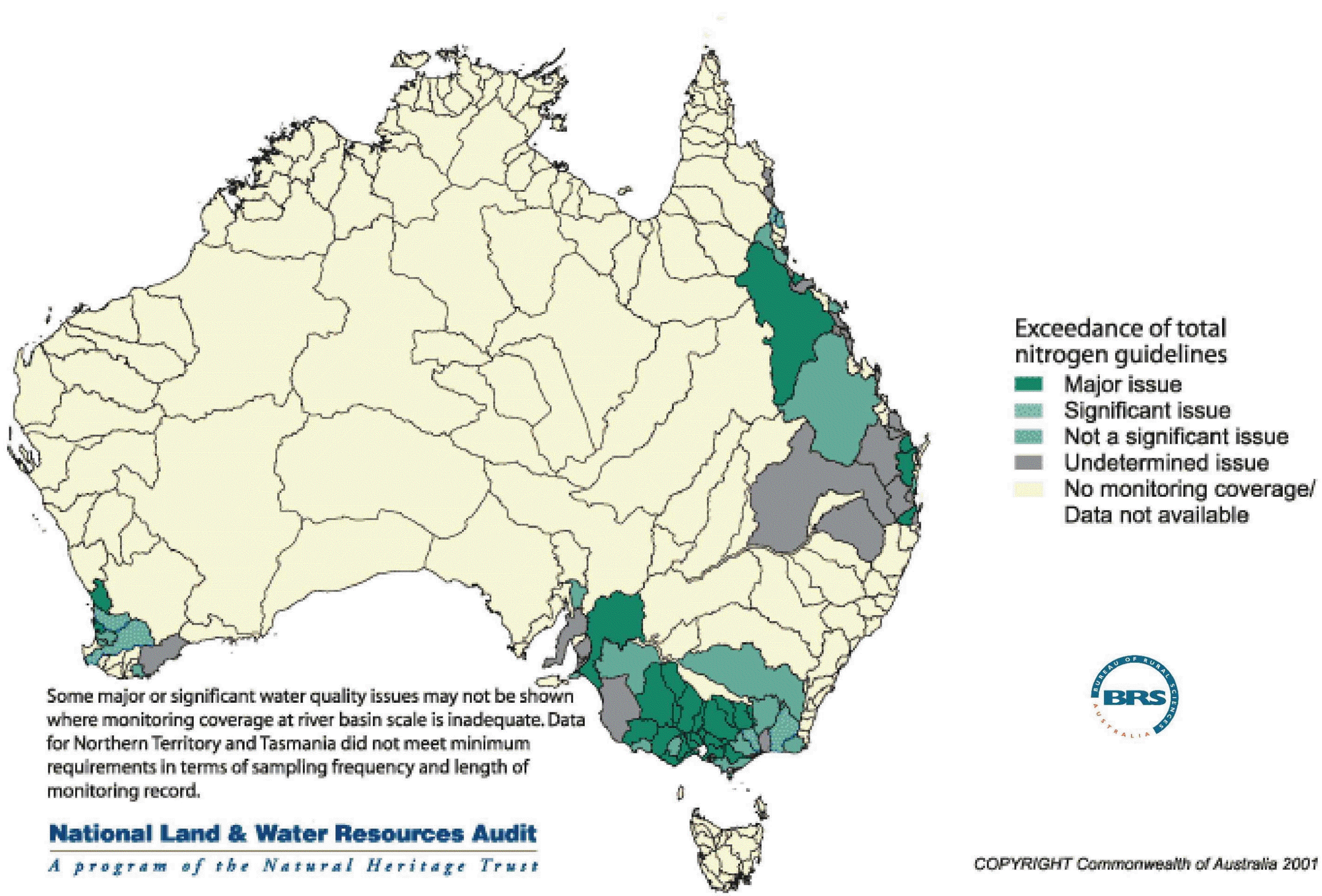


Figure 4. Water Quality in Surface Waters - Nitrogen

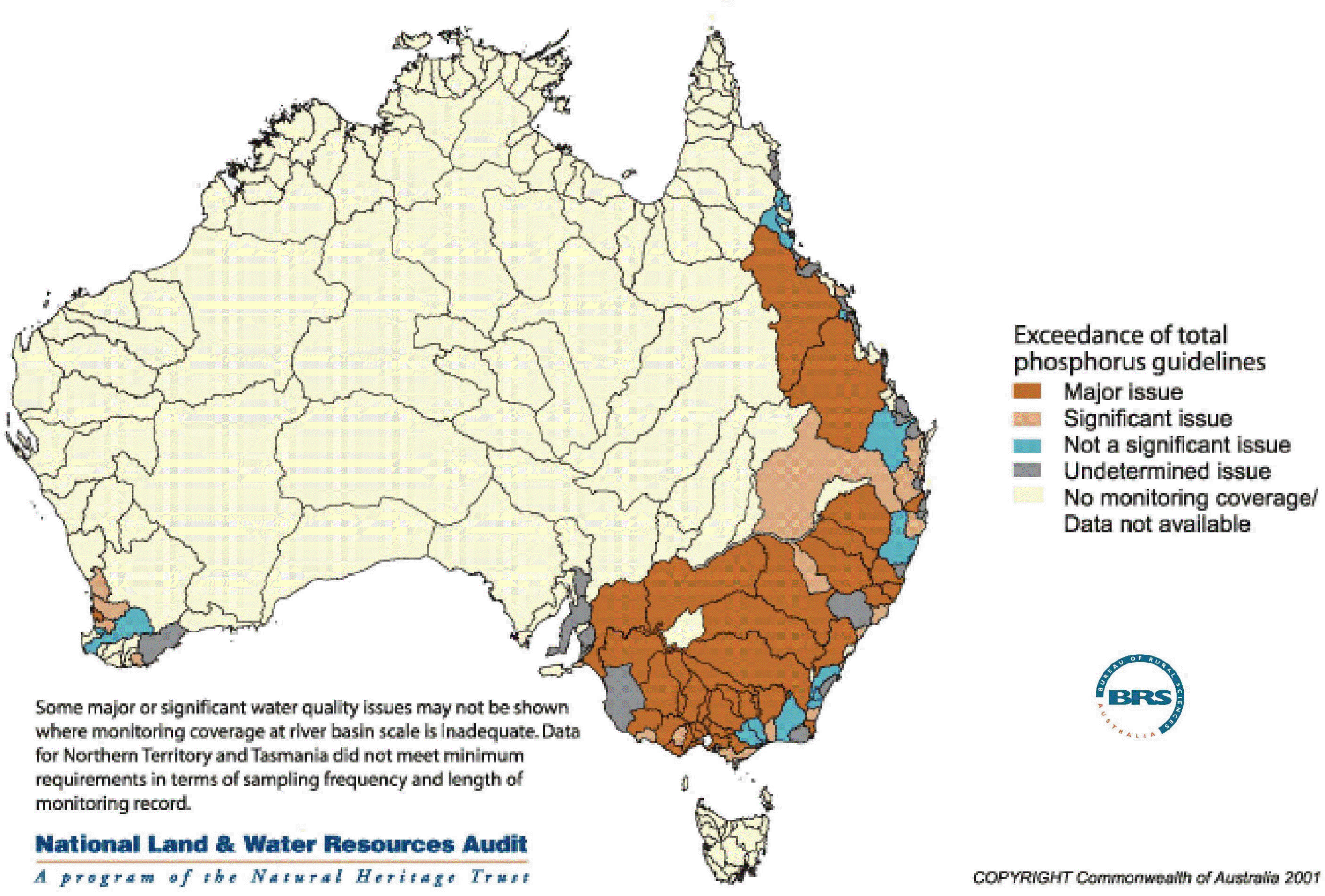


Figure 5. Water Quality in Surface Waters - Phosphorous

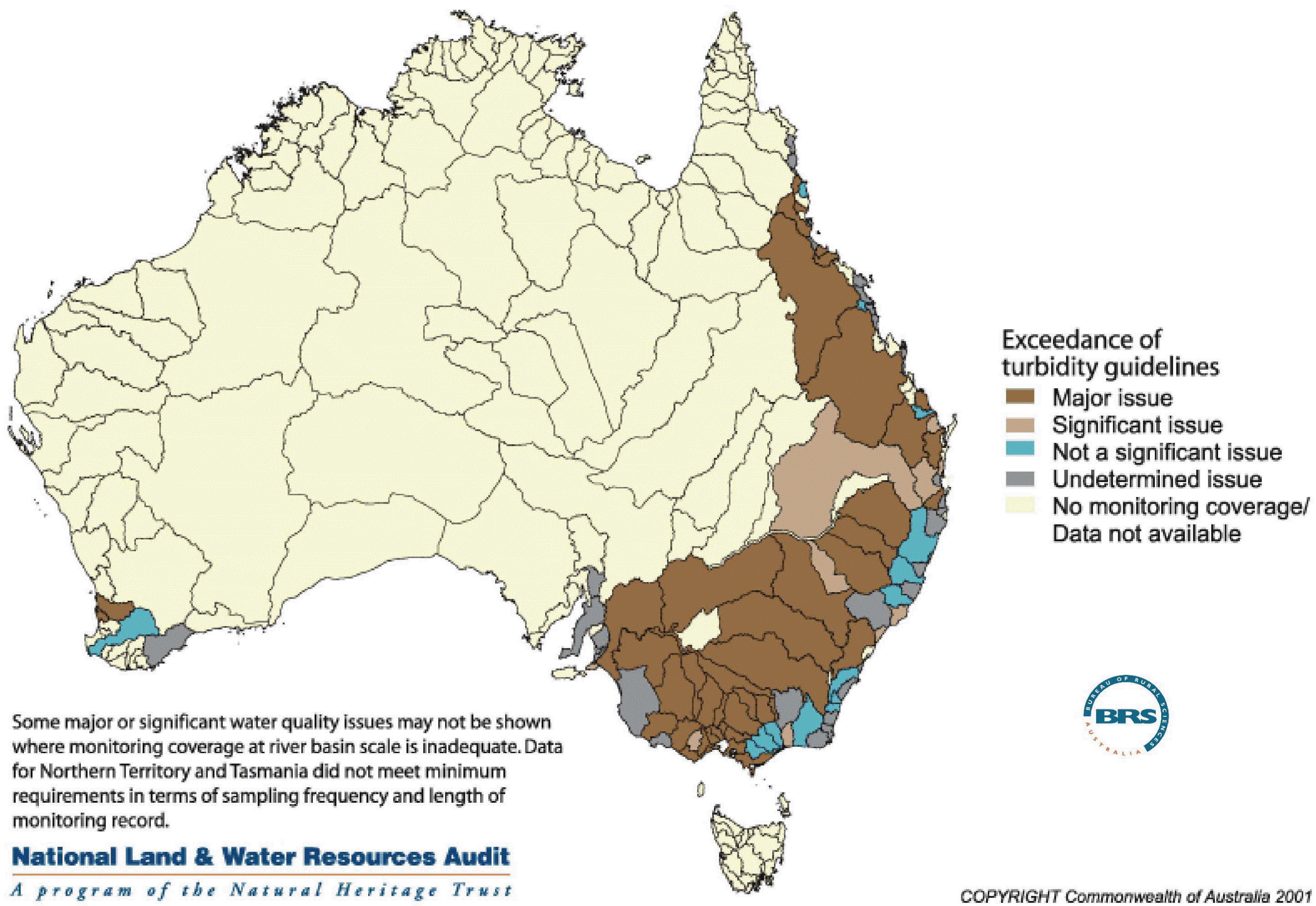


Figure 6. Water Quality in Surface Waters - Turbidity

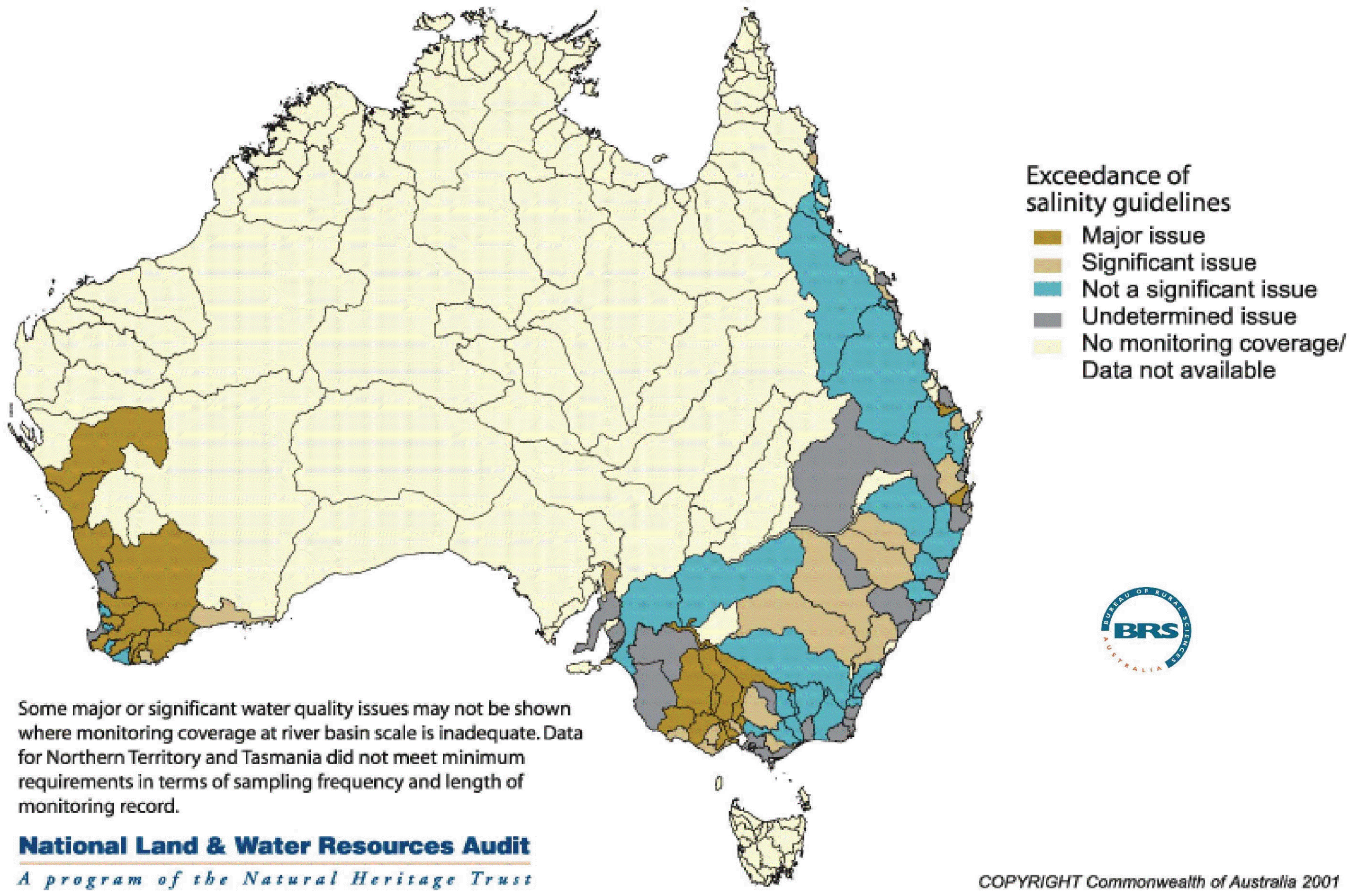


Figure 7. Water Quality in Surface Waters - Salinity

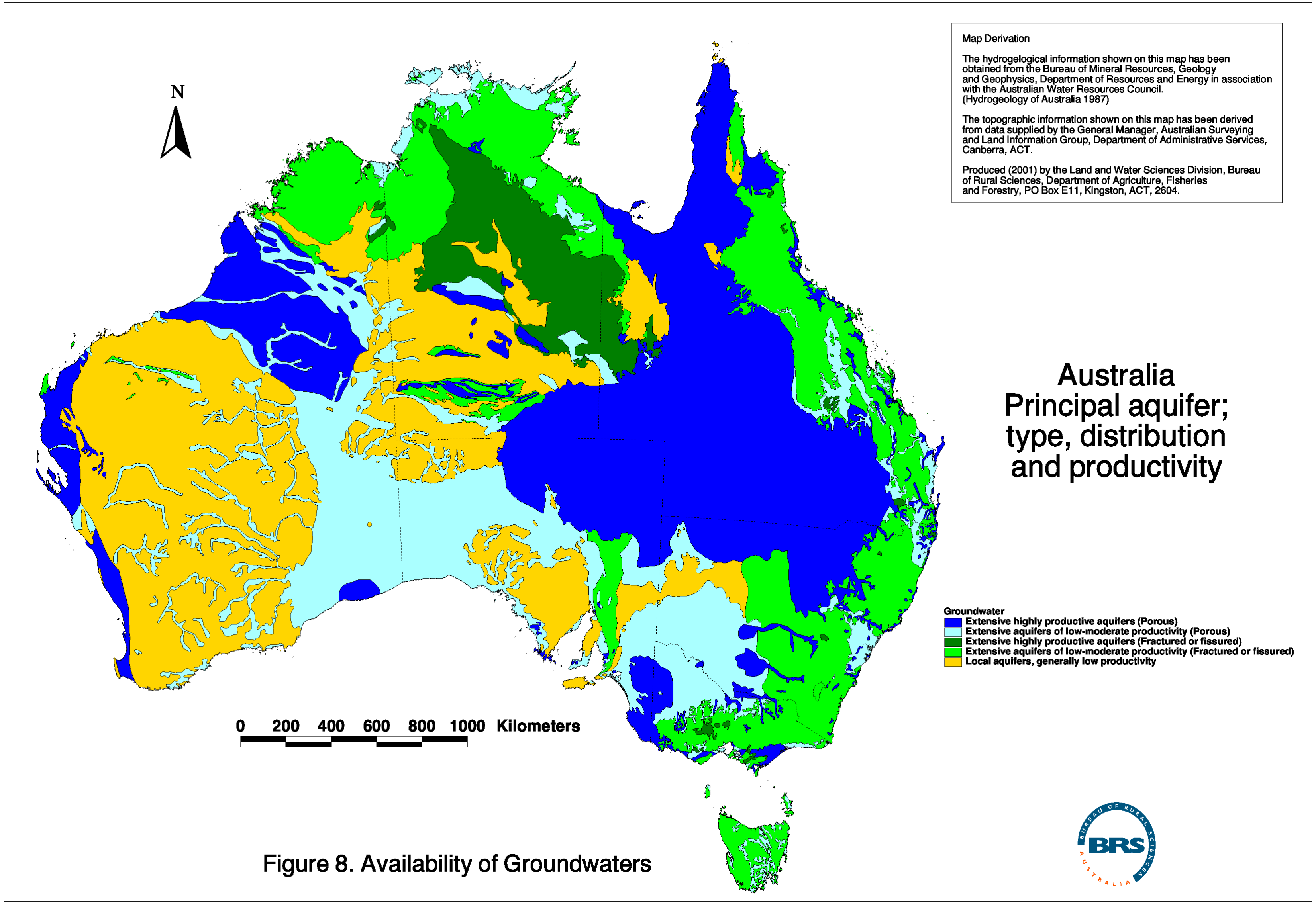


Figure 8. Availability of Groundwaters

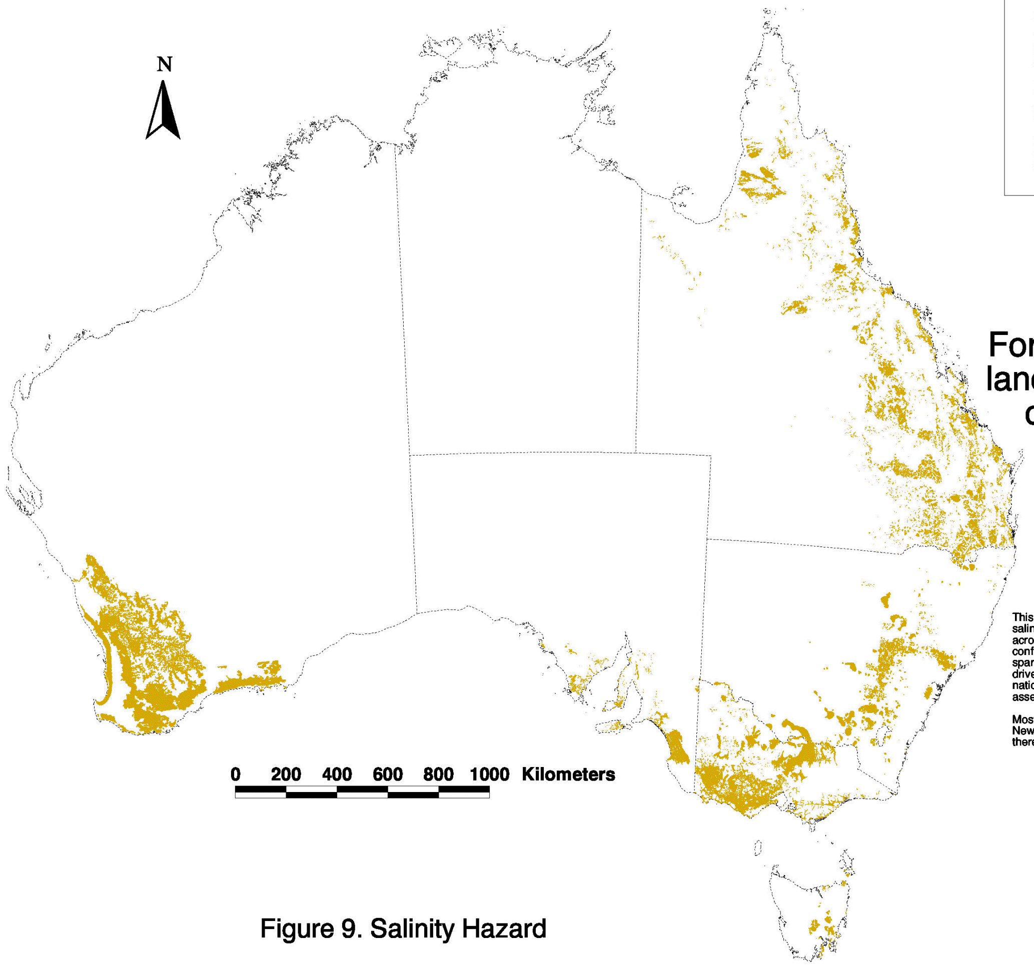


Figure 9. Salinity Hazard

Chapter 8. Erosion of soil by wind

Effects of broadacre livestock industries on the erosion of soil by wind

Wind erosion removes particles that may be rich in nutrients and organic matter

Wind erosion is a serious problem globally with major occurrences in arid and semi-arid regions, including Australia. During a wind erosion event small soil particles, usually rich in organic matter and nutrients become suspended in air and can be transported over large distances. The removal of these particles leads to soil degradation. In parts of Australia, soil formation from bedrock is around 0.4 tonnes per hectare per year, soil loss from wind erosion may however reach several tonnes per hectare per year.

Very high losses occur in extreme events

It has been estimated that the Melbourne dust storm of 1983 involved a loss of 2 million tonnes of soil, including 3,400 tonnes of nitrogen and 110 tonnes of phosphorus (Raupach et al 1994). The February 1966 dust storms were estimated to have had dust emissions of 6 million tons (Shao and Leslie 1997). Meteorological data for Australia from 1957 to 1984 (McTainsh and Pitblado, 1987) shows some areas in Australia can have up to 5 to 10 dust storms in one year. In Eastern Australia in the early 1960's, a set of 41 weather stations recorded about 100 dust storm days each year, by the late eighties this incidence was down to about 15 dust storm days each year (State of Environment Report 1996).

The incidence of dust storms is lessening, but high risk remains

The incidence of dust storms appears to be declining, suggesting that control measures such as minimum tillage and increased surface cover have been successful. Despite this success, wind erosion is highly episodic and future interactions of climate and land management could still produce erosion events.

Wind erosion is influenced by climate, characteristics of the soil and the land surface and by land management practices

Wind erosion is influenced by a complex set of interacting physical processes governed by four main factors:

- climate; kinetic energy from high winds and turbulence causes dust emission from soil. Low precipitation leads to dry soils in which soil aggregates break down and desiccate, producing smaller, lighter, more loosely bound, and therefore more erodible particles. These conditions are most commonly seen in Australia associated with the passage of meso-scale frontal weather systems moving from west to east across Australia during dry summer conditions,
- soil characteristics; mineral composition, crusting, particle size characteristics, including aggregation arising from organic matter and soil moisture content,
- land surface characteristics; microtopography and surface roughness, non-erodible soil aggregates, and vegetation cover,
- land management practices; leading to soil compaction, breaking of surface crusts, increase or decrease in protective vegetation cover, vehicle and animal tracks etc.

Wind erosion events are spatially variable and temporally episodic and occur when a number of high risk conditions coincide.

The risk of wind erosion can be minimised by good management practices

Some of these elements are beyond immediate human control but land management practices can exert large effects in reducing or increasing susceptibility to wind erosion.

The major concern of this review of wind erosion is to identify environmental variables that can be manipulated by livestock industry land management practices to minimise susceptibility to erosion by wind.

Climate

This is a factor over which an individual property owner has little control. There are however some ways in which the effects of climate can be ameliorated at the soil surface microclimate level by dryland management practices which are described below.

Soil characteristics

Maintaining vegetation cover is critically important

Maintenance of soil nutrient status through appropriate fertiliser and soil conditioning inputs will maximise vegetation response to water inputs. Organic matter inputs in grazing systems come primarily from plant growth and have important effects on maintaining soil structure, increasing particle size through aggregation, enhancing water penetration and increasing water holding capacity.

Organic matter in the soil reduces susceptibility to wind erosion

Large, well bound, wet aggregates resist wind erosion far better than small, light, loosely bound particles. Organic matter in soil encourages plant growth and organic matter deposition. Vegetation cover has further feedback effects reducing wind speed, turbulence, and soil surface desiccation, providing more favourable conditions for plant growth and survival.

Vegetation management needs to be linked to better information on climate

One of the clear information needs for the grazing industry is for better predictions and intelligence on the onset of dry conditions that are likely to be prolonged or intense. This will be difficult to achieve but more can be done with existing capability to provide useful information on soil moisture and climate reliability. This could be a significant aid as regional and catchment planning moves increasingly towards control of land development, and support for sustainable management practices.

Land surface characteristics

Vegetation cover increases surface roughness and reduces erodibility

The major variables that can be influenced by land management are the inter-related elements of vegetation cover, soil organic matter, soil nutrients and soil moisture. In grazing systems, the most important variable is surface roughness from vegetation cover, including both annual and perennial plants. Bare soil allows near-surface wind speeds and turbulence to reach high levels but vegetation cover both reduces wind speeds and protects soil through the binding action of roots and litter. Vegetation height and density (density often expressed as leaf area index, LAI) are two major measurable contributors to this effect.

Managing the cover of annual vegetation is critical to protecting soil from wind

Both perennial and annual vegetation can exert major protective effects. The state of annual vegetation is a particularly large source of variability in susceptibility to wind erosion. Maintaining vegetation cover over paddocks has several beneficial effects. Standing vegetation and surface litter, have direct effects by reducing near-surface wind speed and turbulence through aerodynamic resistance. Plants also draw moisture from variable depths below the soil surface. The resulting humidification of near surface air from transpiration, combined with shade from plants and litter, protects the immediate soil surface from desiccation, increasing surface soil moisture content and reducing the susceptibility of soil to erosion by wind.

Sustainable grazing systems should have maintenance of suitable vegetation cover as a major aim

Reduction of plant cover by overgrazing, excessive tree clearing in strategic areas, or fire is a major contributor to wind erosion risk. Sustainable grazing systems should have maintenance of suitable vegetation cover as a major aim. Development of regional and enterprise benchmarks for vegetation cover would be a valuable contribution to aiding sustainable management.

There are ancillary benefits from maintaining vegetation cover and soil organic matter. These are improved water and nutrient availability and use by pastures, and less "leakage" of water and nutrients to groundwater where their availability to pasture is greatly reduced and where they may contribute to rising water tables and its attendant problems of waterlogging and salinisation.

Research needs to be targeted to specific management regimes for individual regions

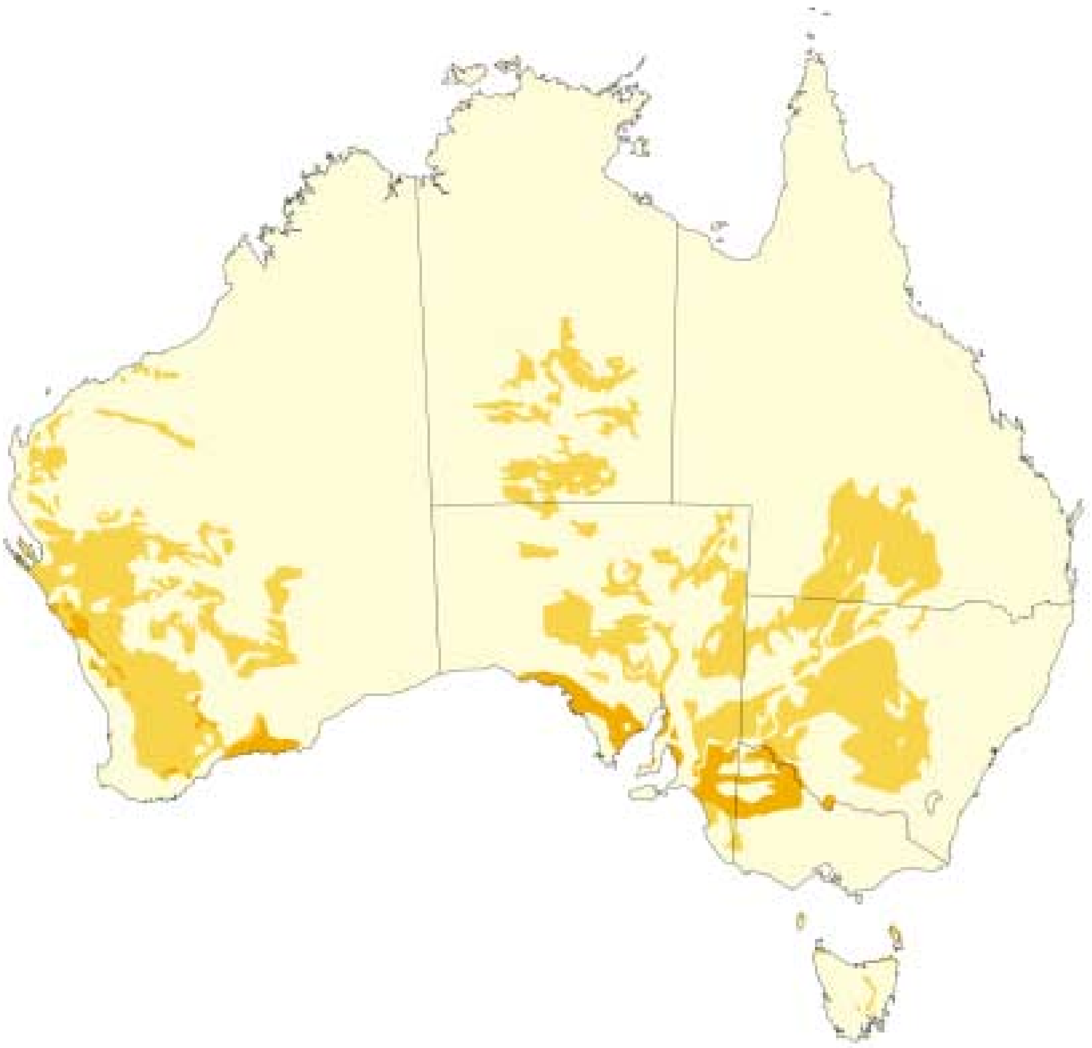
Efficient grazing management for production purposes has many objectives in common with grazing management for resource conservation. Research to define specific management procedures and benchmarks for particular regions will help the adoption of sustainable grazing systems.

Information available in mapped form is limited, but the following examples illustrate the risk and its complexity

Spatial extent of erosion of soil by wind

The following maps indicate case studies that show which areas of Australia have a high risk of wind erosion. With information of this kind regional programs can be developed to target areas of highest risk.

Figure 8.1. Wind erosion in Australia



Distribution of susceptible soils under cropping that regularly suffer extensive, moderate to severe wind erosion when adverse winds coincide with sparsely vegetated or bare soil surfaces.

Areas of grazing and cropping land that may suffer accelerated localised or infrequent wind erosion damage.

Source: Commonwealth of Australia, 1991, Decade of landcare plan: Commonwealth component, AGPS Press, Canberra.

0 1000km

Map projection: Lambert conformal conic
Standard parallels: 18°S, 36°S

Figure 8.2. Wind erosion risk in the Murray-Darling Basin, NSW.

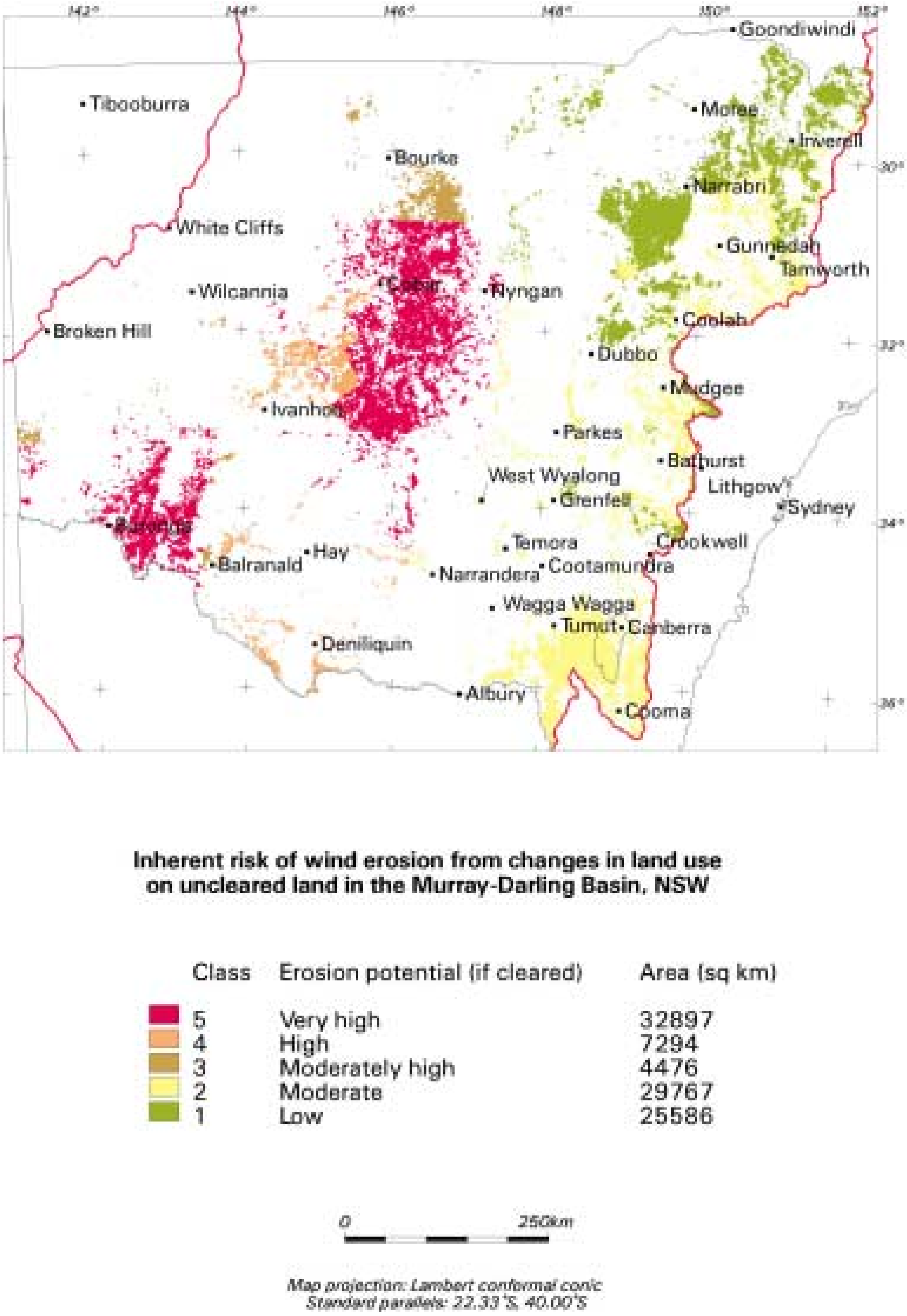
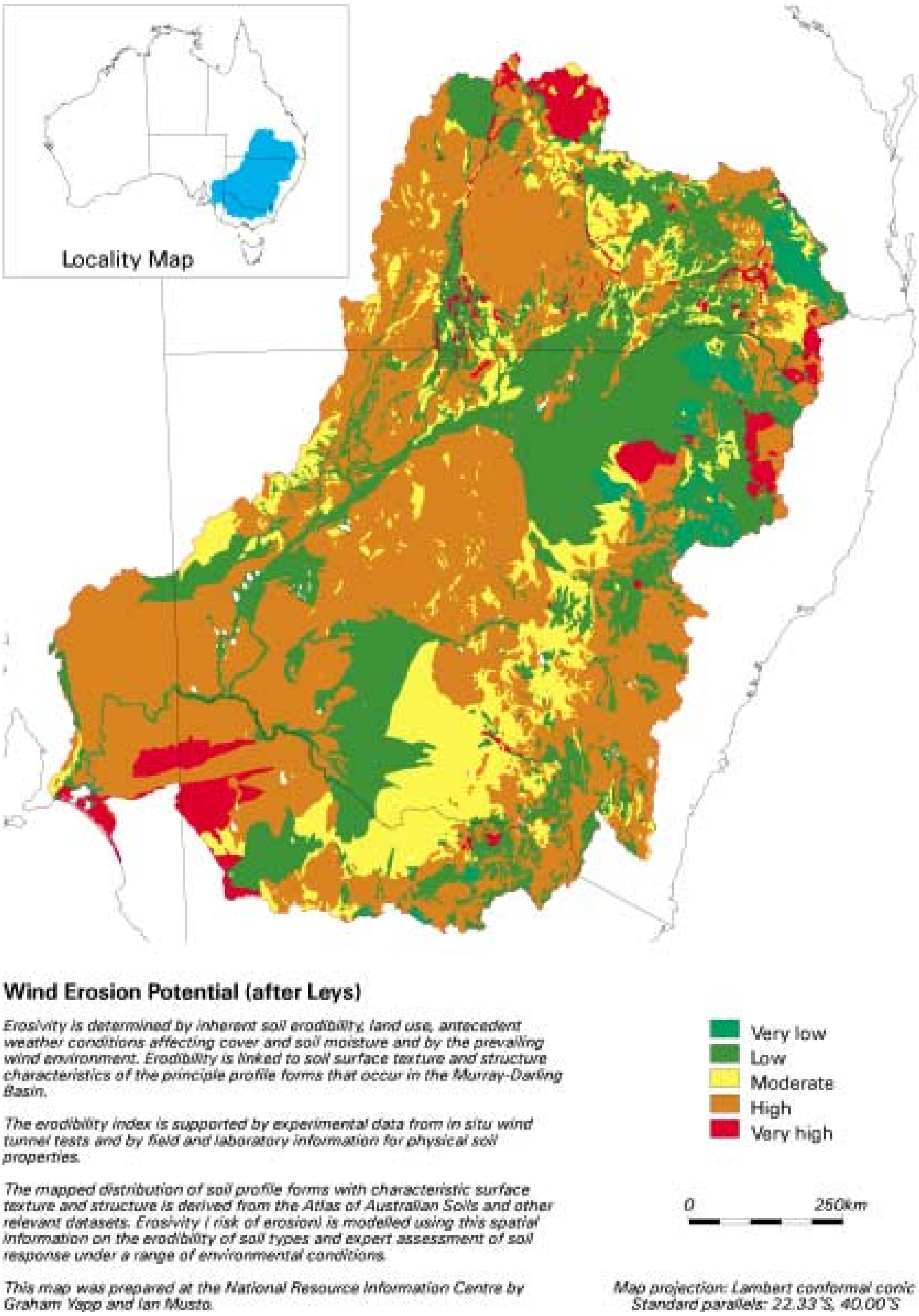


Figure 8.3. Wind erosion potential in the Murray-Darling Basin.



Effects of wind erosion on broadacre livestock issues

Wind erosion directly affects costs and productivity

Public reactions to wind erosion may lead to controls on land use

Environmental issues in this subject area are largely similar to other environmental issues in the way they will affect the industry. This will be by direct effects on the productivity of industry resources and associated input costs, and by the response of consumers and the community through imposition of formal restraints on industry practice and marketing regulation (including meeting access requirements), and informal effects through market acceptance of products. As most consumers live in urban communities, and urban communities are a dominant electoral force in Australia and most of our trading partners, their perceptions of the livestock industry will have major effects in this area.

Issues which have been identified to be of concern in this area are public health, biodiversity, climate change, consumer and market responses, and industry productivity.

Public health and amenity related to air quality and dust emissions (atmospheric pollution) from agricultural land

Wind erosion can have impacts on public health

- the issue known as "PM 10", referring to airborne particles of diameter less than 10 microns. Because of their size these particles remain suspended for long periods and can penetrate deeply into the respiratory system. They can cause asthma and other respiratory complaints.
- demonstration of airborne disease transmission by spores in soil.
- impact on water quality through fallout on catchments and storage facilities

Biodiversity issues

The factors that impact on vegetation cover and increase erosion risk also impact on biodiversity

- reduced vegetation cover related to tree clearing and overgrazing is associated with habitat destruction, and resource degradation. Habitat destruction is recognised as a major cause of reduced biodiversity. While direct effects of reduced biodiversity on ecosystem function are not well understood, and may not always be deleterious, reduced biodiversity is an issue that receives strong political condemnation.

Climate change

Managers must recognise changing climatic conditions and other environmental concerns

- dust and aerosol impacts (from agriculture and other sources) on cloud formation and heat fluxes are increasingly being identified in atmospheric processes contributing to global warming

Consumer and market reaction

- reduced attractiveness of product from livestock industries.
- pressure for regulations to control dust emissions at their source through controls on tree clearing and stock grazing densities to promote better vegetation cover.
- pressure for property certification for environmental soundness to

allow access to certain domestic and export markets.

Issues of industry productivity

Productivity is affected by soil depletion, impaired water availability and higher costs of production

- soil loss, particularly small particles rich in nutrients and organic matter.
- diminished water holding capacity and nutrient availability because of diminished organic matter content leading to reduced pasture productivity and inefficient pasture response to water and nutrient inputs.
- increased runoff and loss of water and nutrients to production areas.
- reduced livestock carrying capacity.
- input costs for fertiliser and soil conditioners to replace nutrients and organic matter.

Sustainable grazing management offers "win/win" opportunities for environmental and industry interests. Suggested responses include:

Tree management is a key strategy for reducing erosion risk

- Tree management (clearing and planting) and grazing management to provide a suitable mosaic of vegetation cover that maximises biomass production and minimises susceptibility to wind erosion is an outcome that will meet both environmental and industry needs. Noting that vegetation in a "vertical" form eg trees, is relatively more effective than "horizontal" vegetation in controlling surface wind speed, a major factor in wind erosion.

Better information is needed for tailored vegetation management strategies

- Examination of where in Australia tree cover is required at regional and farm scales for environmental management purposes, eg windbreaks, water use, slope stabilisation and conservation of biodiversity would provide clear guidance on where further tree clearing could occur and where reafforestation on already cleared land may be required. This information is needed for formulation of rational tree management plans.

Pasture management is the most critical strategy

- In areas where dense tree cover is not required for environmental management purposes then pasture use for livestock can be considered. Grazing management to maintain good pasture cover ensures wind erosion is minimised while ensuring rapid and efficient pasture response to water inputs. Management of senescence in pastures through rotational grazing offers opportunities for good pasture performance for livestock growth and maximises water retention in vegetation and soil, preventing "leakage" of water to subsoil. Other strategies for management of pasture senescence and pasture composition (eg woody weeds), involving fodder conservation, slashing or burning, need to be assessed in the light of their contribution to sustainable pasture management.

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Chapter 9. Erosion of soil by water.

Effects of broadacre livestock industries on erosion of soil by water

Water erosion takes several forms

Erosion of soil by water takes place in three main forms, sheet and rill erosion from rain accumulating on the soil surface, gully erosion where larger volumes of water flow in a concentrated area, and stream erosion along banks and beds of streams and channels.

Sheet and rill erosion varies according to rainfall erosivity, vegetative cover, soil conditions and management practices

Erosion generally exceeds the rate of soil formation

Sheet and rill erosion moves about 14 billion tonnes of soil in Australia annually (Wasson et al, 1996). This is a figure higher than the global average. Sparse vegetation over much of the country, and intense rainfall events contribute to this. In some areas, particularly on slopes and disturbed sites (Edwards, 1991), this can exceed the natural rate of soil formation (about 0.4 tonnes per hectare per year in favourable conditions, equivalent to about 30 mm of soil per 1,000 years). This is particularly so in systems where plant cover has been removed from close contact with soil. Rates of soil loss of 500 tonnes per hectare per year have been observed in tropical cropping systems in Australia. In pastoral systems losses of up to one tonne per hectare per year would be more usual (Australia: State of the Environment 1996).

Gully erosion is exacerbated by increased surface and subsurface flows after clearing and, in Australia, has tended to reach its maximum extent within 50 years of clearing (Edwards, 1991).

Protection of riparian zones is important and more information is needed to guide land management

Rates of stream erosion are poorly quantified in Australia but can be expected to be increased where riparian zones are disturbed by grazing, trampling and vegetation changes accompanying these disturbances. Although good estimates of the magnitude of this problem are not available it can be expected to be a major problem nationally because of the importance of riparian zones for agriculture and conservation, and the proximity of erosion and soil movement to streams and water where many of the consequences of soil erosion by water are manifested.

Water erosion removes fertile fractions of the soil resource

Degradation of vegetation cover leads to increased runoff and exposure of bare soil to water movement. Erosion of soil by water tends to remove small, light, low density or soluble particles. These often have a high level of organic matter and available plant nutrients and their loss results in diminished plant growth and productivity due to reduced water holding capacity of soil, increased run-off, and increased need for nutrient and conditioning inputs to soil.

Impacts of water erosion on water quality and other environmental impacts are widely recognised

Soil erosion by water also contributes to turbidity and sediment in streams. This has impacts on water quality through eutrophication, adds to water treatment costs, reduces the storage capacity of reservoirs and has impacts on riparian and aquatic biodiversity. Studies in south eastern Australia show that sediment accumulation in reservoirs has been declining this century as land management and soil conservation techniques have improved (Australia: State of the Environment 1996).

Erosion of soil by water is influenced by a complex set of interacting physical processes governed by four main factors:

The energy of rainfall (erosivity) is a key determinant of soil loss

1. climate; rainfall quantity, intensity and drop size are major factors and often increase in concert. Kinetic energy from raindrops causes particle detachment from soil which may become dissolved or suspended and removed with run-off. High energy turbulent run-off will reduce sedimentation effects and can carry soil long distances. In Australia, local storms frequently initiate water erosion events, especially as storm centres track across rural landscapes.

The erodibility of soil is influenced by land management practices

2. soil characteristics; soil mineral and organic composition affects particle size, shape, weight and density. Cohesive bonds between particles also influence their susceptibility to detachment and removal. Subsurface flows are influenced by soil type and can have effects eg subsidence and tunnelling, that compound surface impacts but in most Australian pastoral systems this is a relatively minor process. Loss of water holding capacity due to changes in soil characteristics and profile depth lead to reduced plant growth, increased runoff and further erosion.

Vegetation management to increase surface protection and roughness is a key to reducing soil loss

3. land surface characteristics; these are influenced by soil characteristics and other features such as slope, surface roughness and microtopography, non-erodible soil aggregates and vegetation cover. These features influence the energy with which rain strikes the soil, the partitioning into infiltration or run-off, the speed and turbulence of surface flow, and its concentration into channels.

Vegetation management can be supported by other management practices to increase soil protection

4. land management practice; the most critical factor in land management practice is the maintenance of vegetation cover for soil. Pasture, roots and plant litter all exert protective effects against drop impact and surface flows when in close contact with soil. Other management practices such as use of fertiliser and soil conditioner, stocking rates and fire regimes have major effects on water erosion through their effects on quantity and nature of vegetation cover for soil.

The major concern of this review is to identify environmental variables that can be manipulated by livestock industry land management practices to minimise susceptibility to erosion by water.

Climate

This is a factor over which an individual property owner has little control. There are however some ways in which the effects of climate can be mitigated at the soil surface microclimate level by dryland management practices which will be described below.

Soil characteristics

Maintenance of soil structure and nutrient status through appropriate fertiliser, soil conditioning inputs and organic matter management will maximise plant growth and the potential for generating protective cover.

Land surface characteristics

Ground cover maintenance is critically important

Standing vegetation is relatively more protective against wind erosion than water erosion, and conversely plant matter in close contact with the soil surface as prostrate growth or litter is relatively more protective against erosion by water than wind.

Bare surfaces are extremely vulnerable to erosion

Bare soil surfaces are vulnerable to water erosion. Reduction of plant cover in pastoral systems by overgrazing, trampling, excessive tree clearing in strategic areas, or fire is a major contributor to water erosion risk. Sustainable grazing systems should have maintenance of suitable vegetation cover as a major aim.

Land use needs to be matched to slope, soil type and the rainfall regime

Choice of land use with respect to slope, soil type and the nature of rainfall (eg storm frequency) to minimise erosion risk have been described in numerous publications. Provision of datasets describing these elements of the environment at appropriate scales for on-farm use and coupled to expected impacts of certain land management regimes would provide good decision support for selection of suitable land uses on-farm.

Further management support to maintain vegetation cover and soil organic matter on-farm through appropriate stocking rates, grazing management and vegetation composition management will help reduce the extent of water erosion.

Ancillary benefits of maintaining vegetation cover are:

Good vegetation management has additional benefits

- improved water and nutrient availability and their use by pastures,
- less “leakage” of water and nutrients to groundwater where their availability to pasture is greatly reduced and where they may contribute to rising water tables and its attendant problems of waterlogging and salinisation.

Further research into best grazing management practices is necessary

Efficient grazing management for production purposes has many objectives in common with grazing management for long term resource conservation. Research to define specific management procedures and vegetation cover benchmarks for particular regions will help the adoption of sustainable grazing systems.

Spatial extent of erosion of soil by water

Some examples of risk assessment for water erosion are shown in the following maps

The following maps indicate the spatial extent of erosion of soil by water and can be used to determine regional priorities for remediation.

Figure 9.1. Water erosion in Australia

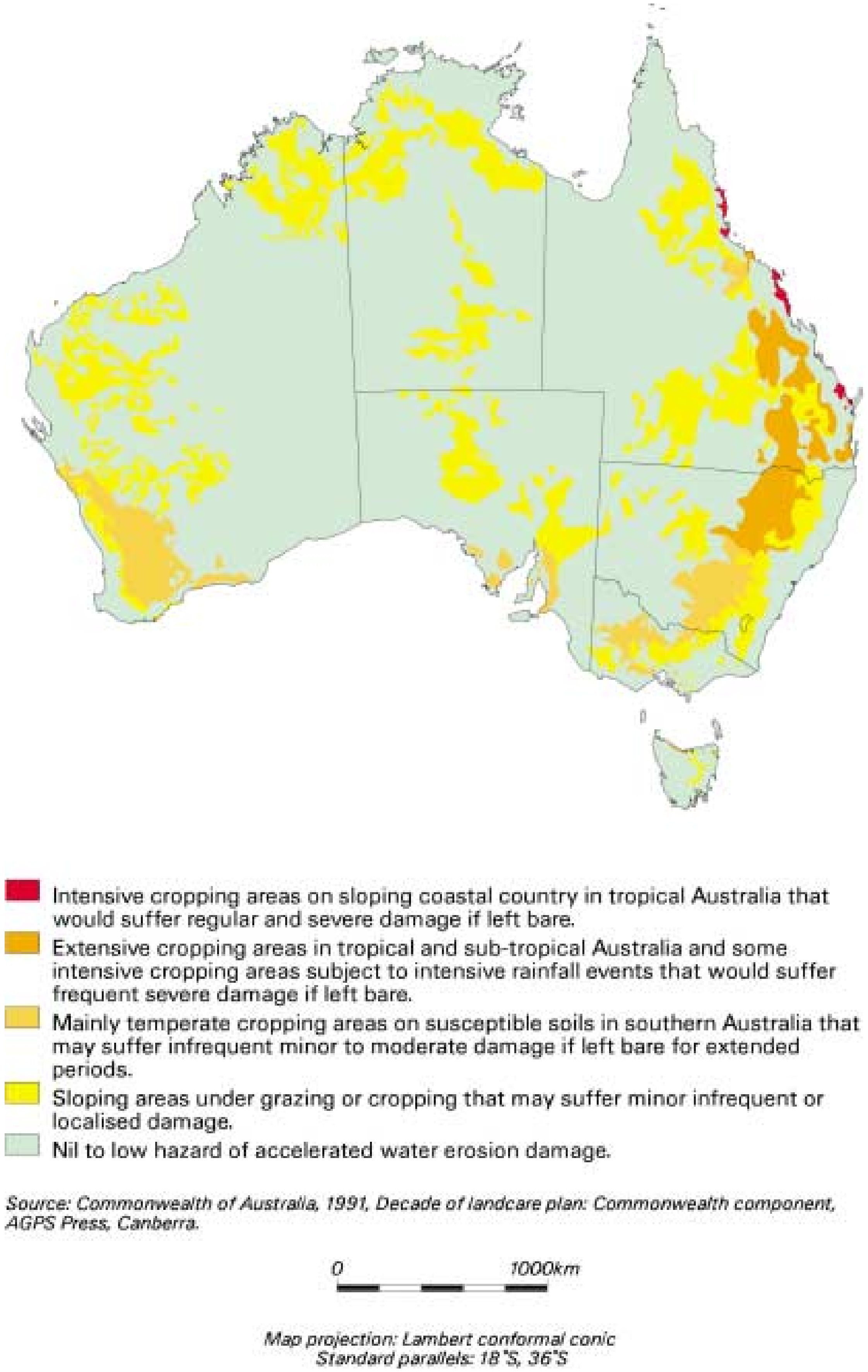
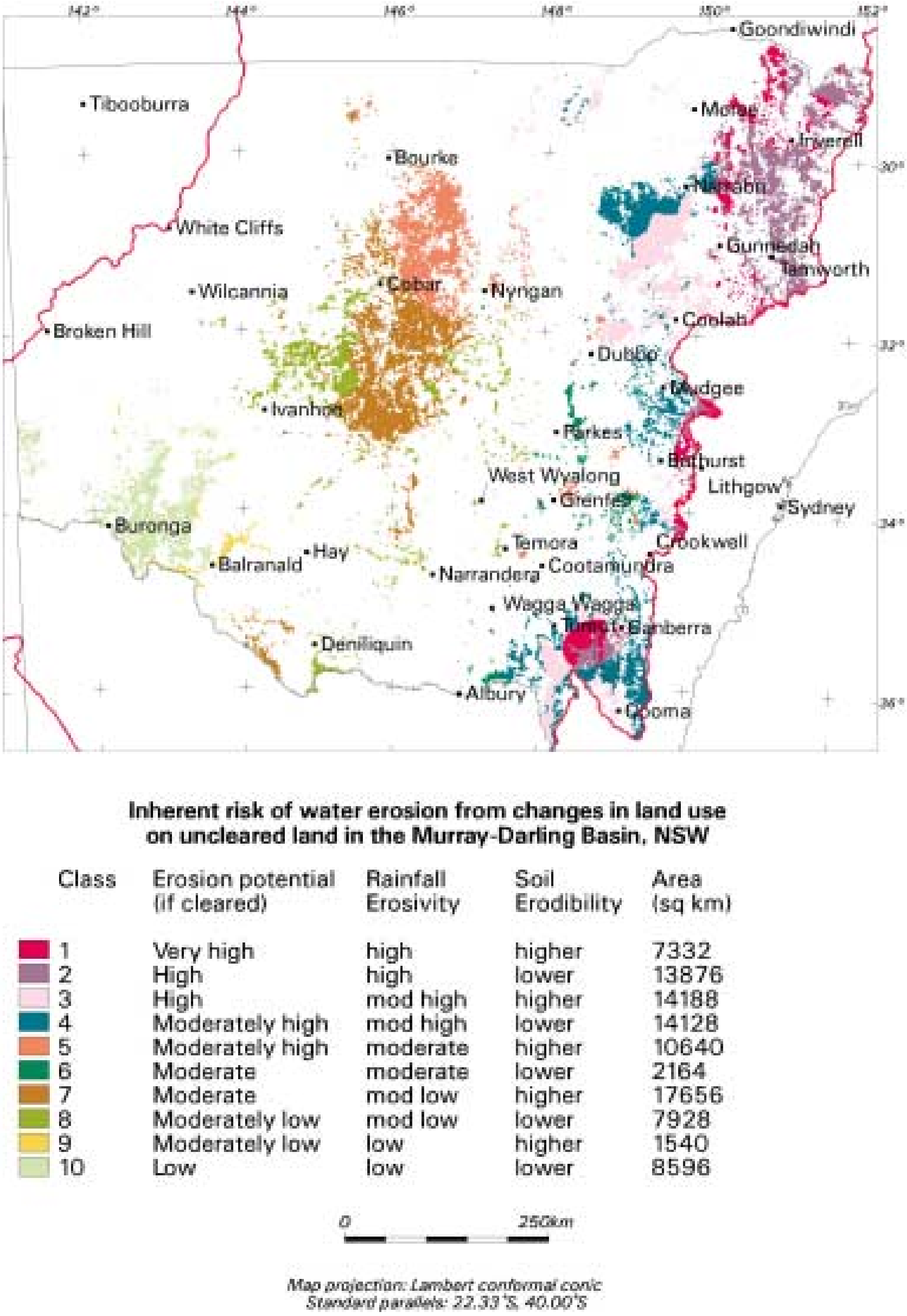


Figure 9.2. Water erosion risk in the Murray-Darling Basin, NSW.



Effects of water erosion issues on broadacre livestock issues

Water erosion affects productivity and can raise consumer and other public concerns

Environmental issues in this area are generally similar to other environmental issues in the way they will affect the industry. This will be by direct effects on the productivity of industry resources and associated input costs, and by the response of consumers and the community through imposition of formal restraints on industry practice and marketing regulation (including meeting access requirements), and informal effects through market acceptance of products. As most consumers live in urban communities, and urban communities are a dominant electoral force, their perceptions of the livestock industry will have major effects in this area.

Issues which have been identified to be of concern in this area are:

Issues include damage to infrastructure, increased costs for protection and maintenance, poor water quality, reduced biodiversity and inferior quality of products

- increased speed and quantity of run-off from grazing land with reduced vegetation and soil cover, leading to increased damage to off-farm infrastructure such as roads and drains, and increased flooding.
- sediment deposition in drains, water courses, and water storage facilities leading to increased maintenance costs and reduced life and value of infrastructure.
- depressed water quality in catchments, streams, lakes, dams (farm and public), estuaries and coastal zones with diminished amenity and impacts on other industries such as fisheries, recreation and tourism.
- biodiversity issues related to diminished water quality through turbidity, eutrophication, and sedimentation. These can result from tree clearing and habitat destruction, overgrazing and resource degradation and manifest as algal blooms and other changes to conditions for wildlife, leading to change in species composition and abundance.
- reduced attractiveness to consumers of product from livestock industries that are seen to be environmentally damaging.

Consumer responses to this situation include:

Responses to water erosion may include increased regulation of the industry

- pressure for regulations to control erosion at its source through controls on tree clearing and stock grazing densities to promote better vegetation cover,
- restricted land use options on sloping ground or vulnerable soil types, particularly where these impinge on urban water supplies or areas with reputed conservation value,
- pressure for industry and individual property certification for environmental soundness to allow access to certain domestic and export markets.

Issues of industry productivity include:

At the property level, erosion lowers soil and pasture productivity, increase input costs, damages farm water supplies and increase the risk of other problems

- soil loss, particularly small particles rich in nutrients and organic matter.
- diminished soil quality leading to reduced pasture productivity and inefficient pasture response to water and nutrient inputs.
- reduced livestock carrying capacity.
- input costs for fertiliser and soil conditioners to replace nutrients and organic matter.
- sedimentation of streams, lakes, farm dams, public dams diminishing life and value of infrastructure
- reduced water quality for use by livestock or other farm uses, including the effects of algal blooms.

Suggested industry responses
These are essentially the same as those made for erosion of soil by wind in Chapter 8. As in that case, sustainable grazing management offers "win/win" opportunities for environmental and industry interests. Effective responses include:

Tree management is also an important tool for reducing water erosion

- tree management (clearing/planting) and grazing management to provide a suitable mosaic of vegetation cover that maximises biomass production and minimises susceptibility to water erosion is an outcome that will meet both environmental and industry needs. Noting that vegetation in a "horizontal" form in close association with the soil surface is relatively more effective than vegetation in a "vertical" form in controlling erosion of soil by water.

Better information is needed to improve tree management strategies at property and regional scales

- examination of where in Australia tree cover is required at regional and farm scales for environmental management purposes, eg windbreaks, water use, slope stabilisation and conservation of biodiversity would provide clear guidance on where further tree clearing could occur and where reafforestation on already cleared land may be required. This information is needed in order to formulate rational tree management plans.

Pasture management is the single most important factor in the livestock industry's response to water erosion risks

- in areas where trees are not required then pasture use for livestock can be considered. Grazing management to maintain good pasture cover ensures water erosion is minimised while ensuring rapid and efficient pasture response to water inputs. Management of senescence in pastures and encouragement of prostrate growth through rotational grazing offers opportunities for good pasture performance for livestock growth, minimises water loss through runoff, and encourages retention in vegetation and soil, preventing "leakage" of water to subsoil. Other strategies for management of pasture senescence and composition (eg woody weeds) involving fodder conservation, slashing or burning need to be assessed in the light of their contribution to sustainable pasture management.

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Chapter 10. Weeds

Introduction

The livestock industry depends on plant communities for productive pastures and the maintenance of ecosystem function. Disruption of these by weeds, pests or disease could have wide reaching impacts on the livestock industry.

A high proportion of Australia's plants has developed in isolation and are vulnerable to introduced and invasive species

Australia's long isolation has assisted in the development of a high degree of endemism in populations of organisms, and this has made many species and whole ecosystems vulnerable to incursions by exotics. Introduction of new organisms into the Australian environment always carries the possibility that they will emerge as a pest. There are few ways of accurately predicting the behaviour of an exotic organism in Australia due to the often unique nature of the Australian environment.

The rate of invasion varies, but is usually initiated by a disturbance to the native ecosystem

Some invading species will produce almost immediate impacts, others may produce little impact until the right conditions for multiplication and transmission occur. "Invasion windows" are usually due to a disturbance in the ecosystem such as unusual seasons, reduction in competition from natives due to disease or pest attack, changed grazing or fire regimes, changes in the water or nutrient cycles, land clearing, and new transport patterns and infrastructure.

The course of invasions is hard to predict and more research is needed

Prediction of plant spread and potential distribution have relied heavily on computer models that combine knowledge of the invading species' biology with climatic and other environmental factors. Despite this, an overwhelming characteristic of the problem of new weeds, pests and diseases is its unpredictability and the continuing emergence of new threats as environmental conditions and industry practices change.

Of about 30,000 exotic species in Australia, only a few have become serious weeds

It is estimated that there are about 30,000 exotic species of plant in Australia, over 2,500 of which have become naturalised. Exotics constitute about 15% of the total number of plant species in Australia (Groves 1986), though many of these are located in gardens and urban areas and do not occur widely in the environment. Perhaps 10% of all new introductions may become naturalised and an even smaller number may become serious weeds. In the past most attention has been given to weeds of agricultural significance but increasing attention is now also being given to weeds that have substantial impacts on non-agricultural ecosystems.

By far the largest proportion of serious weeds found in Australia were deliberately introduced for ornamental or agricultural use. However, undesirable or prohibited species may still enter the continent by many routes. These include:

- airborne in wind or carried by birds or other flying animals, particularly in northern Australia from the Indonesian archipelago;

The rate of spread of weeds depends on a combination of factors; these are well understood for only a few weeds

- shipborne (in ballast water, on hulls, in holds and packing) and in aeroplanes;
- on imported goods, and postal items including internet orders of seeds;
- as contaminants to another legal entry (eg; *Parthenium* weed in contaminated grain);
- with people, either legally as garden and agricultural species, or smuggled in.

Once plants have established in the environment their rate of spread is very variable, depending on mode of dispersal, competition from other plants, presence of natural pests, selection pressure from herbicides, climatic variation and availability of vectors (many of which may be human). Weed spread has been modelled for some weeds whose biology and life cycle are sufficiently well documented.

Effect of weeds on the grazing industry

By definition, weeds are plants that are not helpful to a particular enterprise. There are many pathways by which they cause loss to the grazing industry, including:

- competition with and replacement of more favoured or productive plants;
- alteration of agricultural ecosystem function eg water and nutrient cycling;

Weeds have widespread effects on the productivity of agricultural and pastoral systems

- prevention of access to other plant resources, at various scales, such as around thistles, over whole paddocks or broad landscapes;
- diminished value of products through vegetable fault in wool, grass seeds in carcases, or plant toxins and toxins produced by microorganisms infecting plants leaving residues in offal and carcases (BRS report to MRC, 1995);
- reduced mobility of animals through trauma or poisoning;
- direct mortalities and production losses through poisoning;
- control costs and lost opportunities.

The cost of weeds

Annual losses due to weeds have been estimated at $3.3 billion; a component being to the livestock industries

In the 1996 State of the Environment report, annual losses to agriculture, horticulture, and non-farmed areas, from weeds, quoted figures of Combellack (1989) of about $3.3 billion. These estimates computed the production foregone from weed competition, losses from weed contamination of food and fibre (a big problem in the wool industry), and direct costs of all methods of control, in which herbicides were the greatest part of components estimated. No estimate was made of the labour cost involved, which might well be the most substantial fraction of all. No new estimates of the total financial burden have been made since, and in the case of environmental costs, these would be hard to estimate, because biodiversity valuation does not have an agreed methodology.

Environmental weeds

Other than biodiversity, the effects of weeds on ecosystems are poorly understood

The extent to which weed populations affect ecosystem function and process is poorly understood. In contrast, the effects of weeds and other habitat changes (often associated with agriculture or other human activities) on biodiversity have been given much attention.

While biodiversity may be clearly threatened by exotic incursions of any type (including many crop and pasture species on which agriculture currently depends), it is not clear under what circumstances so-called 'weeds' exert deleterious effects on ecosystem function and processes. In some circumstances introduced species can also be beneficial for biodiversity, increasing the range of species present and filling poorly populated niches, providing diversity and robustness to ecosystems.

Weed research has been concentrated on agriculture, horticulture and forestry

Compared with the extensive research and knowledge on effective weed management systems in agriculture, horticulture and forestry, environmental weed research and management is less developed, often due to poorly identifiable economic benefits. The diversity of species and habitat types affected also militate against uniformly prescribed weed management options, which may be more applicable in less complex environments such as single species crops.

Weeds of grazing environments

Single species invasions are characteristic of northern Australia; multiple species of the south

In northern Australia, major weed invasions appear to be predominantly of a single species or type of weed spreading across large areas, whereas in southern Australia many infection sources exist and multi-species invasions tend to occur where conditions permit (Humphries et al 1991).

In northern Australia, large spreads of exotic woody species such as prickly acacia (*Acacia nilotica)*, parkinsonia *(Parkinsonia aculeata*), mesquite (*Prosopis juliflora*), mimosa (*Mimosa pigra)*, rubber vine *(Cryptostegia grandiflora)* and chinee apple *(Zizyphus Mauritiana)* have significantly altered the relatively open woodland stands that were present at the time of European settlement.

Many weeds are the first 'colonisers' of disturbed areas and they can exclude grazing over large areas

Leguminous shrubs, such as prickly acacia, parkinsonia and mesquite, are typical 'colonising' species which enter newly cleared or disturbed areas. Where canopy cover is removed and soil nitrogen is inherently low, as it is in many arid regions of Australia, such invaders have a long-term advantage. Leguminous shrubs have displaced native sclerophyll shrubs and increased soil nitrogen level to an extent where, after fire, annual exotic grasses invade. These significantly affect subsequent fire regimes, soil organic matter and nutrient levels and inhibit the ability of many specialised native species to re-establish. Their effect is to exclude grazing animals from large tracts of land. This may include riverbanks and other water sources which may be both agriculturally valuable and ecologically sensitive, and where disturbance and overgrazing by stock and native animals can have severe impacts.

Pastoralist, conservationist and community interests may become polarised

Introduced grasses regarded as valuable forage additions, such as buffel grass *(Cenchrus ciliaris),* ponded pasture grasses and pasture legumes such as *Stylosanthes* spp. have been introduced into many regions. The properties of vigorous growth and persistence in the northern environment that make them valuable pasture species have also raised questions of them posing a future threat to biodiversity in conservation areas. As alluded to above, it is not clear under what circumstances a threat to biodiversity might also become a threat to ecosystem function. Even with better knowledge in this area, differences in outlook between pastoral, conservation and wider community interests can be expected in the future.

Rangelands are susceptible to weed problems, including native species that are considered to be weeds

Studies in central Australia and the Western Division of NSW indicated that between 5% and 20% of the flowering plants of these regions are exotics (Grice, 2000). They are predominantly forbs (herbaceous annuals and perennials, including grasses) that have invaded areas between perennial native tussocks where grazing has removed the native forb cover. A proportion are 'declared' noxious weeds (a total of about 85 out of 520 exotics), but at least 50 indigenous species are also considered 'weeds' (such as broad-leaved hopbush, named in the *Western Lands Act 1901* as a woody weed). Some are toxic to livestock, some form dense stands that shade out understorey herbs and grasses or physically prevent access for grazing.

A problem in central Australia is presented by the Athel Pine, which in addition to blocking access to large tracts of land and river front (predominantly the Finke at this stage), also causes salt accumulation, adding to inhibition of understorey development. Rivers and floods appear to have precipitated its establishment and further spread. Other areas may also be at risk, such as the Gascoyne catchment and Riverina.

Several types of weed are now serious problems in high rainfall areas of the coasts and uplands and can have serious impacts on the industry

Higher rainfall areas of Australia have a variety of weeds, including thistles, silver grass, blackberry, gorse and lantana. The value of agriculture in these areas means that development of control programs has been under way for some time and effective integrated management systems for some weeds, such as scotch and nodding thistles, are emerging. In low fertility areas serrated tussock (*Nasella trichotoma*) outcompetes other grasses and presents a major problem. Other unpalatable perennial grasses such as African love grass may pose similar problems in areas denuded by drought or overgrazing.

The Weeds of National Significance project has documented current weed distribution, and estimated future encroachments based largely on climatic suitability.

Further information on these and other weeds can be found at the Weeds Australia website http://www.weeds.org.au which has extensive links to other weed websites in Australia and overseas, and at the CRC for Weed Management Systems.

http://www.waite.adelaide.edu.au/crcwms/

BRS has produced maps using data from the Weeds of National Significance Report

Spatial distribution and intensity of weed problems
The following figures have been developed in BRS using data from the Weeds of National Significance program to provide an overview of the nature and extent of regional weed problems. The 24 weeds of greatest national significance have been assessed by a method that is described in detail on the Weeds Australia website. The method takes into account invasiveness, impacts, potential for spread, and socioeconomic and environmental values.

Figure 10.1 shows how many of the 24 weed species of national significance (WONS) are present in any 50 km square area of Australia. This map has no indication of the intensity of the weed problem. The intensity of the weed problem is derived from a subjective weed density classification where low density = 1, medium density = 2 and high density = 3.

Figure 10.1 Number of weed species of national significance (WONS) present.

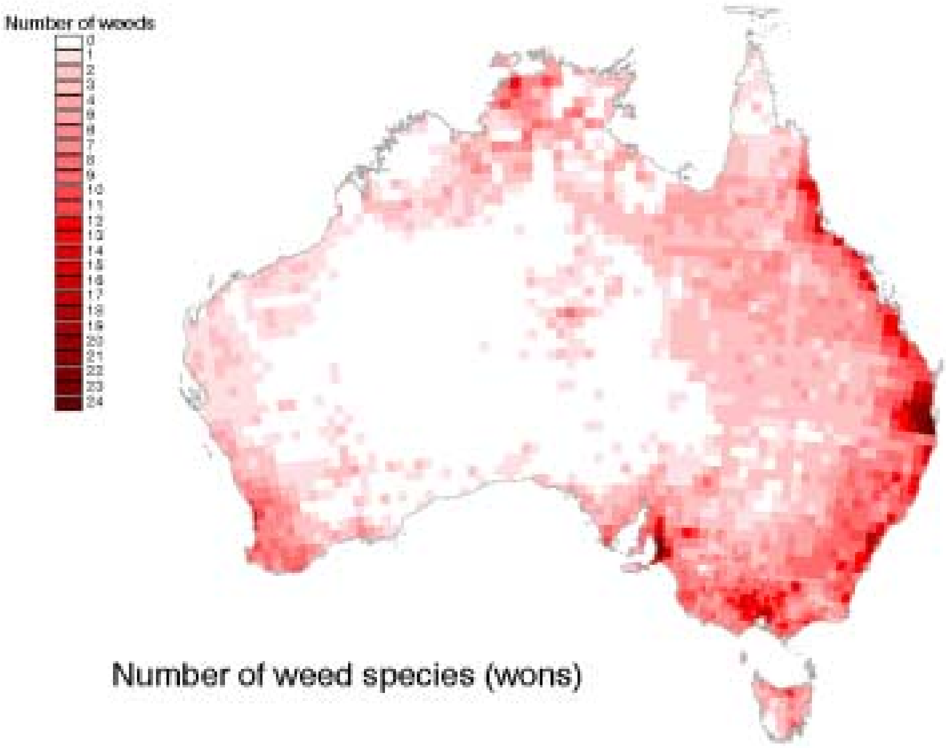


Figure 10.2 shows the average intensity of the weed problem present in any 50 km square area of Australia.

Figure 10.2 Average weed problem intensity.

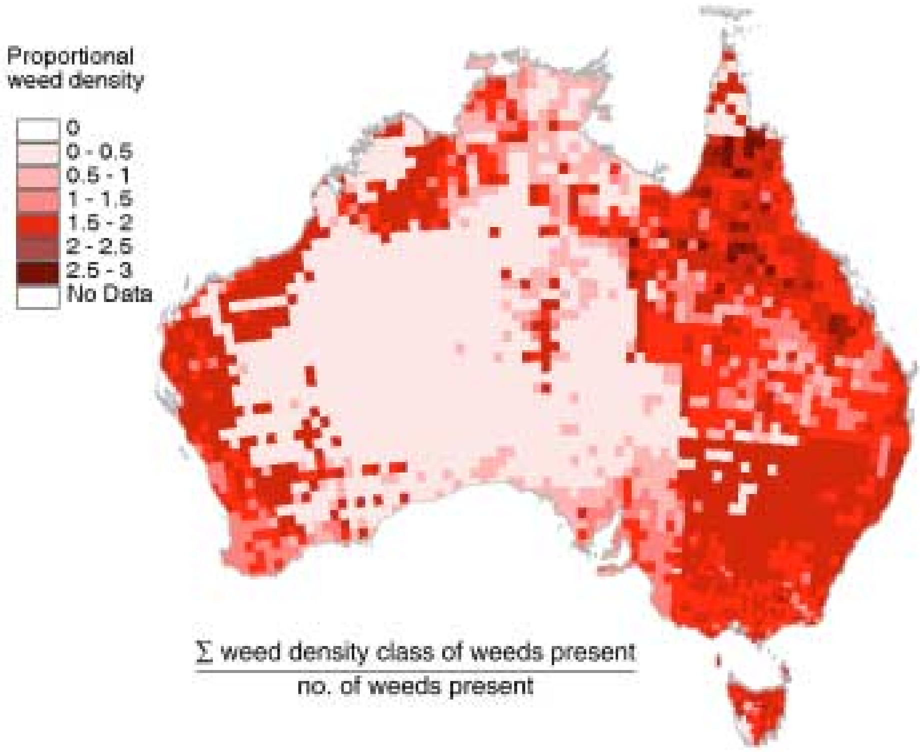
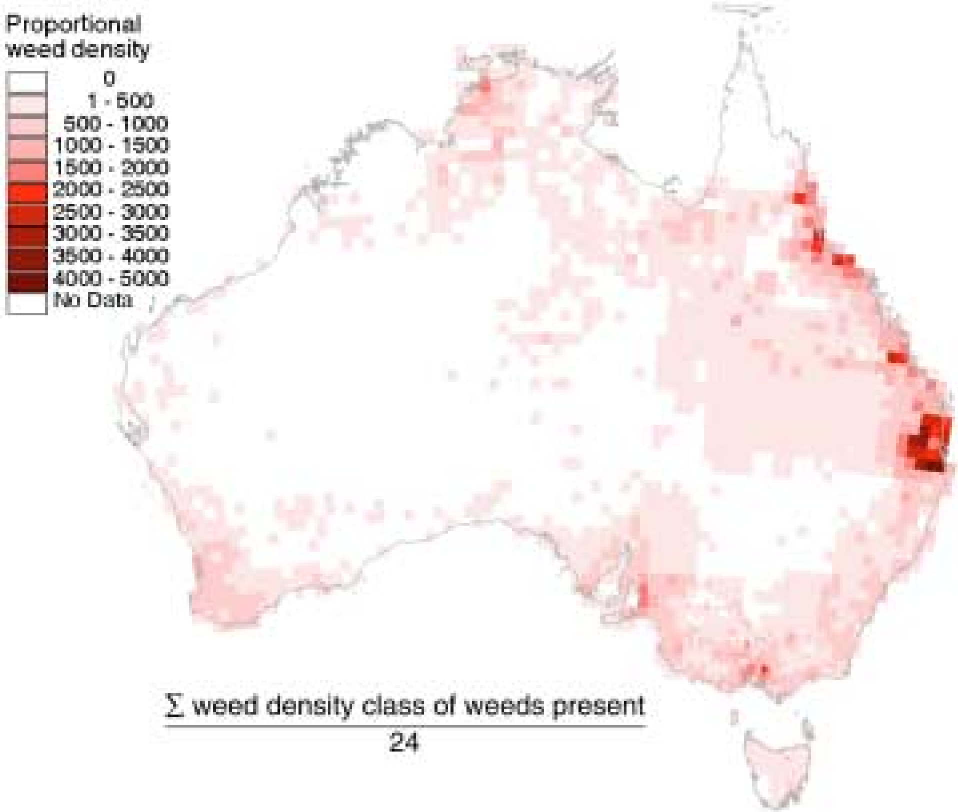


Figure 10.3 shows an index derived from the number of weed species present and their relative density. The highest index is achieved in areas which have many weed species present at high density, the lowest index is achieved in areas which have few weed species present and they are at low density.

Figure 10.3 Combined index of the number of weed species present and their relative density



A high index indicates a large number of the 24 weeds of national significance are present in the 50 km square area and have a high density in that area.

Industry responses to weeds

Strategies for control of weeds in sparsely settled areas need considerable development

In areas of extensive land use, such as pastoral rangelands, efforts to control weeds are severely limited by the immensity of the areas covered, the extremely small population available to tackle weed control and the low economic value of the land. Despite significant efforts to control weeds through quarantine barriers and use of cultivation and herbicides in farmlands, integrated weed management strategies for weeds of national significance in pastoral areas (including biological control), are relatively less developed.

Working with nature is more likely than eradication to succeed in weed control

Viable control programs in extensive pastoral areas can be expected to be those that harness and manipulate ecosystem processes, rather than relying on large scale direct remedial action with high levels of labour and material inputs. Development of sympathetic grazing management, introduction of appropriate species to out-compete weeds, and use of other biological controls can be expected to be major elements of ecosystem manipulation.

Industry practices that can be considered to contribute to weed incursions are:

Some industry practices contribute to weed invasions

- overgrazing with consequent establishment of degraded plant communities in which new plants (weeds) can establish;
- disturbance by trampling in heavy traffic areas, such as water sources, riverbanks, bore drains, shade and preferred pasture sites, allowing weed establishment and spread;
- disruption of fuel build-up and fire regimes that have led to altered plant community composition;
- direct transport of weeds and seeds by stock and vehicles;
- introduction of new species and practices.

Industry responses to prevent further weed incursions will involve implementation of effective grazing management systems that avoid these problems. Key measures can be expected to include:

A number of key measures could be used to reinforce the benefits of effective grazing management

- control of grazing pressure on land to avoid overgrazing and subsequent damage to pastures;
- investment in fencing for stock control to assist regulation of grazing pressure, prevent trampling of plants and soil in sensitive areas such as riverbanks and watering points, and to control movement of stock from infected to clean pastures;
- assessment of available biomass to regulate grazing intensity, monitor fuel build-up and manage use of fire to manipulate plant community composition;
- bore capping and piping to control water flows and access to water, ensuring stock and feral animals are rotated around available pasture rather than allowing overgrazing to occur;
- enclosure of bore drains to prevent weed establishment along drains and further spread by livestock and other animals;
- careful selection of new plant varieties introduced into pastoral environments to avoid future weed problems.

Retiring land from grazing is an option when the costs of weed control exceed the benefits

Where the costs of these management inputs exceed the returns from agriculture the option of retiring land from agriculture should be investigated, along with estimates of accompanying social and environmental consequences. Exclusion of stock from sensitive ecological zones, such as riverbanks, dams, springs, bores and bore drains can have both ecological and production benefits through reduced mustering and other management costs, improved feral animal control, preservation of productive ecosystems, and benefits in the market place with credentials of being ecologically sustainable.

Fire as a management tool

Fire and grazing can combine to ameliorate or, equally, to exacerbate weed problems and good burning strategies are needed in pasture management

Prescribed burning has been established for some time as an ecologically viable method for shrub and woody weed control (Hodgkinson and Harrington, 1985). Shrub invasion is encouraged where grazing reduces biomass below a critical point, and subsequent pasture production can also be reduced (Harrington et al 1984). For burning to be successful there needs to be sufficient fuel build up, which often necessitates reduced stocking rates. A further period of reduced carrying capacity after the burn is required while vegetation cover is restored. There are, therefore, long-term advantages that can be gained but short-term disadvantage that must be borne. Prescribed burning is likely to be the most economically viable option for woody weed control (MacLeod and Johnson 1990) though interactions of fire and other tools such as herbicides may emerge as options. Optimizing the benefits of burning is a necessary part of developing a strategy for use of fire in pasture management.

Research and data collection are needed to improve understanding of the long term effects of fire as a management tool

Development of benchmarks for maintaining existing land resources and preventing further weed incursions are needed, as are benchmarks that point to appropriate times to burn that will optimise long-term changes to vegetation cover relative to the short term costs of burning. It is possible that over-use of fire may also contribute to long-term problems through interference with nutrient and organic matter cycling. However, good regional data that could contribute to benchmarking in this area are difficult to find.

There is more information available about the effects of fire on biodiversity. The frequency and intensity of fires need to fall within certain bounds to allow plants to achieve maturity and set seed, and sometimes to activate seed to germinate (Benson 1985, Benson 1991). Again we find that there are data that relate to conservation of biodiversity, but little information that relates to the more complex issues of ecosystem function, on which agriculture depends, and of which biodiversity is a part.

Future threats

Australia faces threats from the entry of new weeds, and the emergence of major weeds from the exotics already in the country.

Exotics

Quarantine authorities recognise a number of new weed invasion risks

As an island continent Australia is protected from some of the most devastating pests and diseases that have affected other regions, but there are many animal and plant diseases and pests that are of concern to the Australian Quarantine Inspection Service (AQIS).

Given the importance of tree cover – including trees in pastoral systems – threats to tree species must be recognised

One recently identified potential risk is that posed by the myrtaceous rust sometimes known as 'guava rust' (*Puccinia psidii).* This fungal disease has the capacity to attack many species from the myrtle family in South America, including the exotic eucalypts introduced into that continent such as *Eucalyptus grandis* (flooded gum, a favoured tropical plantation crop) and *E. globulus* (Tasmanian blue gum). The rust appears to be able to attack many eucalypt and other myrtaceous species, and would pose an enormous threat to Australia's native eucalypt-dominated forests and woodlands if it were ever to arrive and establish.

The proximity of Australia to the Indonesian archipelago and threats from direct incursions of a wide range of tropical insects, microbes and weeds has been of particular concern to quarantine, plant and animal health officers. A recent example of an incursion that has literally 'blown in' is sugarcane smut.

Potential invasive species, including weeds, are identified on the AQIS website

A summary of the target insects, crops and associated pathogens, and animal pests and diseases that are considered to be the most likely threats to enter via Australia's northern border are given on the AQIS web site http://www.aqis.gov.au/docs/policy/naqstarg.htm. Many of the serious weed threats are environmental weeds of wet areas, such as wetlands, waterways and lakes, that are associated with rice cultivation in south east Asia.

Sleeper weeds

Areas of new development in the north may be more prone to new weed invasions than the longer established south

While there are undoubtedly sleeper weeds waiting to emerge in southern Australia, agriculture there has been established longer than in the north of the country and environmental changes are occurring at a relatively slower rate. A rapidly evolving agricultural sector and the tropical environment of the north suggest a more dynamic situation exists there, with a correspondingly higher chance of a serious problem emerging. The north is also more vulnerable due to the extensive nature of agriculture and settlement, that suggests longer times to detect problems, and smaller economic resources to apply to control measures.

Product quality issues

Grazing management is addressing problems of plant and microbial toxins but more research is needed

Plant and microbial toxins are of potential concern to the meat industry in two areas. The first relates to impacts on production. At present grazing management is a satisfactory way to prevent contamination until improved plant control methods are available. In some instances this will be through accepted methods of weed control, but in others, where plants are natives (e.g. fluoroacetate containing plants of Western Australia) there may be few effective and acceptable methods of control.

The second and major risk to the industry relates to changes in acceptable residue levels in meat and offal that would increase the chance of exceeding permissible concentrations and result in rejection of product. These changes in level may arise from new understandings of the effects of toxins, or from public pressure arising from publicised incidents of animal or human health problems arising from toxins. Good management and surveillance to avoid such incidents seem a prudent approach for the industry (BRS Report to MRC, 1995).

Other residue issues arise from use of offal and from heavy metal contaminated superphosphate

A similar type of threat concerning **heavy metal residues** exists and it is convenient to mention it under the same heading as plant toxins as similar issues arise. Cadmium is the greatest threat and uptake of cadmium by certain plants fertilised with contaminated superphosphate provides the commonest pathway to contaminated offal. Grazing management and surveillance of offal are effective in containing the problem but a change in acceptable residue levels could expose Australian product to increased risk of violations. A similar approach to that suggested for plant toxin control seems the best approach at present (BRS Report to MRC, 1995).

Community perceptions

In the minds of many in the community, grazing activities are associated with a number of unfavourable disturbances to natural ecosystems. These include:

Community perceptions are attributing the livestock industry as the cause of many environmental problems

- land clearing;
- loss of habitat;
- reduction in biodiversity;
- introduction of new plant species;
- disturbance of fire regimes;
- disturbance of existing plant communities allowing new plants to establish eg through trampling and overgrazing; and
- disruption of ecosystem functions eg through loss of deep rooted vegetation.

Community and export market concerns increase pressure for direct government involvement and control by regulation

Community concern in Australia and our export markets, can lead to a range of problems for the industry, ranging from disenchantment with meat products and declining market demand, to pressure for direct intervention by government to prevent activities regarded as destructive to the environment and unsustainable. What form this intervention may take is open to speculation, but it would seem unlikely that public resources will be available on a large scale to overcome problems that affect efficiency of production. Regulation could be used to ensure that private industry capital is used to meet “acceptable” operating standards and environmental outcomes. Public resources may be available to restore environmental values in sensitive areas, probably linked to exclusion of industry or industry operation under strict guidelines.

Enlightened management can counter many unfavourable perceptions of the livestock industry

Many of these perceptions can be countered by adoption of enlightened management which can avoid further damage and remediate many of the existing problems in the landscape. Some of the management options are referred to above and it is clearly an industry challenge to develop management systems that include these options and are sustainable economically and ecologically, and acceptable to the wider community.

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Chapter 11. Conclusions

The extensive changes made to landcover underlie many concerns about impacts on the environment by the livestock industries

The extensive changes made to landcover for development of agriculture and pastoralism underlie many concerns about impacts on the environment by the livestock industries. Most of the concerns about environmental impacts of land use arise from three main issues:

resource degradation "on site" that affects the sustainability and efficiency of production, such as declining soil structure, soil pH and fertility,

effects on biodiversity, especially from land clearing, in areas where conservationists claim there are inadequate conservation reserves, and

effects on air and water quality, including stream and dryland salinity, that extend "off site" and can have major regional impacts.

Biodiversity will continue to force the intensification of national efforts to combat soil and groundwater salinity and associated water quality problems

There is considerable interaction between these issues. For instance, where clearing continues, it seems inevitable that there will be sustained pressure for stronger controls that may extend to broadly applied restrictions. While environmentalists' concerns about loss of biodiversity will continue to be a driving force, the telling factor is likely to be the intensification of national efforts to combat soil and groundwater salinity and associated water quality problems.

Strategic planning by MLA may need to focus on the implications for livestock industries of national, regional and local response strategies, especially programs for revegetation designed to arrest or reverse the processes that drive the rise of water tables.

MLA will require access to information that will enable it to predict or assess the broad impacts on the industry to plan for change in land use and/or land management practices

To deal with this frontline environmental issue MLA will require access to information that will enable it to predict or assess the broad impacts on the industry that will develop over time as it implements requirements for change in land use and/or land management practices. (There will, of course, be a more intensive scale of data integration and analysis needed at the level of impacts on individual production units).

It is likely that many important assessments will have to be attempted, and decisions made, in the face of deficiencies in supporting information.

A high priority for MLA's strategic planning may need to be the collection, analysis and mapping of significantly better data on livestock numbers and distribution, the local and regional value of the industry and its ability to adapt to

requirements that may entail either intensification or destocking and revegetation.

This information will, for example, be extremely important for the industry as regional and local catchment management plans are developed under the Prime Minister's Salinity and Water Quality Action Plan.

While concern is founded in reality, the effects on biodiversity are not well enough known to support consistent industry responses to pressures to restrict land clearance or undertake revegetation

In individual chapters of this report, and again above, we have referred to concerns about loss of biodiversity that has occurred with the extensive change in landcover undertaken to support agricultural development – often initially for cropping but then for pasture or mixed cropping and pasture. While the concern is obviously founded in reality, the effects on biodiversity are not well enough known to support consistent industry responses to pressures to restrict land clearance or undertake revegetation. Nor is there good information on the links between biodiversity and ecosystem function, which is the major underlying issue. A further complication arises over greenhouse gas emissions associated with clearing and burning and, conversely, the assumed benefits of revegetation.

The critical issue for the industry will not be whether these responses are correct. It will be to determine where the desired responses can be carried out to achieve greenhouse and salt and water quality objectives with least adverse impact on the structure and function of livestock industries. (There is, of course, potential for the relatively intensive, consultative and cooperative catchment based planning approach to achieve positive structural change for the livestock industries).

The clear implication for MLA is the need to build the information base for decisions such as how much reallocation of resources, in particular what area(s) of land, will be needed to support the industry if it is to meet strategic production goals.

The evidence in the individual chapters shows that there would be a particular need to build this information base in Queensland. (It should be noted that the first task would be a thorough inventory of existing data and information including assessment of its availability, cost, suitability for integration with other data, gaps and priorities for additional collections, and the availability and competence of support services for information management and scientific analysis).

Australia's agreement to reach prescribed emission targets may take a regional focus and the MLA is likely to need information on the potential effect of regional pressures to reduce the size of animal populations

The report draws attention to the "sensitivity of greenhouse gas emissions from the livestock industries and its link to animal population size". Australia's agreement to reach prescribed emission targets may take a regional focus – ie there will be some pressure to concentrate activities in particular areas where the impact on greenhouse gas reduction is most effective. In response, MLA is likely to need information on the potential effect of regional pressures to reduce the size of animal populations on the overall viability of livestock industries (and the effectiveness of current land management practices, stocking rates etc).

The report also draws attention to how adoption rates influence the effectiveness of approaches aimed at reducing the livestock industries' contribution of greenhouse gases.

MLA is likely to need information that will support the achievement of adoption targets while causing minimal disturbance to the industry at a regional scale.

The MLA may need to address a significant need for social science research and public information resources

While the technical aspects of how to assess the greenhouse benefits of any measures may be researched through other programs and funding arrangements, MLA may need to address a significant need for social science research and public information resources. (Examples may include improved information on producers' understanding of the greenhouse issue and how to develop effective information packages and services to improve understanding and adoption).

Management of the quality of animal feeds is identified as a means to reduce per head emissions of greenhouse gases

A strategic spatial analysis of the links between biological, climatological and sociological factors is needed

Management of the quality of animal feeds is identified as a means to reduce per head emissions of greenhouse gases. We suggest that, while individual studies can deal with particular locations, sources and solutions, a more strategic approach would need to be based on a spatial analysis that considered where known approaches are likely to be most effective in combination with other measures and in relation to stocking densities etc. An integrated spatial analysis would explore the links between biological, climatological and sociological factors, especially the animal population, feed quality, seasonal effects and the existing and potential extent of adoption. Integrated analysis is equally important in rangeland areas where environmental issues are primarily related to biodiversity and soil considerations, and economic and climatic cycles or fluctuations have a compounding effect on environmental degradation.

The report notes that improvements in pasture production that yield increases in the storage of soil carbon are likely to be coupled with higher stocking densities. This clearly affects the value of these increases in terms of the balance between carbon sequestration and increases in emissions of methane and nitrous oxides. This is an example of how

MLA's strategic planning in response to environmental imperatives will need to recognise that a systematic approach will link the various measures such as pasture improvement, tree planting and controlled grazing intensity to maintain ground cover targets.

MLA needs to be able to establish and argue that the industry is addressing environmental goals

The objective for MLA should be the ability to establish and argue that the industry is addressing environmental goals through a complex mosaic of measures targeted to achieve a spatial pattern of multiple benefits while maintaining the profitability and sustainability of the industry. No single approach is likely to achieve environmental objectives without in at least some places having a detrimental effect on the industry.

MLA will need to improve the information base for understanding how to integrate approaches at regional and enterprise levels including an understanding of factors that support or hinder integrated management.

A review of how the industry has responded to and benefited from Integrated Catchment Management (ICM) may be a useful first step.

improved land management practices that have reduced the impact of wind erosion on a large scale and water erosion at more local scales

The report draws attention to the value of improved land management practices that have reduced the impact of wind erosion on a large scale and water erosion at more local scales. It is clear that wind erosion remains a high risk, especially because it impacts on soil fertility and organic matter. Local scale wind damage continues to be a significant contributor to environmental deterioration where grazing contributes to other causes of bare or sparsely vegetated soils. Adoption rates of conservative land management practices can be further improved.

Gully erosion and other impacts on streams represent a strategic environmental issue for the livestock industry

Gully erosion and other impacts on streams represent a strategic environmental issue for the livestock industry. The report refers to impacts in riparian zones through grazing, trampling and vegetation change, exacerbated by access to watering points and crossings. The strategic issue for MLA may be to avoid the need for radical change by sustaining a continual improvement in management that benefits riparian environments. This could avoid non-specific application of restrictions that limit essential access to water resources and/or disrupt established grazing regimes.

There is a heritage of soil loss from past clearing for both cropping and pasture uses

Maintenance of vegetative cover is the simplest and most effective way to reduce sheet erosion by water. There is, obviously, a heritage of soil loss from past clearing for both cropping and pasture uses. Soil movement under pasture systems is generally at a significantly lower rate than under cultivated croplands, but the impact varies according to the tillage method on one hand and the cover maintained under the actual stocking rate on the other.

The best option for response to environmental concern about widespread erosion (and consequent sedimentation and other off-site impacts) is obviously to maintain sufficient cover to protect the soil surface during highly erosive events. Continuing efforts will be required to develop effective early response to drought and to relate grazing pressure to the ability of land to recover.

MLA needs improved information on how to manage grazing, trampling, tree clearing and the use of fire to maintain suitable vegetative cover

Referring to the need to maintain suitable vegetative cover by managing grazing, trampling, tree clearing and the use of fire, the report points to the desirability of improving information on risks in ways that make it useful and available to the industry. One focus would be on the relationship between vulnerability of different soils as determined by their structural characteristics, the slope characteristics of the land, and climatic factors such as storm frequency and intensity. The report concludes that

"provision of datasets describing these elements of the environment at appropriate scales for on-farm use and coupled to expected impacts of certain land management regimes would provide good decision support for selection of suitable land use on-farm".

There may be considerable scope for improving the response to climate variability

While the report notes that climate is a major driver over which pastoralists have little control, there may be considerable scope for improving the response to climate variability given recent improvements in the ability to derive and supply relevant information on rainfall reliability. One of the clear information needs is for better predictions and intelligence on the onset of dry conditions.

MLA could encourage both the application of existing results and further modelling and research into pasture growth.

All responses by livestock industries to environmental issues must be conditioned by the need to improve understanding of the absolute limitations imposed by climate, the regional variability of limiting conditions and the distribution and rate of climate change.

The industry needs clear guidance on where further tree clearing could occur and where reafforestation on already cleared land may be required

As with other environmental issues, tree planting will continue to be promulgated as a solution. Because of the complexity of multiple objectives and the uncertainty about effectiveness of major tree planting programs, appropriate information will be needed at regional and farm scales. For environmental management purposes, it is assumed that information on tree cover (eg for windbreaks, water use, slope stabilisation and conservation of biodiversity) would provide clear guidance on where further tree clearing could occur and where reafforestation on already cleared land may be required.

Acidification can have serious impacts on the productivity of pastures and the growth of other plants, both through toxicity and through deterioration of soil structure and nutrient availability

Agricultural land use practices are the overwhelming cause of soil acidification with nitrate leaching under leguminous crops and pastures and fertilisation as major sources. Other contributors are the removal of organic anions in land clearing, hay and silage, and the removal of wool and meat products. The problem is greater in winter rainfall areas because leaching through the soil profile is related to the effectiveness of water use by plants in active growth stages. Acidification can have serious impacts on the productivity of pastures and the growth of other plants, both through toxicity and through deterioration of soil structure and nutrient availability. While acidification can generally be countered by the application of lime, this is not a trivial cost nor is it necessarily a simple task.

Response strategies for the livestock industry will need to be based on assessments of the balance between risk of soil acidification and the potential loss of productivity

Given the risk that soil acidification may increase in severity and distribution, response strategies for the livestock industry will need to be based on assessments of the balance between risk of acidification and the potential loss of productivity and the cost to counter or prevent acidification.

MLA research effort could focus on new, more effective and economically attractive adaptations to current pasture improvement and management regimes to control soil and soil

water pH through better control of water and nutrient fluxes.

Determining how to maintain acidification below the critical load determined at a scale relevant to soil and climate characteristics will not be a trivial task and attention will need to be given to identification of priority areas.

The main national effort to understand and counter soil and soil water problems is now focussed on salinity.

MLA should focus on "hooking into" current research initiatives in order to maximise their relevance and value to the industry.

The breadth and intensity of existing research and responsive programs suggests that MLA should focus on "hooking into" current initiatives in order to maximise their relevance and value to the livestock industry.

Obviously, land clearance control and major revegetation programs will increasingly impact on pastoralism and industry responses will need to be planned around assessments of suitability for pastures – especially deep rooted species – and tree growth.

An area of R&D that could have prompt beneficial impacts for the livestock industries is the provision of an information base to underpin the definition of regional and enterprise benchmarks for vegetation cover.

Responses to salinity will need to be based on understanding of its most critical impacts on likestock enterprises

Areas at high risk of salinisation include many that are highly important for the livestock industry. Responses will need to be based on an improved understanding of where salinisation will have its most critical impacts on livestock enterprises and on the structural arrangement of industry at local and regional scales.

The report notes that salinity effects on "beneficial water users" in lower parts of catchments may be "blamed" on graziers in the upstream catchment areas.

If intensification of the salinisation problem continues to follow predictions, MLA may need the results of targeted social research to respond effectively to public attitudes and to understand the attitudes of graziers and to determine how these attitudes can be influenced.

The industry will need to improve its capacity to respond rapidly and effectively to public pressure

Clearly, the industry will need to improve its capacity to respond rapidly and effectively to public pressure including pressures to change land management practices and to change land use in order to reduce or minimise salt exports to areas at high risk. Concentration will clearly need to be placed on obtaining a sufficiently detailed understanding of the land use and industry characteristics of the areas of highest concern.

Turning to the issue of soil structure decline, there seem to be grounds to suggest that this is a "sleeper" problem that will have an increasing impact on the livestock industry and, at least in Northern

Australia, can often be attributed to the industry.

MLA strategic planning could include a focus on review and extension of research into the effects of soil structure decline on productivity and erosion.

The potential for soil structure decline to exacerbate sedimentation and impair environmental values may require responsive strategies by the livestock industry

Soil structure decline is "often a slow and insidious process" and not enough is known about how land recovers from soil compaction or about the processes that inhibit recovery. The potential for soil structure decline to exacerbate sedimentation and impair environmental values may also develop as an issue requiring responsive strategies by the livestock industry. A strategic need for MLA could be to access a knowledge base on soil structure. Ideally, there would be an effort to develop indicators of soil compaction and structural decline to provide early warnings of problems. One example could be identification of associations between soil structure decline and invasions by woody weeds.

MLA could develop a compendium of information on possible strategies to address problems and threats of weed invasions

The report draws attention to "invasion windows" and the likely relationship between a change in environmental conditions and the onset of an outbreak of a problem weed. Similarly, a change in land management may be related to the increasing spread of a problem weed. Both sets of cause and effect may work together. In response, one line of inquiry for MLA could be to develop a compendium of information on possible strategies and their potential. This could be derived through comparison of management practices in areas that, though similar in landscape character, are different in the extent or severity of weed infestation. The analysis would need to cover issues such as resilience and the observed rate of recovery under similar treatments.

Better data will be needed for strategic planning based on assessment of the economic cost of weeds in pastures

While, as noted, the 1996 State of Environment Report included information on annual losses due to weeds, this information was based on 1989 data. More comprehensive and up-to-date data will be needed for strategic planning as the two prime causes noted above – change in environmental conditions (climate variability and change) and change in land management practices – increasingly impact on the livestock industries.

There will be a requirement for current and relevant information for assessment of the economic cost of weeds in pastures both in terms of impacts on productivity and profitability and in terms of rehabilitation and sustainability.

It is difficult to develop uniform approaches to weed management given the complexity of the environment of grazing lands

Parallel to the above, there is a need to improve understanding of how environmental objectives that focus on the control and removal of weeds – for example, for the protection and maintenance of biodiversity – could impact on grazing land management practices. This is especially important given the current difficulty in developing uniform approaches to weed management given the complexity of environment of grazing lands. (Uniform approaches may, in any event, be inappropriate). It can be suggested that MLA note the report's suggestion that

> **there is a need for the development of "benchmarks for maintaining existing land resources and preventing further weed incursions"**

and for basic information on some of the triggers for incursions such as the timing and conditions for use of fire in pasture development and land management.

The industry is a major user of Australia's water resources and has major impacts on them

The livestock industries are major users of Australia's water resources and have had major impacts water resources and landscape function across Australia.

> **Use by the livestock industries is estimated to be up to 45% of total water use in Australia (in the order of 9,000 GL/y).**

The water resource base will not limit the expansion of the industry but over-allocation has occurred in some areas

Utilisation for all purposes represents about 20% of the total divertible resource. This suggests that it is not the water resource base that will limit the expansion of the livestock industries. However the potential for further developments is not evenly distributed and over-allocation has occurred in some areas. Greater emphasis on environmental allocations and environmental impacts in the future is likely to slow the expansion of water allocation for the livestock industries.

> **The freeing up of water markets is likely to exert greater pressure for structural adjustment on the livestock industries. These pressures will continue to be greatest on enterprises where gross margins per megalitre are lowest, including the mixed irrigated farming enterprises.**

The major sources of water quality problems include farm fertiliser and pesticide applications that can often be attributed to stocking densities and high irrigation frequency, particularly in the dairy and beef industries

Water use by the livestock industries is dominantly from surface water resources. The surface water system is prone to contamination by nutrients and chemicals from a range of land uses. Poor water quality may be attributed to salinity, turbidity, heavy metals and bacterial contamination. Nutrients and turbidity are important surface water quality issues in many basins across Australia. Agriculture is usually the prime source of nutrients and pesticides. The major sources include farm fertiliser and pesticide applications that can often be attributed to the livestock industries. Major point sources are attributable to intensive rural industries including feedlots, grazing, dairying, abattoirs, dairy sheds, wool scours and butter or cheese factories. Any trend towards higher stocking densities and high irrigation frequency, particularly in the dairy and beef industries, is likely to increase the level of impacts on the environment.

> **If the industry is to maintain a clean and green image, the possibility of pesticide contamination should be eliminated.**

Because the livestock industry over the Great Artesian Basin almost exclusively comprises extensive sheep and cattle grazing, the water reticulation systems are widely distributed. These systems are old, and numerous artesian bores are allowed to run freely through corroded and unchecked bore headworks, with associated water distribution through inefficient bore drains.

Poor infrastructure and seepage losses and evaporation in bore drains has meant that in excess of 90% of water extracted has been wasted.

Industry practices have resulted in unsustainable groundwater water use and falling groundwater pressure is primarily a result of water extractions by the pastoral industry

Industry practices have resulted in unsustainable groundwater water use and depletion of the resource that can be seen in falling groundwater pressures over significant parts of the great Artesian Basin. Falling groundwater pressure is primarily a result of water extractions by the pastoral industry which uses about 90% of all water taken from the Basin. While this issue may not result in large production losses because of the large volume of water available it may be damaging to the industry to be associated with environmental degradation resulting from inefficient water use.

The livestock industries sometimes impact on groundwater dependent ecosystems. While these habitats are generally not widespread, they are often associated with endemic fauna and flora and have high conservation value. As more information becomes available the livestock industries should engage in management practices that more effectively conserve these areas.

Land salinisation and increases in river salinity are the biggest natural resource management issues facing the livestock industries

There is a considerable lag between the time that surface vegetation is changed and the time that salinity problems develop. This lag depends on the time that extra recharge takes to reach the watertable, and the hydraulic characteristics of the groundwater system that determine the rate of transmission of pressure changes and the rate of movement of groundwater to the surface in the lower parts of the landscape. Once salinity problems develop, re-introduction of deep-rooted species will not result in a fall in stream salinity. Land salinisation and increases in river salinity are the biggest natural resource management issue facing the livestock industries. Although land salinisation will result in direct economic loss to the industry, increases in water salinity will not directly affect productivity of extensive grazing areas.

A strategic approach to catchment management and salinity mitigation will be necessary if impacts on the livestock industries are to be minimised.

In summary, there are some key considerations that underpin environmental issues for the livestock industries. These include:

1. the current condition and trend of soil and vegetation resources and their capability to continue to support current use and the changes that will be made in the industry in response to economic and other conditions;

2. the absolute limits imposed by climate and the impact of increasing variability of limiting conditions and trends in climate change;

3. the inevitability of change in human resources, technological inputs and community attitudes and the ways in which these factors operate and support the livestock industries.

The key will be to find a balanced path between changes in environmental conditions and the industry's own inevitable impacts on the environment

The key will be how the livestock industries in general and individual enterprises in particular, find a balanced path between dependence on the environment, externally generated changes in environmental conditions and the industry's own impacts on the environment in the context of global economic futures and local socio-economic developments.

Inevitably, there will be local solutions to pervasive problems that will have industry-wide impacts. Similarly, there will be industry-wide pressures that will be expressed in local impacts that are likely to have widespread cumulative impacts.

MLA needs to determine what is valuable and necessary to keep, and what is counterproductive to the sustainability of the industry or the environment

MLA strategies will need to be able to determine what is valuable and necessary to keep, and be able to understand what is counterproductive to the sustainability of the industry or the environment and it must find effective procedures for change. This will involve a reassessment of old methods and technologies and careful appraisal of new technological applications, especially developments in biotechnology. The end result will need to be incremental advancement towards a better balance between land capability and land use, with the livestock industry being one of the critically important land