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National Land & Water Resources Audit

Rangelands 2008 — Taking the pulse

Australian Collaborative Rangelands Information System

Rangelands 2008 — Taking the pulse

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Abbreviations and acronyms

ABARE	Australian Bureau of Agriculture and Resource Economics
ABS	Australian Bureau of Statistics
ACLUMP	Australian Collaborative Land Use Mapping Program
ACRIS	Australian Collaborative Rangeland Information System
ACRIS-MC	ACRIS Management Committee
ACRIS-MU	ACRIS Management Unit
ALIS	Arid Lands Information System (SA)
ALUM	Australian Land Use Mapping
ARO	Australia's Resources Online
AussieGRASS	Australian Grassland and Rangeland Assessment by Spatial Simulation
AVHRR	Advanced Very High Resolution Radiometer
AWR 2005	Australian Water Resources 2005
BoM	Bureau of Meteorology
BRS	Bureau of Rural Sciences
CAPAD	Collaborative Australian Protected Areas Database
CAR	comprehensiveness, adequacy and representativeness
CRC	cooperative research centre
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DIWA	*Directory of Important Wetlands in Australia*
DNRETA	Department of Natural Resources, Environment and the Arts (NT)
DPI&F	Department of Primary Industries and Fisheries (Qld)
DSE	dry sheep equivalent
DSI	Dust Storm Index
EMU	Ecosystem Management Understanding (Project)
EPA	Environmental Protection Agency (Queensland)
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Cwth)
ERIN	Environmental Resources Information Network
GAB	Great Artesian Basin
GIS	geographic information system
GLM	Grazing Land Management (program)
GPS	global positioning system
IBRA	Interim Biogeographic Regionalisation for Australia
ILMO	Indigenous land management organisation
IPA	Indigenous Protected Area
IUCN	International Union for Conservation of Nature
MAT	management action target
MCA	multi-criteria analysis
MCAS-S	Multi-Criteria Analysis Shell for Spatial Decision Support
MODIS	moderate resolution imaging spectroradiometer
MRBGI	Multiple Regression Bare Ground Index
NAP	National Action Plan for Salinity and Water Quality
NDVI	Normalised Difference Vegetation Index
NGO	non-government organisation

NHT	Natural Heritage Trust
NLWRA	National Land & Water Resources Audit (the Audit)
National M&E Framework	National Monitoring and Evaluation Framework
NRM	natural resource management
NSW	New South Wales
NT	Northern Territory
NVIS	National Vegetation Information System
QDNRW	Department of Natural Resources and Water (Qld)
Qld	Queensland
RAP	Rangeland Assessment Program (NSW)
RCI	Resource Capture Index
RCT	resource condition target
RMDC	rapid mobile data collection
SA	South Australia
SLA	statistical local area
SLATS	State-wide Landcover and Trees Study (Qld)
TGP	total grazing pressure
TM (Landsat)	Thematic Mapper sensor on board the Landsat Earth Resources satellite
TSDM	total standing dry matter
Vic	Victoria
WA	Western Australia
WARMS	Western Australian Rangeland Monitoring System
WoNS	Weeds of National Significance

Executive summary

Major findings

This report, *Rangelands 2008 — Taking the Pulse*, is the first time that disparate datasets have been brought together at a national and regional scale to report change in Australia's rangelands. The rangelands cover some 81% of Australia and are popularly known as 'the outback'.

- Rainfall variability is one of the major drivers of change in the rangelands. Managing short-term (seasonal and yearly) variability within the context of longer-term climate change is a key challenge to ensuring sustained production and biodiversity conservation.
- Much of our current understanding of change in the rangelands derives from pastoral monitoring programs that report specifically on pastoral land management.
- Landscape function — a measure of the landscape's capacity to capture and retain rainfall and nutrients — increased or remained stable between 1992 and 2005 at a majority of pastoral monitoring sites.
- Historically, rangeland biodiversity has substantially declined, and there is no reason to believe that the decline has been arrested. Our ability to report change in biodiversity continues to be limited by inadequate data.
- Up to 40% of some tropical savanna bioregions burn each year. A national system for reporting the extent and frequency of fire is now in place.
- Eleven plant species have the capacity to permanently alter ecosystems across Australia's rangelands.
- Land values increased appreciably between 1992 and 2005 across most of the grazed rangelands — far more than could be accounted for by increases in real productivity.
- The Australian Collaborative Rangeland Information System (ACRIS) provides an excellent baseline for ongoing tracking of natural resource management in the rangelands.

The rangelands — popularly known as 'the outback' — cover 81% of Australia's land area (Figure 1). Revenue generated through mining (more than $12 billion annually), tourism (more than $2 billion annually) and agriculture ($2.4 billion in 2001) contributes significantly to Australia's economy. The rangelands are relatively intact ecosystems and contain important components of Australia's biodiversity. Additionally, they are home to many Indigenous people and have important cultural value for most Australians.

Figure 1 Extent of the rangelands and major population centres in Australia

Source: NLWRA, 2007

There are many natural resource management challenges in the rangelands. Historical declines in biodiversity may be continuing under current land management practices. Dry years are normal, making it difficult to distinguish the effects of inappropriate grazing practices from the effects of drought. Other pressures include inappropriate fire regimes, weeds, grazing by kangaroos and feral animals, and water extractions and diversions.

Governments' task is to balance economic and social needs with the maintenance of productive land resources and the conservation of biodiversity. Regional investment priorities, national, state and Northern Territory (NT) legislation, and international conventions and strategies all guide the use and management of different parts of the rangelands. The effectiveness of these various policies and investment strategies can only be judged by access to information such as ACRIS is providing.

Policies, programs, and on-ground management of natural resources should all be based on the best available data. ACRIS — a partnership between government organisations responsible for rangeland management — is a coordinating mechanism for collating and synthesising information. This report is the first time that disparate datasets (from 1992 to 2005) have been brought together to present integrated results at a national and regional scale for policymakers and managers.

Rangeland environments

The rangelands encompass tropical woodlands and savannas in the far north; vast treeless grassy plains (downs country) across the mid-north; hummock grasslands (spinifex), mulga woodlands and shrublands through the mid-latitudes; and saltbush and bluebush shrublands that fringe the agricultural areas and Great Australian Bight in the south. Across this gradient, seasonal rainfall changes from summer-dominant (monsoonal) in the north to winter-dominant in the south. Soils are characteristically infertile. Great climate variability and the dominating influence of short growing seasons distinctly characterise rangeland environments.

Interpreting the data

The Natural Resource Management Ministerial Council tasked the ACRIS Management Committee with exploring Australia's capacity to identify, explain and forecast the impacts of environmental, economic and social change in the rangelands. The committee's report, synthesised from jurisdictional pastoral monitoring data and other national sources, presents findings for a number of information types grouped by theme (Table 1).

In reporting on change in the rangelands, data have generally been aggregated to regions or subregions from the Interim Biogeographic Regionalisation for Australia (IBRA). A bioregion is a large, geographically distinct area of land and/or water that has assemblages of ecosystems forming recognisable patterns within the landscape. In addition, some socioeconomic data, such as that of the Australian Bureau of Statistics, are aggregated into statistical local areas (SLAs).

Several aspects of data availability and suitability were identified that, if improved, should lead to more comprehensive and confident reporting in future (see 'Issues in reporting' box).

Table 1 Information types, grouped by theme, used by ACRIS to report change in the Australian rangelands between 1992 and 2005

Theme	Information type
Climate variability	■ seasonal quality as context for interpreting change
Landscape function	■ landscape function (the capacity of landscapes to capture and retain rainwater and soilborne nutrients for plant growth)
Sustainable management	■ critical stock forage ■ pastoral plant species richness ■ distance from stock water ■ invasive weeds
Total grazing pressure	■ domestic stocking density ■ kangaroo density ■ feral animals
Fire and dust	■ fire regime ■ atmospheric dust (Dust Storm Index)
Water resources	■ information sources for water availability and sustainability
Biodiversity	■ protected areas ■ number and status of threatened species/communities ■ habitat loss by clearing ■ effects of stock waterpoints on biota ■ fauna and flora records/surveys ■ 'transformer' weeds ■ condition of wetlands ■ habitat condition ■ bird population composition
Socioeconomic	■ socioeconomic profiles ■ value of non-pastoral products in the rangelands ■ land use and pastoral land values

Key issues and findings

Climate variability and management influences

'*Seasonal quality*' describes the relative value of recent rainfall for vegetation growth and is used to help distinguish the impacts of climate variability from those of grazing management and fire. The term is italicised throughout this report to emphasise its use for indicating the effects of recent climate.

→ Findings

Seasonal quality between the early 1990s and 2005 was generally above average in the north and northwest, variable in much of central Australia, initially above average in most of the Western Australia (WA) and South Australia(SA) shrublands followed by drier-than-average conditions, and below average followed by drought conditions in the eastern grasslands and mulga lands.

→ Management implications

Pastoralists and other land managers are likely to face increased rainfall intensity and cyclone incidence across the north, and decreased rainfall and changing seasonal patterns across southern and southeastern regions. Increased atmospheric carbon dioxide may enhance photosynthesis, partly offsetting the expected reduction in plant growth in areas of decreased rainfall.

Landscape function and grazing pressure

'Landscape function' — a measure of the landscape's capacity to capture rainfall and nutrients — provides an assessment of landscape condition and resilience, including cover of perennial plants.

'Critical stock forage', which can be reported using a subset of the data used for landscape function, comprises perennial forage species known to decrease with excessive grazing (typically, palatable perennial grasses in the north and centre, and palatable chenopod shrubs in the south).

Grazing by livestock (cattle and sheep), feral herbivores (goats, donkeys, horses, camels) and kangaroos affects landscape function and critical stock forage, particularly when total grazing pressure remains high in years of lower *seasonal quality*.

→ Findings

Results are based on monitoring programs that provide information about pastoral land management, not ecological sustainability.

Data from the majority of monitoring sites in 26 bioregions in WA, SA, New South Wales (NSW) and the NT suggest an increase or stability in landscape function, given the trends in *seasonal quality* and known stocking densities from 1992 to 2005. Baseline condition is unknown and a 'no change' (stable) result may not be favourable for sites in degraded landscapes (ie increased landscape function is a more desirable outcome in such cases). Reported change applies to the local area of monitoring sites, not the whole of each bioregion.

In Queensland, five bioregions showed seasonally adjusted stability or increase in landscape function from road-traverse data. Six bioregions had decreased landscape function.

Critical stock forage has remained stable or improved at the majority of sites in 28 bioregions with suitable data for reporting, despite periods of low *seasonal quality* and variable stocking density. As for landscape function, baseline condition is unknown and stability may be an unfavourable result for sites in degraded landscapes.

In some pastorally important bioregions, recent stocking density has remained high as *seasonal quality* has deteriorated.

Kangaroos contribute between 20% and 40% of the livestock grazing pressure in the southern and eastern rangelands. There is considerable year-to-year variation in the contribution of kangaroos to total grazing pressure relative to livestock. Feral herbivores also contribute significantly to total grazing pressure in some areas. Their distributions across the rangelands are known reasonably well, but reliable data on regional densities are generally lacking.

→ Management implications

Without adequate knowledge of baseline condition and more extensive monitoring data, it is difficult to assess the impact of recent grazing management practices. While there is a view that management practices are benign, that assessment could be overoptimistic, particularly where 'no change' has occurred at sites in poor condition.

In some northern bioregions (eg the Pilbara), the buoyant live-shipper market into Southeast Asia has resulted in a considerable increase in cattle numbers during generally good seasons. In other areas, intensification through lease subdivision, development of grazing infrastructure and improved fire management have accompanied this expansion in cattle numbers (notably in the Sturt Plateau bioregion).

Future improvement (where possible) in landscape function and critical stock forage requires that pastoralists continue to make timely adjustments to total grazing pressure in line with variable *seasonal quality*. This imperative is increased with higher stocking densities under intensified production. The continued timely delivery of information to pastoralists and land management agencies about trends in landscape function and critical stock forage should assist appropriate future land management practices.

Biodiversity

Biodiversity is the variability among living organisms from all sources, and includes diversity within species and between species and diversity of ecosystems. Land clearing, wildfire and grazing have affected biodiversity in parts of the rangelands, but our ability to report change in biodiversity is limited due to inadequate data.

→ Findings

Historically, there have been substantial declines in rangeland biodiversity, and there is no reason to believe that they have ceased, given current land uses and time lags in biological responses. This assumption is backed by documented declines in the detection rates of some bird species in the rangelands by the Birds Australia volunteer network.

The Collaborative Australian Protected Areas Database (1997–2004) (CAPAD) documents significant changes in management intent for some areas, most notably in the Great Victoria Desert and Central Ranges bioregions of central Australia where Indigenous communities have agreed to manage very large areas of their land for biodiversity conservation.

The extent of woody cover has significantly decreased due to broadscale clearing in a limited number of bioregions on the eastern margin of the rangelands (Queensland and NSW). Case studies show that loss and fragmentation of habitats have affected several rangeland species.

In many pastorally productive regions, increased numbers of waterpoints have reduced the area of land remote from water. In some instances, water-remote areas can make a de facto contribution to biodiversity conservation, as lower total grazing pressures in those areas may provide refugia for biodiversity.

→ Management implications

The New Atlas of Australian Birds (Barrett et al 2003) provided valuable insights into change for approximately 60 bird species, but there were limitations in the more remote parts of the rangelands due to scarce data and high seasonal variability.

CAPAD allowed reporting of change in the extent of Indigenous protected areas, private protected areas and the National Reserve System. However, absence of data on the effectiveness of management (for instance, in weed and feral animal control) prevents quantification of improvements in biodiversity outcomes. A key challenge is to establish the capacity to manage those areas effectively for biodiversity conservation.

The most pastorally productive bioregions remain the most poorly represented within the National Reserve System.

Areas remote from water in pastoral country can contribute to biodiversity conservation, but their value diminishes where they occur as isolated patches and where weeds, feral animals and fire are inappropriately managed.

Fire regimes

High fire frequency and intensity, and large-scale fires, can damage rangelands, as can the absence of fire where it was once part of the ecosystem. A national system for reporting the extent and frequency of fire is in place and can now track changes in fire regimes.

→ Findings

Across northern Australia, up to 40% of some tropical savanna bioregions burn each year. Altered fire regimes are having significant impacts on components of the native flora and fauna.

→ Management implications

In areas such as the Sturt Plateau bioregion, communities are working with government to manage fire for improved production and conservation outcomes. Elsewhere, there are programs to re-establish Indigenous burning practices (eg the West Arnhem Land Fire Abatement Project).

In the semiarid eucalypt and acacia woodlands in the eastern rangelands and in the northern tropical savannas, reduced fire frequency affects the management of woody thickening, a significant issue for the pastoral industry in some regions.

Weeds

Weeds affect both production values and biodiversity conservation. Eleven plant species have been identified as 'transformer weeds' that permanently alter ecosystems and habitats. The transformer weeds include rubber vine, prickly acacia and four exotic grasses.

→ Findings

Despite an improved ability to map the distribution and abundance of some significant weeds, such data are absent or inadequate for many others.

→ Management implications

Inadequate data on changes in the distribution and abundance of important weed species make it difficult to quantify those species' effects on production and biodiversity conservation at a bioregion scale.

Some transformer weeds, such as buffel grass, can also provide an important economic resource to the pastoral industry. Addressing the lack of agreed protocols for the use of such species, and minimising their impacts on biodiversity values, remain significant challenges.

Land values

Socioeconomic data for the rangelands are difficult to extract from national statistical datasets, but changes in pastoral land values (which may reflect relative profitability, asset-to-income ratios and ability to service debt) have been reported. There are problems in comparing values derived by differing means in each jurisdiction, but these indicators reveal important long-term trends in the social and economic viability of pastoral land.

→ Findings

Land values have increased in the order of 150%–300% for many bioregions over part or all of the reporting period.

→ Management implications

Generally, increases in land values were far more than could be accounted for by increases in productivity (turn-off of meat and/or fibre). Increasing cattle prices during parts of the 1992–2005 period may have contributed to increased financial productivity over and above any gains in agricultural productivity, but this was not the case for the wool industry.

For established rangeland pastoral enterprises, the increase represents a substantial boost in asset wealth. However, those who have recently bought rangeland properties may be under greater pressure to maintain a return on equity, and hence to overstock.

The value of regional comparisons

Summaries for individual bioregions, and in some cases for broader regions where particular unifying themes are apparent, provide important insights, particularly in relation to varying management strategies and practices.

An example is the northern beef industry, for which recent good seasons have coincided with the rapidly developing demand for live cattle in easily accessible Asian markets and thereby dramatically improved economic prospects. This has resulted in significant enterprise intensification, including subdivision of leases, infrastructure development (additional waterpoints, fences and yards), and herd build-up, particularly in the Sturt Plateau and Pilbara bioregions. The economic opportunities provided by these developments have encouraged better herd and land management, including regional fire control programs. However, those successes may be threatened by a return to poorer seasonal conditions in the future; how management responds by adjusting stock numbers will test the sustainability of the industry.

Issues in reporting

In compiling *Rangelands 2008 — Taking the Pulse*, several issues related to data availability and suitability were identified.

- Existing jurisdictional monitoring systems cannot provide all the information required for comprehensive national reporting.
- Integrated programs for more effectively monitoring biodiversity and landscape function are required.
- The focus has been on reporting change, with less attention paid to quantifying baseline condition.
- Because site-based data collection is rarely statistically robust, it is not valid to infer that site data represent the whole of any region; improved reporting of some parameters will come from linking ground-based data collection with appropriate remote sensing.

Emerging information users

Given significant shifts in management responsibilities in the rangelands, Indigenous landowners, natural resource management (NRM) groups and the non-government environment sector are all potential clients for future information products from ACRIS.

Indigenous land managers

Indigenous people now have primary responsibility for managing 27% of the rangelands. ACRIS has a role in assisting that management, but there may be value in exploring specific additional Indigenous needs that ACRIS could satisfy. The scale of information needs for Indigenous organisations and commercial pastoralists is largely congruent at property to subregional scale, usually at a finer scale than ACRIS currently delivers.

Regional natural resource management groups

As regional NRM groups are responsible for implementing NRM programs to improve land management and biodiversity conservation, ACRIS can potentially help by providing contextual data at appropriate scales. For example, ACRIS data on recent *seasonal quality* and fire history (in northern Australia) and seasonally interpreted changes in landscape function and critical stock forage are useful for regional NRM planning. In return, data collected by NRM groups could assist ACRIS in reporting change at the regional scale. For example, property managers in the Northern Gulf Resource Management Group (north Queensland) are using global positioning system (GPS) units to record the locations of infrastructure, land types, weed infestations and pasture condition classes — information of value to ACRIS.

Non-government environment sector

The non-government environment sector acquired 25 rangeland properties (approximately 18 000 km^2) for biodiversity conservation in the 10 years to 2007. The Australian Wildlife Conservancy and Bush Heritage Australia are required to report to investors on the effectiveness of their management in meeting conservation objectives, and ACRIS may be able to assist by providing regional context. Sharing of data from non-government sources would also assist ACRIS with regional reporting of change, as demonstrated by the information on rangelands avifauna from volunteer members of Birds Australia. There is considerable potential for such 'citizen science' to contribute to the capacity of ACRIS to document environmental change.

ACRIS — maximising future value

This first attempt at bringing together disparate environmental, economic and social data to report changes in the rangelands has demonstrated that ACRIS can identify significant and emerging trends.

This success is largely due to the availability of long-term, consistent information sets, such as those provided through pastoral monitoring. Those datasets have allowed reporting on change in the environmental parameters being directly measured. When they are integrated with other datasets, such as kangaroo density and fire frequency, more robust interpretations of changes in resource condition and in biodiversity are enabled.

The existing monitoring programs are national assets for policy and program purposes. Their value would be even greater if they were expanded to sample the landscape comprehensively and if gaps such as biodiversity monitoring could be addressed.

As well as providing comprehensive reporting, ACRIS is a valuable forum for collaboration between agencies and across jurisdictional boundaries. The challenge now is to consolidate the lessons, skills and mechanisms developed through the production of this report into a permanent, dynamic information system. The goal of ACRIS is to enhance its ability to meet the information needs of those involved in the sustainable use, conservation and management of Australia's unique rangelands at bioregional to national scales.

Future monitoring requirements

Australia's rangelands are characterised by huge climatic variability and by a rich mix of diverse people, land uses and land management practices. The strength of *Rangelands 2008 – Taking the Pulse* lies in the report's documentation of changes over a relatively long period (1992–2005) and its identification of the major drivers of change and the extent of their contribution to those changes.

Although reporting at a national scale is useful for national policies and programs, reporting at a bioregional scale is equally useful in allowing cross-regional comparisons. As there is no 'one size fits all' response appropriate for managing the rangelands, given their size and variability, the ability of ACRIS to produce data and information at appropriate scales is a challenge for the future.

In some regions, stocking densities appear to be out of step with declining *seasonal quality*. There are also areas where total grazing pressure has increased due to kangaroos and feral herbivores, particularly goats. The ability of ACRIS to track trends in landscape function and critical stock forage for these 'at risk' regions would help us to assess whether risks are increasing or decreasing over time. The decreased extent of destructive late dry-season fires in some northern bioregions suggests that fire management is improving, although a longer period of monitoring is required for confirmation.

ACRIS provides an excellent baseline for ongoing tracking of NRM in the rangelands.

1 Introduction

Rangelands 2008 — Taking the Pulse has been compiled by the Management Committee of the Australian Collaborative Rangelands Information System (ACRIS-MC). The report is based on data that describe change in the Australian rangelands' natural resources. Most of the available data cover the period from 1992 to 2005.

The report's title derives from the dynamic but sometimes fragile nature of the rangelands, and the need to monitor the way this large part of Australia responds to human impacts. As medical staff take our pulse as a measure of our health, so we take the 'pulse' of the rangelands to determine how they are changing through time. The analogy is strengthened by viewing satellite images of vegetation growth over a 10–20 year period. The sequential images appear as a beating heart, as vegetation greens (grows) each summer in the monsoonal north, most winters in the south and irregularly in the arid interior.

Effective decision-making requires an understanding of those changes. This report aims to document change in resource condition in the rangelands by bringing together data (the quantities or numbers that represent change) and information (how we interpret those numbers) to test, for the first time, their capacity to present a national picture. The source of data and information is ACRIS.

Australia's rangelands

The rangelands are those areas where the rainfall is too low or unreliable and the soils too poor to support regular cropping. This definition covers about 81% of Australia and includes diverse savannas, woodlands, shrublands, grasslands and wetlands (Figures 1.1 and 1.2). For ACRIS reporting purposes, the rangelands are the vast areas of arid and semiarid Australia, including the monsoonal north (Figure 1.3). Areas of native pastures in temperate southern Australia, such as those in the higher ranges of New South Wales (NSW), the Australian Capital Territory, Victoria and Tasmania, are excluded from ACRIS reporting.

Figure 1.1 Mitchell grassland, central Australia

Photo: NT Department of Natural Resources, Environment and the Arts

Figure 1.2 Desert sand dune

Photo: Robert Ashdown

Extensive grazing on native pastures occurs across most of Australia's rangelands. Other uses include defence force training, activities managed or controlled by Indigenous people, national parks, mining, tourism and biodiversity conservation. A significant area of the rangelands used for extensive commercial grazing is state- or territory-owned public or Crown land, although there are significant areas of freehold in Queensland and NSW. Rangelands owned by the Crown are mostly leased for extensive grazing; however, the Crown reserves the right to change land use if economic and societal values change markedly.

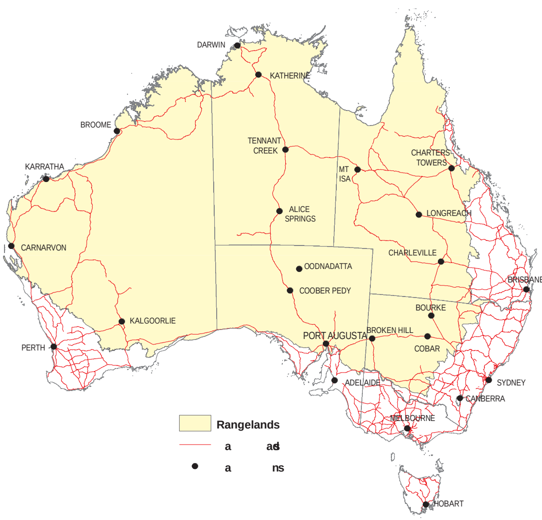
A defining characteristic of the rangelands is variability. Several major droughts and wet periods have occurred since the beginning of Australian pastoralism. Rainfall varies greatly from year to year, season to season and place to place.

This variability means that assessing change is particularly difficult: change can be slow to emerge and hard to detect, or it can occur so rapidly that institutional systems may be insufficiently prepared. Major changes to resource condition can be caused by the grazing pressure of domestic stock, kangaroos, and a wide variety of feral animals, including rabbits, goats, camels, horses and donkeys. Total grazing pressure from these animals is strongly influenced by the location of waterpoints in the landscape. Grazing near waterpoints can accelerate soil erosion and alter vegetation composition and structure, with ephemeral species typically replacing palatable perennial grasses and shrubs.

Fire is also a major driver of change in Australia's rangelands, but the size and incidence of fires are now markedly different from those before European settlement. Changed fire regimes can have both short- and long-term effects, with the latter including thickening of the perennial woody vegetation in woodlands, savannas and grasslands due to fire suppression. Woody thickening can affect both pastoral production and conservation values.

Similarly, exotic weed invasions pose a major threat to the ecology of Australia's rangelands, with significant costs from lost production and for weed control. Dingoes, foxes and feral cats are predators having major effects on native animal populations.

Figure 1.3 Extent of the rangelands



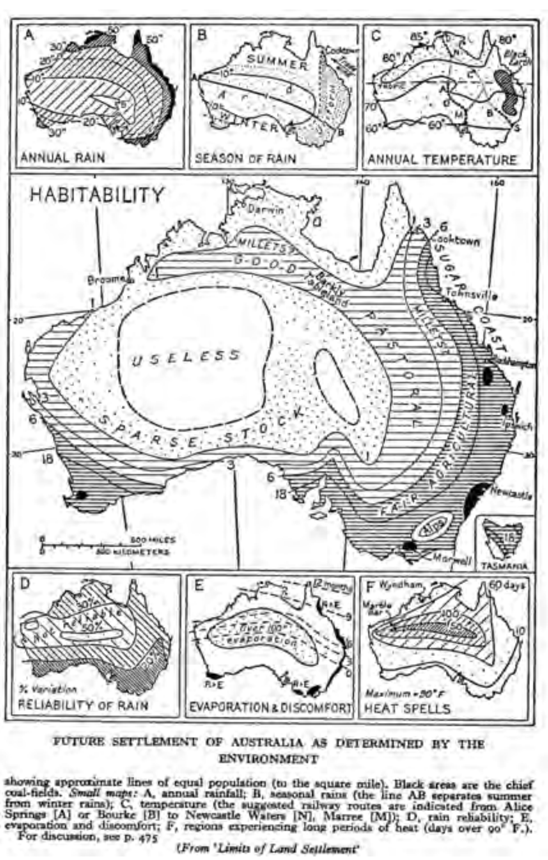
Source: NLWRA, 2007

Rangeland values

The rangelands provide substantial benefits to Australia, for example production of agricultural commodities, mineral extraction, the use of natural resources such as water for a range of purposes, and cultural values fundamental to Indigenous Australians. All these values are increasingly being recognised by the wider community. Historically, that was not the case — parts of the rangelands were considered useless (Figure 1.4).

The value of rangeland resources to society changes over time and varies between individuals and communities. For example, a particular plant species may be regarded as a pest from the perspective of biodiversity conservation, but may be seen as highly useful for economic production.

Figure 1.4 1947 map of Australia showing areas of rangeland considered useless



Source: Griffith Taylor (1947). Map accessible at http://www.austehc.unimelb.edu.au/fam/0003_image.html# (accessed 3 July 2007).

Biodiversity

Australia's rangelands comprise a great variety of habitats (Figure 1.5), which support a rich diversity of species and biotic communities. The rangelands have some of Australia's most intact ecosystems, and many are still relatively unmodified. However, some of those ecosystems are extremely vulnerable, particularly to grazing pressures, inappropriate fire management practices and exotic invasive species.

Figure 1.5 Mt Ilbillee, Everard Ranges, SA

Photo: Peter Canty, SA Department for Environment and Heritage

Australia's rangelands comprise a great variety of habitats. This example is of Mt Ilbillee in the Everard Ranges, far north South Australia (SA).

Economic

Much of Australia's mineral wealth, worth approximately $12 billion each year, is derived from the rangelands (Figure 1.6).[1] In addition, grazing of sheep and cattle ($1.8 billion in 2001) and other non-pastoral agriculture ($627 million in 2001; Chudleigh and Simpson 2004) are substantial sources of income. The rangelands present opportunities for 'clean and green' food and fibre, and for harvesting wild animal and plant products. Tourism in the rangelands generates a yearly revenue estimated to exceed $2 billion (NLWRA 2001a).

1 http://www.rangelands-australia.com.au/frameSet5_CurrentIssues.html (accessed 3 July 2007)

Figure 1.6 Mine shafts at Coober Pedy, SA

Photo: Allan Fox and the Department of the Environment, Water, Heritage and the Arts

Social and cultural heritage

Approximately 600 000 people live in the rangelands, including populations in centres such as Darwin, Alice Springs and Mount Isa (ABS 2001). The landscapes and cultural heritage of inland Australia have an intrinsic social value for all Australians. The rangelands provide a sense of place and identity for many Indigenous Australians.

Water resources

The rangelands rely on surface water in the large catchments or drainage basins (eg Lake Eyre Basin) together with artesian water sources such as the Great Artesian Basin (one of the world's largest underground potable water sources) and other subartesian aquifers. The rangelands also have major river systems, such as the Gascoyne River in Western Australia (WA), the Victoria River in the NT, the Burdekin River in Queensland, and the rivers of the Lake Eyre Basin (Figure 1.7) and parts of the Murray-Darling Basin in southeastern Australia. The episodic and ephemeral nature of such a vital resource makes water a key force defining land use and management.

Figure 1.7 Flooding rains, Windorah, western Queensland

Photo: Robert Ashdown

Carbon sequestration

Rangelands contribute to Australia's carbon account through the carbon in their soils and woody vegetation. Although carbon storage per unit of area is low, the extent of the rangelands means there is a significant total carbon store. Managing those carbon stores in relation to fire and vegetation clearing and thickening will present challenges in the future.

Information requirements

Baseline and trend information on change in environmental, social and economic indicators is essential to inform natural resource management (NRM) policy development and decision making, particularly when considering trade-offs between competing values. This information is required at a range of scales, from national to local.

Australian and state or territory governments

At the national, state and territory levels of government, information is required to support legislative and policy initiatives, for example to:

- underpin assessments of the status and trends in condition of a jurisdiction's resources at scales that allow broad priorities to be set and outcomes to be evaluated against those priorities
- evaluate regional plans in the context of partnership initiatives (eg the Natural Heritage Trust and the National Action Plan for Salinity and Water Quality) to ensure that the plans are robust and address priority issues in the region
- examine options for changed land use
- track progress in initiatives, their impacts and effectiveness in fostering change to meet objectives and targets
- monitor compliance with legislation
- meet regional, national and international reporting obligations (for example, the Australian Government is required to report to the United Nations Convention to Combat Desertification).

Regional organisations

Regional communities and organisations require data and information about the condition of their natural resources to:

- underpin community participation in preparing, implementing and evaluating NRM and property management plans
- improve awareness of landscape processes
- provide an understanding of the geographic distribution of key issues and their implications across a region
- track improvements in the condition of the environment and progress towards meeting targets and agreed outcomes in regional plans
- assess the effectiveness of land management strategies (including simulation models that explore the environmental impact of different management actions).

Local communities

Local communities require an improved understanding of their natural resources and the processes driving change to:

- develop improved NRM systems
- better quantify biophysical processes
- create improved landscape-management tools.

Australian Collaborative Rangeland Information System

ACRIS is a partnership between Australian Government organisations and those agencies in WA, SA, the NT, Queensland and New South Wales responsible for resource management and biodiversity conservation. The role of the state/territory agencies is to collect and interpret rangeland data and make them available to ACRIS. ACRIS also draws on data available from Australian Government sources, such as the Australian Bureau of Statistics. ACRIS facilitates data collation and documentation for reporting on regional and national changes in the rangelands.

Figure 1.8 ACRIS — a partnership between Australian, state and territory government agencies dealing with rangelands issues

The Australian Collaborative Rangelands Information System (ACRIS)

Data and information sources

Environmental
Economic
Social

National
Jurisdictional
Regional
Commissioned

ACRIS partners

Management Committee

Australian Government	State/NT Governments
DEWHA	Qld
DAFF	NSW
The Audit	SA
CSIRO	WA
DK-CRC	NT

Management Unit

Working Groups
Biodiversity
Socioeconomic
Indigenous

Reporting

Published reports through the Audit

Information available on the web

http://www.environment.gov.au/land/management/rangelands/acris/index.html

Potential future partners

NRM groups
Land councils

CSIRO = Commonwealth Scientific and Industrial Research Organisation; DAFF = Department of Agriculture, Fisheries and Forestry; DEWHA = Department of the Environment, Water, Heritage and the Arts; DK-CRC = Desert Knowledge Cooperative Research Centre; The Audit = National Land & Water Resources Audit

Themes are used as the framework for presenting data and information types in this report:

- climate variability
- landscape function
- sustainable management
- total grazing pressure
- fire regimes and dust generation
- water use and management
- biodiversity
- socioeconomic change.

ACRIS relies on state/territory agency partners to regularly update this information.

Ongoing challenges for ACRIS are to:

- foster long-term institutional commitments to rangeland monitoring
- promote monitoring activities that provide national and regional trend information and fill important gaps in data
- provide consistent information across all rangeland regions at appropriate scales
- maintain national databases and the capacity to interpret information against the background of long-term climatic variations and emerging policy and management issues.

ACRIS management

The ACRIS Management Committee (ACRIS-MC) oversees ACRIS (Figure 1.8), and includes representatives of the rangeland states and the Northern Territory, and the Australian Government (Department of the Environment, Water, Heritage and the Arts; Department of Agriculture, Fisheries and Forestry; National Land & Water Resources Audit; and Commonwealth Scientific and Industrial Research Organisation). The ACRIS-MC has convened working groups to assist in reporting on specific areas, such as biodiversity and socioeconomics.

As well as providing a forum for identifying and evaluating effective procedures for monitoring biodiversity, the Biodiversity Working Group has assisted in collating and interpreting available data reporting status and trend in biodiversity for this report. The primary role of the Socioeconomic Working Group is to facilitate the ongoing collection, collation, integration and management of socioeconomic information needed for NRM decision making in the rangelands. An informal Indigenous working group has helped ACRIS engage with groups providing NRM assistance to Indigenous communities.

Implementation and operation of ACRIS is coordinated through the ACRIS Management Unit (ACRIS-MU) located within the Desert Knowledge Cooperative Research Centre in Alice Springs. The role of the ACRIS-MU includes:

- collating various key regional and jurisdictional data
- conducting meta-analysis as appropriate
- interpreting results with respect to climate and other drivers of change
- reporting national syntheses of data.

The ACRIS-MU fulfils an important function in distributing suitably collated and analysed data to individual jurisdictions to assist interpretation of their data.

Building on the 2001 Rangelands report

Rangelands — Tracking Changes (NLWRA 2001a) provided an assessment of the information needed to report on change in the condition of the nation's rangelands. In 2005, the Natural Resource Policies and Programs Committee, an advisory committee to the NRM Standing Committee, agreed on the themes for a national report on change in the rangelands. The themes are climate variability, landscape function, sustainable management, total grazing pressure, biodiversity, management of water resources, and socioeconomics. *Rangelands 2008 — Taking the Pulse* builds on the identification of those needs and provides data and information for each of the identified themes (Table 1.1).

Rangelands 2008 — Taking the Pulse reports *change*, as distinct from *state*, in the Australian rangelands for the period from 1992 to 2005. It builds on *Rangelands — Tracking Changes*, with several new information types reported here (Table 1.1). For example, a number of maps in the earlier report documented the status of some indicators of rangeland condition, but few illustrated changes in condition.

This report is based on mostly unpublished data providing coverage from a regional to a national scale. This national synthesis is not, as is often the case, based on consensus of 'expert opinion' or literature reviews, which often have limited spatial or temporal relevance to the entire rangelands.

The information in *Rangelands 2008 — Taking the Pulse* provides the basis for the ongoing improvement of monitoring and reporting systems for Australia's rangelands.

Table 1.1 Information types reported in *Rangelands 2008 — Taking the Pulse*, compared with those in *Rangelands — Tracking Changes*

Reporting in *Rangelands 2008 — Taking the Pulse*	Reporting in *Rangelands — Tracking Changes*[a]
Theme: climate variability ■ *seasonal quality* as context for interpreting change	Impacts on biophysical resources ■ climate variability ■ predicting pasture availability ■ seasonal characteristics and influence on vegetation
Theme: landscape function ■ change in landscape function	Changes in biophysical resources ■ changes in landscape function
Theme: sustainable management ■ change in critical stock forage ■ change in pastoral plant species richness ■ distance from stock water ■ invasive weeds	Changes in biophysical resources ■ introduced plants and animals
Theme: total grazing pressure ■ change in domestic stocking density ■ change in kangaroo density ■ feral animals	Changes in biophysical resources ■ total grazing density ■ introduced plants and animals
Theme: fire and dust ■ change in fire regime ■ change in atmospheric dust (Dust Storm Index)	Changes in biophysical resources ■ fire
Theme: water resources ■ information sources for water availability and sustainability	Changes in biophysical resources ■ water availability and sustainability
Theme: biodiversity ■ change in protected areas ■ change in number and status of threatened species/communities ■ habitat loss by clearing ■ stock waterpoint effects on biota ■ fauna records and surveys ■ flora records and surveys ■ transformer weeds ■ wetlands: condition and change ■ habitat condition derived from remotely sensed groundcover ■ bird population composition	Changes in biophysical resources ■ changes in biological diversity ■ native vegetation clearing ■ supporting information (photo records)
Theme: socioeconomics ■ socioeconomic profiles ■ value of non-pastoral products in the rangelands ■ change in land use ■ change in pastoral land values	Socioeconomic information ■ land use and tenure ■ individual (land manager) attributes ■ business attributes ■ community attributes
Institutional responses ■ regional activity ■ Natural Heritage Trust investment	Institutional responses ■ institutional activity

a NLWRA (2001a)

Key questions

Rangelands 2008 — Taking the Pulse seeks to inform important policy and management-practice questions for the rangelands:

- Where are the ecologically significant regions?
- Where are the most economically productive areas?
- How do grazing systems affect the ecological health of rangeland environments and native biodiversity?
- Where are there strong or emerging tensions between pastoral production and the desire to conserve native flora and fauna?
- How do invasive species and fire impact on pastoral production and native flora and fauna?
- What are the constraints and opportunities for further development of grazing and agriculture?
- Where do grazing and agriculture face structural adjustment pressure?
- What are the demographic, social and economic trends in rural communities, and how do those trends affect the communities' capacity to achieve and manage structural adjustment?
- How can information on natural resources be managed to meet the requirements of Indigenous land managers and regional NRM groups?
- What are the impacts of climate variability and long-term climate change on productive capacities and conservation challenges?

Structure of the report

This report begins by addressing the defining characteristics and values of Australia's rangelands, and then presents information to assess change in rangeland characteristics and values. Results, and their integration across themes, comprise the major part of the report.

Chapter 1 Introduction

An overview of Australia's rangelands and ACRIS's role in assessing changes in resources

Chapter 2 Assessing change

Concepts and approaches in monitoring and assessing changes in rangelands

Chapter 3 Change in the rangelands

National results for each of the reported ACRIS themes

Chapter 4 Focus bioregions

Regional case studies highlighting specific issues in selected rangeland bioregions

Chapter 5 Emerging information needs

Emerging information needs and new stakeholders

Chapter 6 ACRIS — data into information

Integration and information management — using the system

Appendix Jurisdictional reporting

An update (since 2000) from each ACRIS partner on its ongoing rangelands information activities (see NLWRA 2001a for detail on jurisdictional monitoring programs)

2 Assessing change

This chapter describes how change is detected through monitoring activities, the reasons change occurs, and how we interpret change. An important issue in interpreting change is the reliability of the data available. The chapter also describes how Australian Collaborative Rangeland Information System (ACRIS) data are used to document change in Australia's rangelands by summarising available information into regions. It ends by briefly describing pastoral monitoring programs of the states and the Northern Territory (NT) that contribute data for reporting change.

Detecting change

Change is part of the natural world and can be detected by a number of methods — for example, by taking photos from a fixed position (Figure 2.1) or by taking complex quantitative measurements over time (Figure 2.2). If changes are detected, how do we interpret them?

The sequence of photos in Figure 2.1 illustrates some of the more spectacular vegetation change

Figure 2.1 Change in the Ord Victoria Plain bioregion, NT

April 1973

June 1978

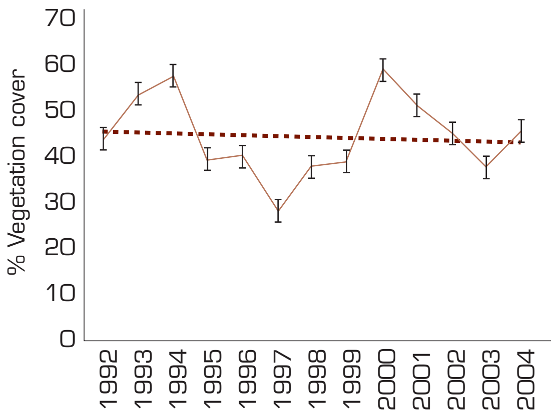
June 1989

June 2000

Sequence of photos from a fixed location at the Victoria River Research Station, 40 km north of Victoria River Downs Homestead and 220 km southwest of Katherine in the Northern Territory.

Photos: CSIRO, Alice Springs

Figure 2.2 Vegetation cover at monitoring sites in the NSW Murray-Darling Depression bioregion, 1992 to 2004



Means and standard errors for vegetation cover measured at 67 Rangeland Assessment Program monitoring sites in the NSW Murray-Darling Depression bioregion.

Source: Rangeland Assessment Program, NSW Department of Environment and Climate Change

in Australia's rangelands. In April 1973, immediately before the construction of a cattle-proof exclosure, extensive areas of bare soil were evident. By 1978, those areas had revegetated with grasses, forbs (also known as herbs) and the introduced shrub *Calotropis procera* (rubberbush). The rubberbush died out by 1989 and was replaced by native tree and shrub species. The native perennial black spear grass (*Heteropogon contortus*) progressively dominated the pasture from 1989 onwards. Why did these changes occur? Were the changes desirable?

A second example from a different location (Figure 2.2) shows that some of the year-to-year differences in mean cover were statistically significant. Were those differences part of a longer-term change or simply variations about a mean? A trend line fit to the data (dashed line) visually suggests a small decline from 1992 to 2004, but linear regression analysis reveals no significant trend.

These examples show that detecting change in Australia's rangelands presents challenges, not only in collecting and presenting data, but in interpreting and understanding the causes of change.

Drivers of change

Throughout most of the rangelands and for much of the time, rainfall is the principal driver of change. When it rains, how much falls and what follow-up occurs have a profound effect on vegetation and animal population responses. Recurring periods of higher rainfall also influence longer-term vegetation structure, for example by promoting woody thickening.

ACRIS uses the term *seasonal quality* to describe the relative value of recent rainfall for vegetation growth. Its application helps filter the impacts of climate variability from those of grazing management (see Box 2.1). Examples of its use are provided in Chapter 3. Where management effects have been reliably and clearly separated from seasonal effects, land managers can be encouraged to implement more appropriate resource management practices. Again, where there is clarity, it should be possible to adjust policy instruments to help achieve desired targets.

Fire can also influence long-term vegetation change. For example, across the semiarid savannas a decreased frequency or absence of fire shifts the balance from grasses to trees. In contrast, an increased frequency of fire has an adverse effect on biodiversity.

Grazing by domestic livestock and feral animals can also adversely affect vegetation and soils, particularly when total grazing pressure is high in times of drought. The challenge in analysing monitoring data is to separate grazing effects on change from those due to season, fire and other factors.

Box 2.1 Matrix: *seasonal quality* and direction of change

To assign causality to vegetation change, such as that measured by site-based pastoral monitoring data collected in Western Australia (Watson et al 2007a), ACRIS uses a 'quality of preceding seasons x direction of change' matrix, where ✔✔ indicates an increase although seasonal conditions were below average, and ✘✘ indicates decline when an increase or no change was expected because seasonal conditions were above average. *Seasonal quality* is based on the amount of rainfall in the growth season(s) prior to the monitoring period, compared with the long-term record.

Table 1 Information types, grouped by theme used by ACRIS to report change in the Australian rangelands between 1992 and 2005

	Change in reported attribute		
Seasonal quality	Decline	No change	Increase
Above average	✘✘	✘	—
Average	✘	—	✔
Below average	—	✘	✔✔

The usefulness of this matrix for interpreting change is increased if vegetation data are intentionally collected to enhance management effects and dampen seasonal effects. For example, by focusing on longer-lived perennial species, Watson et al (2007b) excluded ephemeral species that rapidly respond to temporary bursts of rainfall. Grazing effects, both positive and negative, were emphasised by reporting on changes in those species known to decline with prolonged heavy grazing. Other examples of interpreting change with respect to seasonal quality are provided in the 'Landscape function' and 'Sustainable management' sections in Chapter 3.

Interpreting change

There are three important components to interpreting change:

1. How much change is required for us to differentiate a trend (signal) from background variation (noise)?

   Sources of variation can include short-term climatic fluctuations, dynamic responses of biota to those fluctuations, and variations in the measurement of those responses. Statistically, variations in mean data are indicated by standard errors (standard deviations of the mean), for example in mean vegetation cover (Figure 2.2).

   Benchmark or reference areas, where available, can help indicate whether an area being assessed has changed from a relatively natural or undisturbed state (see Box 2.2).

2. Is the change good or bad?

   Detecting change and interpreting its value are two steps. Greater clarity is obtained if the process of detecting change is separated from judgments on the value of the change (Ludwig et al 1997). A single change can be seen from completely different perspectives by various end users, for example:

   - an increase in unpalatable perennial grasses may increase landscape function but reduce grazing value
   - the spread of exotic buffel grass — *Pennisetum ciliare* (syn. *Cenchrus ciliaris*) — may improve pastoral productivity but decrease biodiversity

Box 2.2 Reference areas

Reference areas are relatively undisturbed areas that help to benchmark the current status of an area being monitored. Reference areas close to the areas being assessed are the most useful because they experience similar climatic conditions and are more likely to have the same landscape characteristics (ie landform, soils, geomorphology) and fire histories.

In the absence of a suitable reference area, experienced assessors might develop notional (or virtual) benchmarks based on physical evidence from elsewhere and ecological knowledge of how landscapes change in response to various forms of disturbance (eg grazing, fire, altered hydrology due to evident erosion).

Care is required in selecting and managing reference areas, particularly where exclosures are built to protect the reference area from disturbance, in order to avoid artificial conditions that might generate spurious changes.

Reference area 1973

Assessment area 1973

Reference area 1989

Assessment area 1989

The reference area at top left is a guide for assessing the status of the disturbed area at top right. The two areas are in close proximity, have similar microtopography and soils, and experience the same rainfall. However, in 1973 the amount and composition of pasture were obviously vastly different. Ecological knowledge of change trajectories is also useful; for example, the top left reference area was understood to be in good condition in 1973, but by 1989 (bottom left) its vegetation composition and structure had changed considerably (as did that of the assessment area, lower right). See Foran et al (1985a) and Bastin et al (2003) for a more detailed description of change at these sites.

Photos: CSIRO, Alice Springs

- feral goats can add to damage caused by other grazing animals by increasing total grazing pressure but in some regions are a harvestable resource.

3. What caused the change? Was it entirely natural or did we, as humans, have an impact? Is it desirable? If not, what management responses are required to ameliorate that impact?

   Change is relative, and its magnitude needs to be interpreted with respect to what change is expected and what management response is appropriate for each rangeland setting.

   Change may require different management and policy responses in different regions. Wildfire, for example, is a natural part of the tropical savannas. If rainfall patterns were to change so that parts of the eastern rangelands potentially burned as extensively and frequently as rangelands in northern Australia, those areas would require

   - immediate and appropriate on-ground responses to manage increased fire risk
   - policy changes to prescribe what burning activities occur at different times of the year.

Sources of data on change

The preceding examples (Figures 2.1 and 2.2) demonstrate biophysical change — that is, change in the environment — but economic and social changes are also important to the wellbeing of Australia's rangelands. ACRIS uses a combination of available ecological, economic and social datasets to understand and report change.

The ACRIS datasets

Data have been drawn from state and NT pastoral monitoring programs, from nationally collected information and from other available sources.[2] State/territory agencies present monitoring data in different ways for their individual purposes. The ACRIS Management Unit collates those data, and the ACRIS Management Committee (ACRIS-MC) reports the findings under themes (Table 2.1).

[2] See the ACRIS website (http://www.environment.gov.au/land/publications/acris) for jurisdictional data and information contributing to this national synthesis.

Social and economic census data

The Australian Bureau of Statistics (ABS) provides social and economic information through the Census of Population and Housing and the Agricultural Census, both held every five years. In other years, the ABS uses smaller sample surveys of farm businesses to collect agricultural commodity data. These social and economic data provide important contextual information that can be used to support decision making in developing policies affecting the rangelands.

Social and economic data are also available from farm surveys conducted by the Australian Bureau of Agricultural and Resource Economics (ABARE). The surveys cover financial, physical and socioeconomic aspects and provide a broad range of information on the current and historical economic performance of farm business units. ABARE conducts the Australian Agricultural and Grazing Industries Survey annually. However, in most rangeland regions sample sizes are small, making it difficult to report reliably at the regional scale.

The Bureau of Rural Sciences (BRS) provides scientific analysis and information on the social consequences of policy decisions relating to agricultural industries. Surveys and research undertaken by BRS will contribute to future analyses in the rangelands.

Other datasets

ACRIS uses some additional national-scale datasets for reporting change in the rangelands (Table 2.2). The reliability of these datasets for reporting change or status is also indicated (see later in this chapter). Details of change are provided, where applicable, in the findings for each reported information type in Chapter 3.

Scale and resolution

The scale and resolution of available data are important issues in understanding change. For example, the data on vegetation cover changes in the Murray-Darling Depression bioregion (Figure 2.2) came from 67 monitoring sites spread across 79 060 km^2 (one site per 1180 km^2). Each site is 9 hectares, which represents the smallest unit of resolution. Together, the 67 sites provide a reasonable sampling density (compared with other regions where

Table 2.1 Datasets used to report change in Australia's rangelands

Theme	Information type	Datasets	Description
Landscape function	Landscape function	Agency monitoring of the pastoral estate in each rangeland jurisdiction	See Table 2.3 for brief descriptions of each monitoring program and Appendix 1 for further detail.
Sustainable management	Critical stock forage		
	Species richness (pastoral estate)		Data for selected species groups within the pastoral estate available for WA and NSW. See Table 2.3 for further detail.
	Distance from water	Mapped waterpoints	Jurisdictional mapping of waterpoints for pastoral leases in SA, WA and the southern NT. Supplemented by Geoscience Australia's database of waterpoints. Unable to report change. Waterpoint data are also used in the Biodiversity theme because distance from water affects many species.
	Weeds	Relative abundance in 0.5-degree grid cells	Relative abundance (absent; present; low, medium or high density) of nationally significant rangeland weeds. This information type reports status, not change.
Components of total grazing pressure	Domestic stocking density	Australian Bureau of Statistics (ABS) census and survey data concorded to bioregion	ABS conducts periodic surveys of domestic stock numbers via a complete Agricultural Census (every five years) and sample surveys in intervening years. Queensland Department of Natural Resources and Water (QDNRW) staff use those data in their AussieGRASS simulations of pasture growth. QDNRW concorded stock numbers from statistical local areas to Interim Biogeographic Regionalisation for Australia (IBRA) bioregions and sub-IBRAs and provided those data to ACRIS. Data available from 1983 to 2004.
	Kangaroo density	Aerial surveys in Qld, NSW and SA	Systematic aerial surveys. Data available for the period from 1984 to 2003. Analysis conducted by the University of Queensland (and others) and results made available to ACRIS.
	Feral ungulates	Relative abundance in 0.5-degree grid cells	Relative abundance (abundant, common, occasional, absent) of feral ungulates. This information type reports status, not change.
Fire and dust	Fire (extent, intensity and frequency)	WA Landgate fire-scar mapping	Monthly mapping of fire scars from National Oceanic and Atmospheric Administration (United States) Advanced Very High Resolution Radiometer satellite imagery. Data available for the entire rangelands between 1997 and 2005.
	Dust	Dust Storm Index produced by Griffith University	Time-integrated maps of atmospheric dust levels from Bureau of Meteorology records. Maps and spatially averaged Dust Storm Index (DSI_3) by bioregion available by calendar year (1992 to 2005) and time-integrated average for 1992–2005.
Biodiversity	Protected areas, with progress to CAR (comprehensive, adequate and representative)	Collaborative Australian Protected Areas Database (CAPAD)	As part of the Australian National Reserve System Program, biennial reports from relevant state and territory agencies to CAPAD on the size of protected areas within each IBRA bioregion. The 2006 update of CAPAD is progressing, with completion late in 2007; however, these data were not available for this report.
	Threatened species and biotic communities	Environment Protection and Biodiversity Conservation database on number and status of threatened species and communities	Threatened species and communities are listed by bioregion under the *Environment Protection and Biodiversity Conservation Act 1999*. The rangeland states and NT have assembled data reporting change in the numbers of species and communities by bioregion, listed by threatened status: critically endangered, endangered or vulnerable.

Theme	Information type	Datasets	Description
Biodiversity	Habitat loss: extent and fragmentation due to tree clearing	Clearing mapped from Landsat TM imagery	Selected results for Queensland based on the State-wide Landcover and Trees Study (SLATS) program. Similar results for parts of the northern NT and the eastern rangelands in NSW where clearing occurs. Clearing is not a major issue in WA and SA rangelands.
	Bird population composition	Birds Australia Atlas	Abundance and distribution of bird species across the rangelands, as surveyed and reported by members of Birds Australia. Coverage across the rangelands is sparse compared to coverage in more populated regions.
	Waterpoint distribution and distance	Mapped waterpoints	Habitat remoteness indicator based on jurisdictional mapping of waterpoints for pastoral leases in SA, WA and the southern NT. Unable to report change nationally.
	Terrestrial fauna surveys	Number of surveys and records for fauna	The number of fauna surveys, and records for species collected across rangeland IBRA bioregions and subregions. Changes can be reported where sites have been resurveyed.
	Terrestrial flora surveys	Number of surveys and records for flora	Across rangeland bioregions and, where available for sub-IBRAs, the number of flora/vegetation surveys and records on plant species. Changes can be reported where sites have been resurveyed.
	Transformer weeds	Maps of weed distributions	The distribution and abundance of invasive exotic plants that transform habitats for native biota. Changes can be mapped where weed distributions have been resurveyed.
	Wetlands	Numbers of Ramsar and other critical wetlands	Distribution and condition of wetlands critical as habitat for biota such as waterbirds and frogs across rangeland IBRA bioregions.
	Habitat condition	SLATS-derived Multiple Regression Bare Ground Index	As an indicator of habitat condition for biota, the extent, amount and type of groundcover measured remotely across the rangelands. Archives of Landsat imagery provide for reporting change.
Socioeconomic	Agricultural commodities	ABS Agstats, 1997 and 2001; annual Australian Bureau of Agriculture and Resource Economics farm surveys; ABS 2001 Population Census	Data analysis and reporting by Agtrans Research (Qld) to the National Land & Water Resources Audit (Chudleigh and Simpson 2004).
	Land use	Jurisdictional databases of land use	Data on land use across rangeland jurisdictions from sources such as the Australian Collaborative Land Use Mapping Program.
	Land values	Jurisdictional databases of land value	Data from each rangeland jurisdiction showing change in pastoral land values.
	Socioeconomic trends	ABS Census ABARE surveys	Eight aspects of socioeconomic data from ABS 2001 Census and 10 socioeconomic statistics from annual ABARE farm surveys from 1999 to 2006 are discussed in the context of understanding land management behaviour.
	Socioeconomic investigation	Socio-Economic National Coordinating Committee indicators and 'People and Land Management in the Rangelands' survey instrument	Indicators and a survey related to the understanding of land management practice behaviour. Together, they were used to test the predictive power of proxy indicators.

Table 2.2 Datasets other than climate and pastoral monitoring programs available to ACRIS

Theme	Information type	Dataset	Reliability in reporting change
Sustainable management	Distance from water	Mapped waterpoints	Not able to report change. Accuracy in mapping waterpoints highest in SA. Moderate to high reliability in reporting for WA and southern NT pastoral lands. Reliability uncertain for waterpoints based on the Geoscience Australia database (NSW, Qld and northern part of NT).
Total grazing pressure	Domestic stocking density	ABS Census and survey data concorded to bioregion	Variable, depending on number of farm businesses surveyed. Known differences for some bioregions based on this dataset and other stock records. Probable moderate reliability for most bioregions with predominantly pastoral tenure (where tenure area >50% of bioregion area). Low reliability for bioregions where commercial grazing is a minor land use.
	Kangaroo density	Aerial surveys in Qld, NSW and SA	Moderate to high reliability. Systematic surveys with robust correction factors applied. Rigorous techniques applied by University of Queensland (and others) to standardising jurisdictional datasets, then analysing and reporting trends.
Fire	Fire regime (extent, intensity and frequency)	WA Landgate fire-scar history and 'hotspot' maps	High reliability. Systematic procedures applied to standardise National Oceanic and Atmospheric Administration Advanced Very High Resolution Radiometer satellite imagery data source. Skilled operators used for fire mapping. Less reliable results where fires were very small (less than a few square kilometres in area) or of low intensity.
Dust	Dust Storm Index (DSI)	DSI_3 produced by Griffith University	Reliability maps provided with DSI_3 information type. As with rainfall, DSI_3 reliability is related to the density of Bureau of Meteorology stations reporting dust, their frequency of reporting, the period over which observations are available and the accuracy of observations.
Biodiversity	Clearing extent	Extent of clearing mapped from Landsat TM imagery	Reliability directly related to the extent and timing of multitemporal coverage of Landsat TM imagery. The accuracy in mapping woody cover decreases when groundcover is actively growing (ie green). Agency methods are documented and image analysts are trained. State-wide Landcover and Trees Study (SLATS) has a high degree of ground validation.
	Waterpoints	Mapped waterpoints	Able to report change for case studies, not nationally. Reliability as for distance-from-water information type under Sustainable management.
Socioeconomic	ABS statistics	ABS statistics	High to very high, particularly for census data.
	ABARE statistics	ABARE statistics	Based on a survey (not a census) with low or zero responses for some IBRAs, so conclusions must be considered as tentative.

ABARE = Australian Bureau of Agricultural and Resource Econoomics; ABS = Australian Bureau of Statistics

Note: Reliability in reporting change is also shown. The method for calculating reliability scores for the Landscape function theme and Critical stock forage and Plant species richness information types (Sustainable management theme) are demonstrated later in this chapter. Reliability scores for each are mapped in Chapter 3.

there are similar data) and some confidence in reporting on vegetation cover changes in the bioregion for the land types represented by the monitoring sites. However, management decisions about vegetation cover are made at the scale of pastoral leases (50–500 km^2), both by individual managers and by land administrators, and not all pastoral leases have a monitoring site. Therefore, there can be a disparity between the scale of management (pastoral lease) and the scale being reported (bioregion).

Regionalisations

By aggregating and summarising information into regions across Australia's rangelands, areas of greatest change can be assessed. Different regionalisations have been developed for particular purposes. Three have been used in this report: the Interim Biogeographic Regionalisation for Australia (IBRA), natural resource management (NRM) regions, and statistical local areas (SLAs).

Interim Biogeographic Regionalisation for Australia

A bioregion is a large, geographically distinct area of land and/or water that has assemblages of ecosystems forming recognisable patterns within the landscape.[3]

The IBRA regionalisation divides Australia into 85 bioregions and 404 subregions. There are 52 bioregions or parts of bioregions in the rangelands (Figure 2.3).

IBRAs were initially established to support the development of the National Reserve System, but their ecological relevance has led to their adoption for many other purposes, including some elements of the national monitoring and evaluation framework for the Australian Government's NRM initiatives.

The ACRIS-MC judged the IBRA scale and, in some cases, subdivisions of the IBRA (ie sub-IBRA scale) as the best compromise for reporting socioeconomic, ecological and biodiversity change. Whether IBRA or sub-IBRA scales were used depended on the extent and spatial resolution of the available data.

Natural resource management regions

The 56 NRM regions across Australia (Figure 2.3) were established to provide the spatial basis for the regional NRM plans that guide investments under the Australian Government's Natural Heritage Trust. NRM regions are based on a combination of local socioeconomic and administrative characteristics, and, where appropriate, may take account of biophysical characteristics such as river catchments.

NRM regions in the rangelands vary enormously in size, both within and between jurisdictions. The boundaries of the NRM regions do not necessarily have ecological significance; for example, one NRM rangeland region covers the entire NT.

Statistical local areas

SLAs are the spatial units (typically determined by shire boundaries) used by the ABS to report socioeconomic statistics (Figure 2.4). A map of the median age of farmers across many remote rangeland areas (Figure 2.5) illustrates how data can be presented using SLAs.

Comparing regional assessments

Different regionalisations are used by various disciplines because of their particular interests or aims. For example, economists work with SLAs, while natural resource managers might use NRM regions or bioregions or, at a finer scale, land systems. Land systems map and describe the land resources (geology, landforms, geomorphology, soils and vegetation) of a region.

There are important constraints to note when assessing and comparing change using different regionalisations. For example, a group of ground-based monitoring sites may broadly represent an IBRA but not an SLA. Depending on the density and distribution of monitoring sites, it may be possible to report at scales finer than SLAs and IBRAs (eg sub-IBRAs).

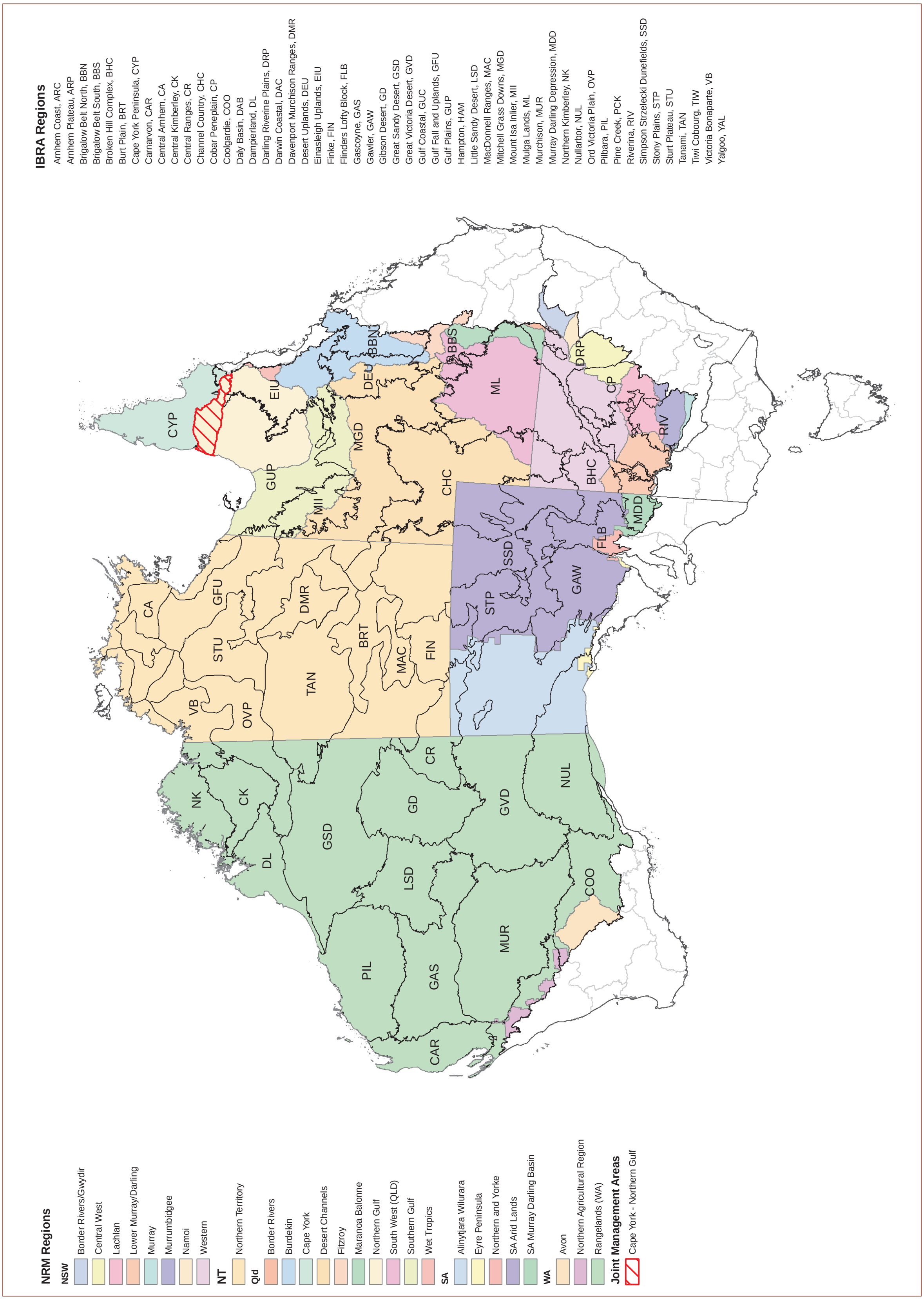
IBRA regions often cut across pastoral lease boundaries. When information is collected by pastoral lease (for example, the ages of farm managers in Figure 2.5), data for a single pastoral lease may have an impact on assessments in two (or more) IBRAs. Regionalisations based on SLAs tend to include whole pastoral leases.

ABS data are collected by 'census collection districts' and then concorded up to SLA and IBRA regions for ACRIS reporting.

Using concordance procedures, it is usually technically possible to compare assessments by adapting datasets from one regionalisation to another, but this can be a laborious process. Where data are based on few and dispersed samples, concordance from one regionalisation to another may not be possible. For example, it may be inappropriate to concord socioeconomic data such as 'ages of farmers' collected from a small number of survey samples in sparsely populated areas within a large SLA to smaller component IBRAs (Figure 2.5).

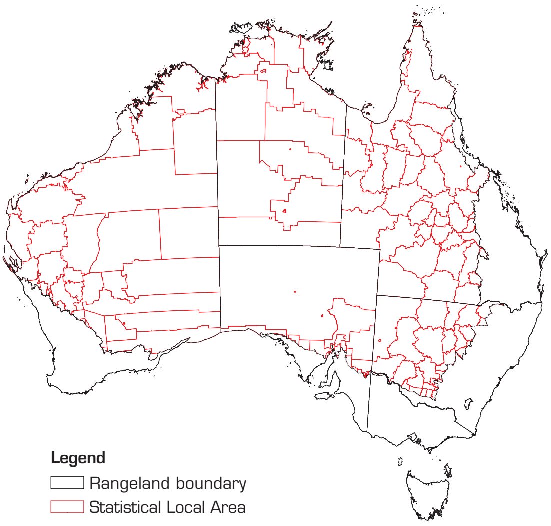
[3] See http://www.environment.gov.au/parks/nrs/ibra/index.html (accessed 2 February 2006)

Figure 2.3 IBRA and NRM regions within Australia's rangelands



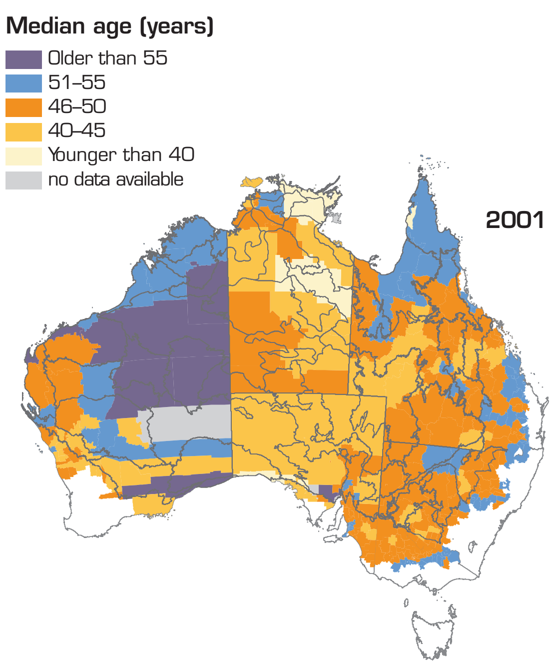
Source: Department of the Environment, Water, Heritage and the Arts

Figure 2.4 Statistical local areas for Australia's rangelands



Source: Australian Bureau of Statistics

Figure 2.5 Median age of farmers and farm managers for statistical local areas in the rangelands



Note: Lines show IBRA bioregion boundaries.
Data: ABS 2001 Population and Housing Census. Map: BRS, 2007

Assessing change using ACRIS

The capacity of ACRIS to deliver a consistent and reliable view of change in the rangelands was initially tested in a set of separate assessments using a case-study approach for five pilot regions, covering the period from 1992 to 2002. The pilot regions were the Victoria River District (NT), Desert Uplands (Queensland), Darling Riverine Plains (New South Wales, NSW), Gascoyne–Murchison (Western Australia, WA) and Gawler (South Australia, SA). Details of the five pilot-region assessments are in separate reports available on the ACRIS website.[4] Each of the five rangeland regions was assessed for the capacity of ACRIS to provide information on:

- plant species known to be critical for stock forage (related to the sustainability of the pastoral industry)
- native plant species present (an indicator of significance to production and to biodiversity conservation)
- landscape function (an indicator of ecosystem efficiency, particularly relating to use of rain)
- land cover (a basic measure of protection against erosion, as well as an indicator of woody thickening)
- the capacity for people to adjust to changes in their business (biophysical, social and economic), this adaptive capacity being a crucial aspect of societal response to environmental problems.

The pilot-region assessments indicated that ACRIS could reliably report that:

- critical stock forage species had generally improved
- diversity of native plant species was stable in most pilot areas
- landscape function was mostly stable, although it had decreased in some areas during drought periods
- tree cover had decreased due to clearing in two regions, but other components of cover had remained generally stable
- people in the pilot regions were effectively adapting to change, but national census data show that communities living in the rangelands are becoming less diverse, possibly resulting in a reduced capacity to adjust to future changes.

Overall, these pilot-region assessments demonstrated that, where there are sufficient data at the regional scale, ACRIS has the capacity to synthesise those data to report reliably on change in the rangelands at a national scale.

4 http://www.environment.gov.au/land/publications/acris (accessed 3 July 2007)

Box 2.3 Reporting change

The ACRIS-MC has elected to use maps to show the changes detected from site-based monitoring. Maps provide geographic context and visual effect compared with tables. Both 'gross change' and 'seasonally interpreted change' (based on *seasonal quality*) are mapped. For each theme and information type (Table 1.1), mapped values are the percentage of reassessed sites showing degree and direction of change (as 'no change', 'increase' or 'decrease') beyond a specified threshold for each of landscape function, critical stock forage and native-plant species richness.

Particular caution is required in interpreting maps produced from site-based monitoring. Mapped change derives from pastoral monitoring sites (see also Appendix 1), and those sites are located according to specified criteria (eg at a set distance from stock waterpoints in particular parts of the landscape) to meet the objectives of the monitoring program (eg to determine grazing effects on pasture quantity and quality). As such, there is bias in where sites are positioned (eg parts of the landscape highly sensitive to grazing may be rarely, if ever, monitored). The extent of resources required to maintain monitoring programs also means that replication of sites across the landscape is not possible. In addition, many monitoring programs lack adequate control sites against which current condition and trends can be assessed.

These sampling issues mean that site-based monitoring cannot account for all the spatial heterogeneity and biophysical processes occurring in complex landscapes. In essence, pastoral monitoring systems can only report on the soils and vegetation found within the area of the site, and their limitations for regional reporting of landscape health have been demonstrated (Pringle et al 2006). Figure 2.6 shows that, while ground-based monitoring sites provide useful information about the parts of the rangelands they are designed to represent, they cannot be expected to provide a complete assessment, and complementary approaches are needed.

Where appropriate, this report applies caveats to interpretations drawn from site-based results. In particular, maps used to depict change by bioregion (or sub-IBRA) for pastoral country should be interpreted cautiously. The changes shown only apply to the sites and not to the whole bioregion.

Figure 2.6 Erosion front, Murchison region, WA

In this photo, an erosion front is working from the right to left. If a monitoring site were located in the area to the left, it might show positive change, for example increased shrub density, but at the same time degradation is occurring in areas to the right.

Photo: Peter-Jon Waddell, WA Department of Agriculture and Food

Reliability in reporting change

Reliability is described as a rating of the confidence the ACRIS-MC has in reporting change for different information types and indicators. Where reliability is shown as high in Chapter 3, the ACRIS-MC is confident that the reported result truly reflects actual change in the bioregion. To the extent possible, a score that indicates the reliability of a reported result is provided for each bioregion. For the Landscape function theme and Critical stock forage and Plant species richness information types (Sustainable management theme), reliability scores are mapped by bioregion (Chapter 3). A ranked or quantitative approach has generally been used, but for reporting of some information types a quantitative assessment of reliability was not feasible and a qualitative (expert) assessment has been used. The reliability of seasonally adjusted changes was also assessed.

It is valid to compare reliability estimates from bioregions using the same data type. For example, it is valid to compare reliability estimates of Western Australian Rangeland Monitoring System (WARMS) pasture monitoring data for the Murchison IBRA (high reliability) with estimates for the Northern Kimberley IBRA (moderate reliability). However, caution is necessary when comparing reliability estimates between different data types, such as between WARMS pasture data, fire extent and dust values (see Chapter 3).

Site-based monitoring

A ranked assessment of reliability in reporting change was applied to monitoring data collected by the state and NT pastoral monitoring programs. This quantitative assessment of reliability was based on five criteria:

1. Site density in each bioregion

   This was calculated by first dividing the area of pastoral tenure by the number of monitoring sites (km^2/site).

   This result was then converted to a density score between 1 and 20, where:

   density score = 20 – (site density/100).

   Higher scores correspond with higher site densities. Most bioregions had a score between 10 and 18 (effectively, >100 to <1000 km^2/site) for most monitoring programs. There were occasional negative values (>2000 km^2/site), which were arbitrarily assigned a low density score (between 1 and 3).

2. Site distribution within each bioregion (very uniform = 10, very patchy = 1).

3. Data type (quantitative = 10, qualitative or estimated = 5).

4. Repeatability of assessments (very high = 10, very low = 1).

   Quantitative techniques that measure vegetation and soil are assumed to be more repeatable than methods using estimations or qualitative rankings. Repeatability scores for the latter were boosted where techniques are clearly documented and observers well trained.

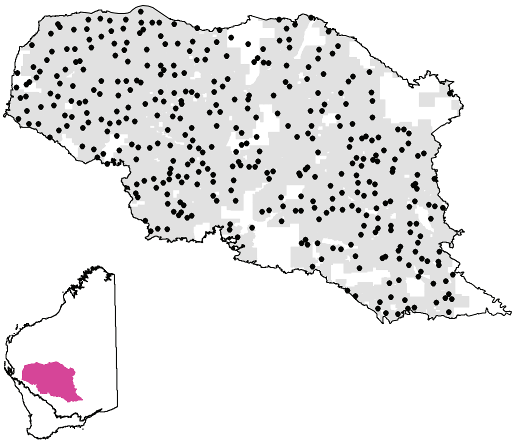
5. Relevance of data type for reporting change in the information type (very high = 10, very low = 1).

   The Resource Capture Index derived from WARMS data, for example, provides a direct estimate of landscape function. Some landscape function indices compiled from other monitoring data provide indirect information and remain untested, and were given a low relevance score.

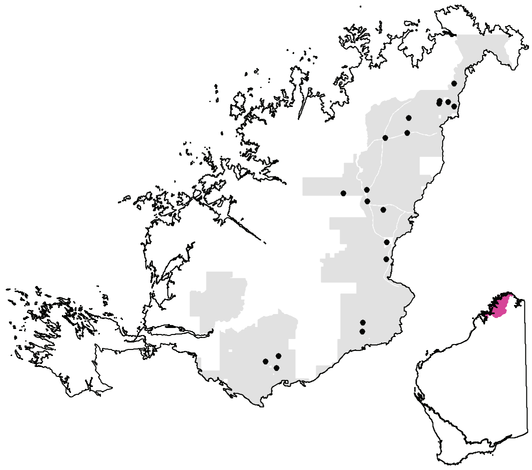
The five scores were summed to provide a value for each bioregion between 10 (lowest reliability) and 60 (highest reliability). Those values were then mapped to each pastorally important bioregion where pastoral monitoring was conducted for reporting change in Chapter 3. An example is shown in Figure 2.7; in that case, the site-based data for the Murchison bioregion in WA had a relatively high reliability score of 48, whereas the Northern Kimberley bioregion had a moderate reliability score of 38.

Monitoring of the pastoral estate in Queensland is based on repeated roadside observations of several vegetation and soil attributes made by the one highly skilled observer ('rapid mobile data collection', or RMDC; Hassett et al 2006). Those assessments have been judged as showing moderate reliability for most bioregions, decreasing to low reliability where observations are less dense and, in some cases, less frequent. RMDC data are supported by AussieGRASS simulation and the State-wide Landcover and Trees Study (SLATS)-derived Multiple Regression Bare Ground

Figure 2.7 Reliability scores for reporting change in landscape function and critical stock forage, Murchison bioregion and Northern Kimberley 1 sub-IBRA region, WA



WARMS sites, Murchison bioregion
584 km^2/site, sites uniformly distributed
Reliability Score = 48 (out of 60) = High



WARMS sites, Northern Kimberley 1 sub IBRA
1072 km^2/site, sites patchily distributed
Reliability Score = 38 (out of 60) = Moderate

Note: Change results for each information type are based on vegetation data collected at fixed sites as part of the Western Australian Rangeland Monitoring System (WARMS). Dots show the locations of WARMS sites. Shading denotes areas of pastoral tenure.

Source: WA Department of Agriculture and Food

Index (MRBGI). AussieGRASS is a pasture growth model that incorporates the complex interactions of climate, soils, vegetation, fire, animal numbers and management actions to predict total standing dry matter in kg/ha for 5 km × 5 km grid cells. Both data types have total and frequent coverage, but reliability in reporting change for the region is reduced (ie low to moderate) because:

- AussieGRASS data are simulated rather than actual
- MRBGI data reliably represent groundcover, but actual relationships with landscape function and sustainable management (eg critical stock forage) are not yet established.

Remote sensing-based monitoring

Available data from satellite imagery (typically Landsat) are quantitative and usually provide total coverage. Where the procedures for using remote sensing data are well documented and adequate training is provided, there is a high degree of repeatability. However, reliability is reduced because available methods (typically, grazing gradient analysis and land cover change analysis) do not provide a direct measure of landscape function or critical stock forage.

Reliability of other data sources

Various analyses and presentations of rainfall data are used in this report to evaluate climate variability. The main data source is SILO gridded rainfall.[5] Reliability of these data is directly related to the density of reliable recording stations, which is highest in the southeast and southwest of Australia (ie outside the rangelands; Figure 1 in Jeffrey et al 2001). The density of recording stations decreases to moderate around the periphery of the rangelands, is low throughout much of central Australia and is very low in the western deserts.

5 http://www.bom.gov.au/silo (accessed 23 April 2006)

Figure 2.8 Measuring shrub attributes as part of the Western Australian Rangeland Monitoring System

Photo: Simon Eyres, WA Department of Agriculture and Food

Data sources other than rainfall and pastoral monitoring programs have been assessed by the ACRIS-MC as having varying levels of confidence in reporting different types of change (shown in the right-hand column of Table 2.2). It is important that this confidence is explicitly stated for each theme and information type reported.

State/territory pastoral monitoring programs

Monitoring is the process of making repeated observations, assessments or measurements in the same area. Observations can be direct, for example by measuring attributes in the field at fixed sites (Figure 2.8), or indirect, for example by acquiring data from remotely sensed images.

Each state or territory with pastoral areas has some form of monitoring program that reports on vegetation changes. The essential features of those programs are summarised in Table 2.3. Some monitoring programs also record information on soil surface condition.

Considerable effort has been invested in defining indicators for monitoring biodiversity (Smyth et al 2003), in testing the efficacy of some of those indicators at regional and enterprise scales (Hunt et al 2006), and in evaluating current state/territory activities that measure and use biodiversity indicators (Day 2007). However, systematic data to report change in biodiversity are scarce in comparison with pastoral monitoring data. Ten indicators are described in the Biodiversity theme of Chapter 3, and status and change are reported largely by way of case studies.

Table 2.3 Key features of state/territory programs for monitoring vegetation change across pastoral estates

Jurisdiction	Monitoring program	Features
WA	Western Australian Rangeland Monitoring System (WARMS)	Ground-based (~1600) fixed sites with suitable data for reporting change. WARMS allows reporting of change based on those sites for advising the WA Pastoral Lands Board, WA Government, state of the environment reporting agencies etc. Attributes of perennial vegetation and soil surface condition are recorded: perennial grass frequency and crown cover in the northern grasslands (Kimberley and Pilbara) and density and canopy size of longer-lived shrubs in the southern shrublands (Gascoyne–Murchison, Goldfields and Nullarbor). Sites are reassessed every three years in the grasslands and every five years in the shrublands.
SA	Pastoral Monitoring System	Ground-based and remote sensing components. Fixed sites in the southern shrublands; remote sensing (grazing gradient methods) in the northern cattle country, supplemented by photopoints and ground observation. Reporting by pastoral lease (for compliance purposes) with results amalgamated to district level. Each lease assessed at least once every 14 years. Shrub density, groundcover and crown separation ratios recorded at fixed sites (~400 sites with suitable data for reporting change).
NSW	Rangeland Assessment Program	Ground based, ~310 active sites across western NSW, assessed annually. Purpose is to advise individual lessees of vegetation change, with results amalgamated for regional reporting. Data recorded on chenopod bush density, pasture species frequency, estimated pasture biomass and soil surface condition. Canopy cover of trees and shrubs measured at three-year intervals. Data are supplemented by photopoints, observations and landholder records of rainfall and management.
NT	Tier 1 and Tier 2	Tier 1: Ground-based, ~3200 sites, assessed on ~3 year cycle. Purpose is to advise the NT Pastoral Land Board of changes in lease resource condition. Composition (by biomass) and cover of pasture estimated at each site. Presence and nature of weeds and erosion also recorded. Tier 2: Remote sensing to support Tier 1 monitoring. Land-cover change analysis in the northern savanna and grazing gradient analysis in the semiarid and arid south.
Qld	Rapid Mobile Data Collection (RMDC)	RMDC: observations of ground and woody cover, pasture biomass and composition, pasture utilisation, weediness, erosion etc at many points along road traverses. Repeat traverses allow change to be reported. Data originally collected to validate results from AussieGRASS simulation and SLATS (woody cover and clearing). RMDC data used here to report change in landscape function and critical stock forage in lieu of monitoring data from fixed sites. AussieGRASS: spatial simulation of pasture growth and utilisation, total standing biomass and groundcover. Model inputs include rainfall, soil nutrients and regional stocking densities.
	State-wide Landcover and Trees Study (SLATS)	SLATS: remote sensing-based biennial coverage (all of Qld) from 1989 to 2001 and then annually to 2006. Used for reporting change in woody cover and clearing in different regionalisations. Multiple Regression Bare Ground Index derived from SLATS data now allows monitoring of groundcover.

Key points

- ACRIS is an information system that analyses available data to assess change across Australia's rangelands. Information in ACRIS is gathered from a variety of sources, but generally includes information from:
  - national datasets based on remote sensing, population census and other sources
  - pastoral monitoring programs within rangeland jurisdictions.
- Assessments provide for a national view of change reporting by IBRA bioregions or, where feasible, by sub-IBRAs (eg for case study areas), or where necessary by SLAs (eg for some socioeconomic indicators).
- There are particular challenges in collecting suitable and representative data, and in interpreting and understanding causes of change.
- Data reliability is critical and remains a concern for some types of information in certain regions (eg there are few rainfall recording stations in desert regions). Pastoral monitoring sites are numerous and widespread but even in pastoral regions usually sample the landscape selectively, lack replication or controls, and remain sparse or absent in areas with largely non-pastoral land uses.

3 Change in the rangelands

Findings on assessed change in the rangelands are presented in this chapter against each of the themes and information types listed in Table 3.1. These eight themes are considered to be key issues for Australia's rangelands, and any changes in attributes and indicators related to them are of critical importance.

Each theme is introduced with some background on its key features and issues. Key points are listed at the end of reporting for each information type within themes.

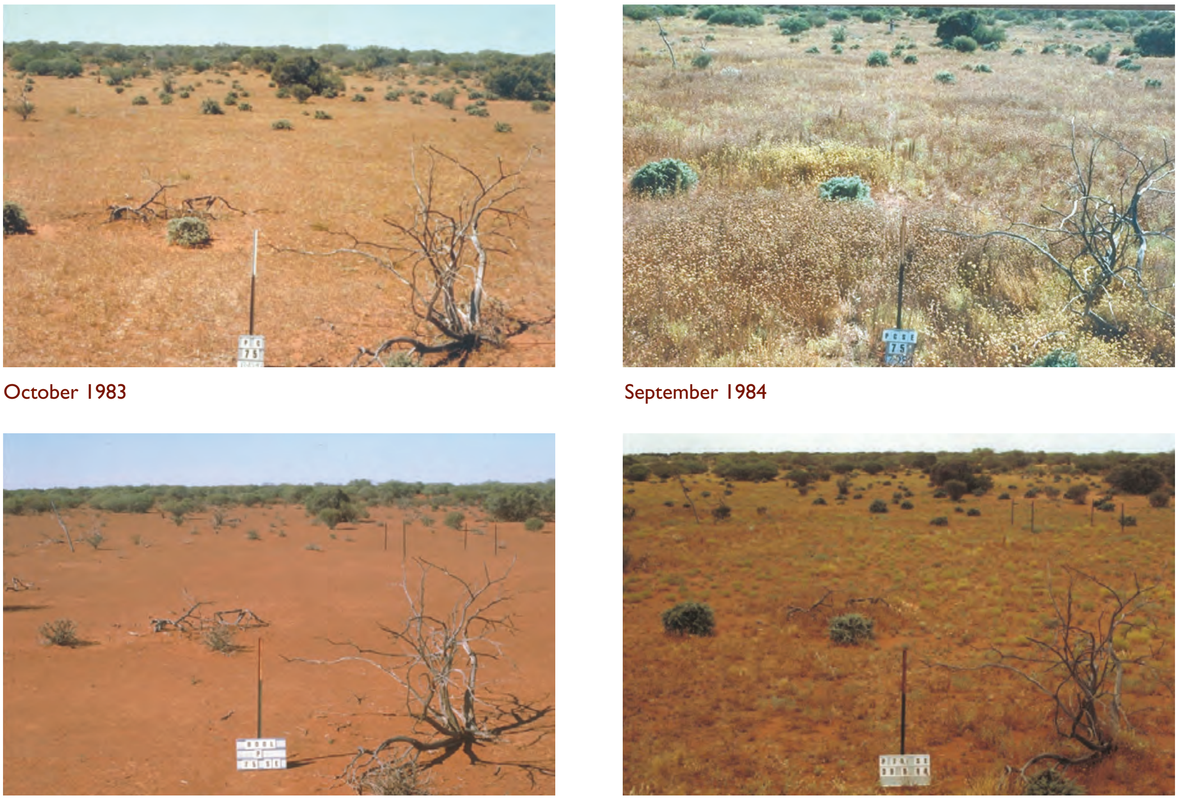
Climate variability

Of all the climatic factors, rainfall is undoubtedly the major driver of ecosystem and landscape processes in Australia's rangelands. The amount and intensity of rain, and follow-up rains, have a profound effect on the composition and amount of vegetation (Figure 3.1). Slightly below average rainfall in 1983 produced 254 kg/ha of herbage at the Carnarvon bioregion site in Figure 3.1; very high rainfall in 1984 produced

Table 3.1 Themes and information types

Theme	Information type
Climate variability	■ seasonal quality as context for interpreting change
Landscape function	■ change in landscape function
Sustainable management	■ change in critical stock forage ■ change in pastoral plant species richness ■ distance from stock water ■ invasive weeds
Total grazing pressure	■ change in domestic stocking density ■ change in kangaroo density ■ feral animals
Fire and dust	■ change in fire regime ■ change in atmospheric dust (Dust Storm Index)
Water resources	■ information sources for water availability and sustainability
Biodiversity	■ change in protected areas ■ change in number and status of threatened species/communities ■ habitat loss by clearing ■ effects of stock waterpoints on biota ■ fauna records and surveys ■ flora records and surveys ■ transformer weeds ■ wetlands: condition and change ■ habitat condition derived from remotely sensed groundcover ■ bird population composition
Socioeconomic change	■ socioeconomic profiles ■ value of non-pastoral products in the rangelands ■ change in land use ■ change in pastoral land values

Figure 3.1 Effects of rainfall variability on plant growth, Carnarvon bioregion, WA, 1983 to 1988



October 1983

September 1984

October 1987

September 1988

Photo: WA Department of Agriculture and Food

752 kg/ha. A drought period in 1987 produced only 15 kg/ha, but by September 1988, following a slightly below-average season, herbage mass had increased to 356 kg/ha. This rainfall-driven variability in herbage production is a feature of semiarid rangelands and had little or no impact on overall rangeland condition (defined broadly as the capacity of vegetation to respond to rainfall), or on the composition of communities of perennial plants. Throughout the 1983–88 period, range condition on this site essentially remained stable.

Rainfall variability occurs over two timeframes: within year (season-to-season) and between years (year-to-year). Sequences of dry years (droughts) typically reduce groundcover and increase wind and water erosion, and require management responses such as reducing stock numbers. Conversely, sequences of wet years may result in fuel accumulation and wildfires, and also require land management decisions.

Climate variability information

The Bureau of Meteorology (BoM) publishes a number of climate-related information types on its website.[6] Information is available on recent and longer-term climate, drought and seasonal outlooks. The Queensland Government's Long Paddock website supplies information to better manage climatic risks and opportunities, particularly those associated with the El Niño – Southern Oscillation phenomenon.[7] A related Queensland Government website[8] and the BoM website link to the SILO products and tools, which provide more detailed information about past and predicted rainfall. Australian Collaborative Rangeland Information System (ACRIS) has used SILO gridded historical rainfall data extensively in this report for describing seasonal variability.

6 http://www.bom.gov.au/climate
7 http://www.longpaddock.qld.gov.au
8 http://www.nrw.qld.gov.au/silo

Pasture growth following rainfall can be modelled by the AussieGRASS model[9], and those data are also used here to describe past seasons.

Vegetation growth is monitored with satellite imagery using the Normalised Difference Vegetation Index (NDVI), an indicator of photosynthetic activity or vegetation 'greenness'. Continental images of NDVI processed to estimate both 'season quality' and 'ecosystem health' are routinely produced by the Australian Government.[10]

Seasonal quality

The term *seasonal quality* is used to report the relative value of recent climate (principally rainfall) on biological functioning. Relative value (quality) is judged with reference to the longer-term record. 'Biological functioning' broadly means vegetation growth as a basic resource for both livestock (forage) and fauna (food, shelter). *Seasonal quality* is italicised throughout this report to emphasise its use for indicating the effects of recent climate, as indicated by different measures of rainfall or simulated pasture biomass.

Many climate-related information types are available, and no single type fully represents *seasonal quality*. Three broad information types were used to describe *seasonal quality*:

1. Rainfall based on spatial averaging of SILO gridded rainfall across the reporting unit — for example, an Interim Biogeographic Regionalisation for Australia (IBRA) bioregion. Annual, monthly and daily surfaces of interpolated rainfall for Australia at a 0.05-degree resolution (~5 km × ~5 km) are available by data licence agreement.[11]
2. Pasture biomass (kg/ha) as predicted by the AussieGRASS model. Pixel size is as for SILO gridded rainfall (~5 km × ~5 km). Total standing dry matter (TSDM) data are spatially averaged by IBRA bioregion or sub-IBRA region to reflect *seasonal quality* (Table 3.2).
3. Images of vegetation 'greenness' across Australia are produced by the Australian Government Department of the Environment, Water, Heritage and the Arts. Greenness is based on NDVI, which is derived from the United States National Oceanic and Atmospheric Administration's Advanced Very High Resolution Radiometer (AVHRR) satellite imagery. Pixel size is 0.01 degree (~1 km × ~1 km). The rationale for using NDVI is that there is an increase in photosynthetic activity over most of the growing season, and the magnitude of the increase is an indicator of rainfall effectiveness. The NDVI 'flush' for each pixel is compared over time to give relative ratings of greenness. The ratings are then displayed as images to show variations in greenness across the landscape.

The NDVI flush in any year can be expressed as a percentage of the flush range (from 0% minimum flush to 100% maximum). This relative, or scaled, percentage highlights areas that have not reached their previous minimum or maximum growth, as well as those areas where the previous range has been exceeded. The analysis of past years is the same, but new extents have been accounted for, so every value is within the range limits.[12] These NDVI images are not reported in this Climate variability theme, but are presented in Chapter 4 for selected focus bioregions to illustrate spatial variations in 'greenness'.

The SILO gridded rainfall and AussieGRASS simulated pasture growth information types were used to derive indices of *seasonal quality* (Table 3.2) related to amount of rainfall, decile rank within a given time period, and cumulative percentage deviations from the long-term mean or median. The various indices are compiled from spatially averaged input data for each rangeland IBRA bioregion or sub-IBRA region.

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9 http://www.longpaddock.qld.gov.au/AboutUs/ResearchProjects/AussieGRASS (accessed 3 July 2007)

10 See http://www.deh.gov.au/erin/ndvi (accessed 3 July 2007)

11 http://www.bom.gov.au/silo (accessed 23 April 2006)

12 See http://www.deh.gov.au/erin/ndvi/images/seasqual/pdfrl02c.html for further explanation (accessed 2 April 2008).

Table 3.2 Indices of *seasonal quality* derived from SILO gridded rainfall and AussieGRASS simulated pasture biomass

Indicator	SILO gridded *rainfall*	AussieGRASS simulated *pasture biomass (TSDM)*
Amount	Rainfall (mm) for: ■ calendar year ■ growing season (summer or winter) ■ 'rainfall' year (1 April to 31 March)	TSDM amount (kg/ha) for calendar year
Decile rank	Decile rank of a particular year (calendar, growing season or rainfall year) in the ACRIS reporting period (1992–2005) against the long-term record (1890–2005)	Decile rank of a particular year in the ACRIS reporting period (1992–2005) against the long-term record (1890–2005)
Cumulative percentage deviation from the long-term (1890–2005) mean	For each bioregion (or sub-IBRA), calculated as: i. The percentage difference between rainfall each year (calendar, growing season or rainfall) and the corresponding long-term mean. ii. Percentage deviations are then summed for all 14-year periods between 1890–1903 and 1992–2005. A 14-year period is used so that the ACRIS reporting period (1992–2005) can be compared with all previous 14-year periods (1991–92 to 2004–05 used for indices based on the summer growing season and rainfall year). Accumulated large negative or positive deviations indicate predominantly poorer or better seasons, respectively, for that bioregion for that period.	
Cumulative percentage deviation from the long-term median	As above, but using the long-term (1890–2005) median	

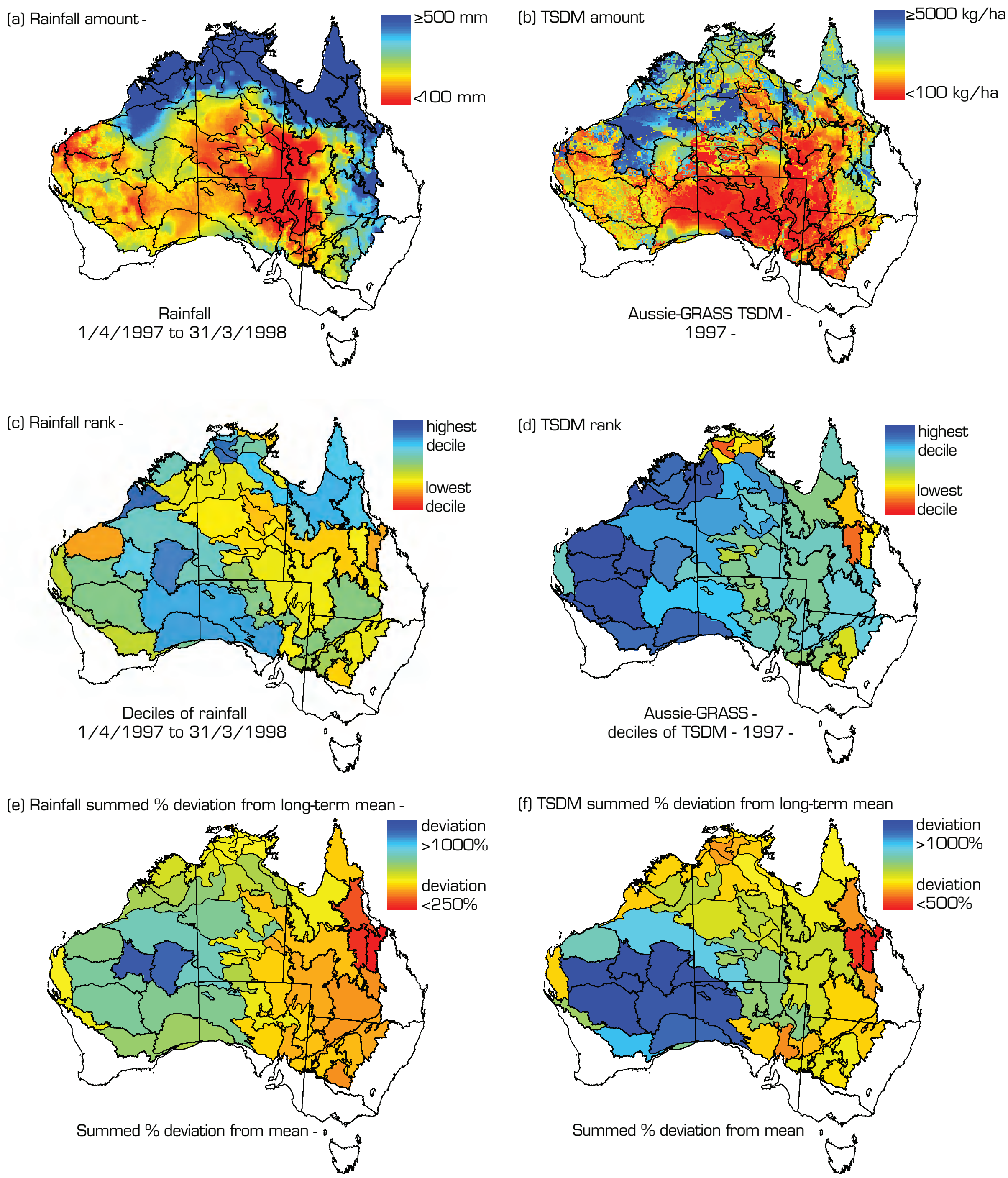
IBRA = Interim Biogeographic Regionalisation for Australia; TSDM = total standing dry matter

Seasonal quality for a selected year

For one rainfall year (1 April 1997 to 31 March 1998) across all rangeland IBRA bioregions, *seasonal quality* was indicated by both rainfall and TSDM. Rainfall patterns were derived from SILO gridded data; TSDM data were simulated by the AussieGRASS model. These *seasonal quality* patterns (Figure 3.2) indicate the following:

- Rainfall was highest in northern Australia and along the eastern edge of the rangelands, and lowest in central and southern Australia (Figure 3.2a).
- Simulated pasture biomass was generally higher in northern Australia and lowest in the south and east of the rangelands (Figure 3.2b). This modelled biomass represents the interaction of rainfall with other factors, such as soil fertility, temperature and recent fires.
- Based on the rainfall year ranked as deciles relative to the long-term (1890–2005) record for each bioregion (Figure 3.2c), *seasonal quality* was highest in the southern and western parts of the rangelands, and also in the north (Cape York, the Gulf and Arnhem Land).
- Simulated pasture biomass was in the highest deciles over most of the rangelands, except for the Top End of the Northern Territory (NT), northeast Queensland and the rangelands in southeast New South Wales (NSW) (Figure 3.2d).
- For the combined reporting period (1992–2005), based on the summed percentage deviations of annual rainfall from the long-term mean, *seasonal quality* was generally highly positive in the western half of the rangelands (apart from the far west), decreased to negative in the east, and was lowest in northeast Queensland (Figure 3.2e).
- For the combined reporting period (1992–2005), the summed percentage deviations of the AussieGRASS simulated pasture biomass data from the long-term mean resulted in a similar pattern of *seasonal quality* (Figure 3.2f). Relative to historical data since 1890, bioregions in the west and southwest had the highest *seasonal quality*, which decreased to the north and east, and was the lowest in the eastern rangelands.

Figure 3.2 *Seasonal quality*, all rangeland bioregions

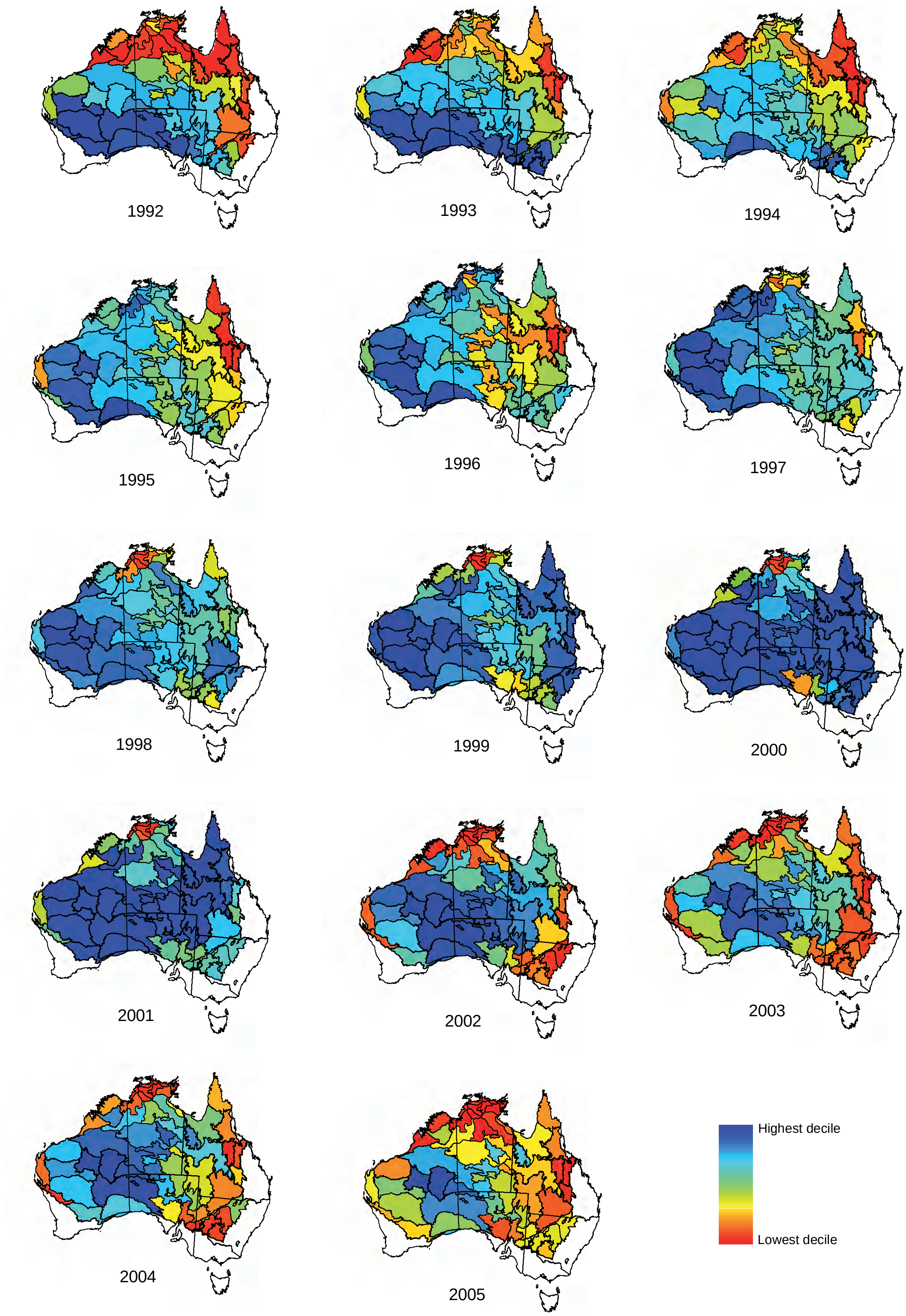


Rainfall

Simulated pasture biomass (TSDM)

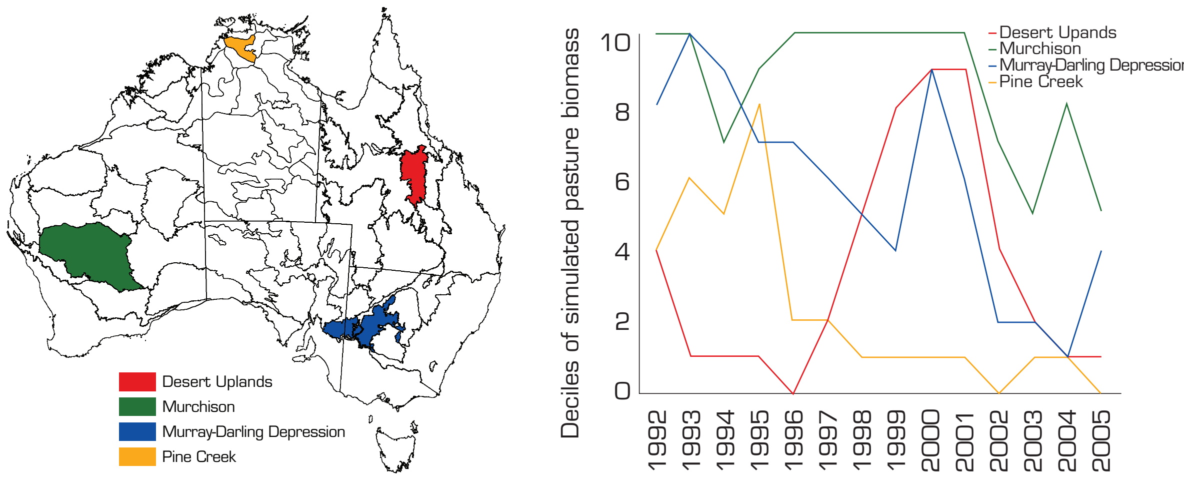
Data source: http://www.bom.gov.au/silo (accessed 23 April 2006). Maps compiled by the ACRIS-MU.

Figure 3.3 AussieGRASS simulated pasture biomass, 1992 to 2005, against the long-term (1890–2005) record



Data source: John Carter, Queensland Department of Natural Resources and Water. Maps compiled by ACRIS-MU.

Figure 3.4 Simulated pasture biomass, four bioregions, 1992 and 2005



Left: The four bioregions. Right: Simulated pasture biomass (kg TSDM/ha) between 1992 and 2005 for four rangeland bioregions at left, graphed as deciles (0–10) relative to the long term (1890–2005)

Data source: John Carter, Queensland Department of Natural Resources and Water

Overall, the decile-ranked data were easiest to calculate and provided a practical interpretation of *seasonal quality* as related to rainfall and plant growth. However, spatial averaging across a bioregion is likely to hide smaller areas (eg subregions) with drier or wetter conditions.

Pasture biomass by IBRA bioregion, 1992–2005

Changes in *seasonal quality* can be indicated by variations in pasture biomass as illustrated by AussieGRASS simulations from 1992 to 2005 (Figure 3.3). For each calendar year, the predicted TSDM data were spatially averaged by IBRA bioregion and displayed as decile ranks, which indicated the following:

- The best *seasonal quality* relative to predicted growth conditions was in the 'deserts' of eastern Western Australia (WA), western South Australia (SA) and southwestern NT.
- The majority of the rangelands experienced generally high *seasonal quality* through the 1997–2001 period. Regional exceptions at various times were the Top End of the NT and the Gawler bioregion in SA.
- Bioregions in the north and east had some of the lowest *seasonal qualities*. Below-average seasons also extended to the east and southeast rangelands at the start of the period (1992) and at the end (2002 to 2005). The Brigalow Belt North, Desert Uplands and Einasleigh Uplands bioregions in Queensland had only four high-quality seasons (1998 to 2001).
- Periods of poorer *seasonal quality* in the northeastern and southern rangelands, and in the Carnarvon area of WA, were related to periods of lower rainfall (ie reduced standing dry matter related to lower rainfall). In contrast, poorer *seasonal quality* in the Top End and Kimberley regions while soil moisture was plentiful was probably due to limited available soil nitrogen for plant growth.

Time traces of changes in pasture biomass

Time traces can be used to interpret how *seasonal quality*, as pasture biomass, varied within particular regions. For example, time traces revealed that predicted pasture growth, relative to the long term, differed markedly between four bioregions (Figure 3.4). The different traces reflect changes in *seasonal quality*.

These time traces indicate the following:

- For the Desert Uplands bioregion in Queensland, there was a clear cycle of rapidly increasing and then decreasing *seasonal quality*. These patterns broadly agreed with those for rainfall deciles in that region (data not shown).

- The time trace for the Murchison bioregion emphasises the run of above-average seasons between 1996 and 2001. However, when making bioregional summaries, spatially averaging pasture biomass data may conceal variability within the bioregion. For example, there was considerable spatial variability in rainfall in some years within much of the western Murchison, which experienced severe drought after 2001. Some of these subregion areas were still the subject of Exceptional Circumstances drought relief measures in 2007.
- *Seasonal quality* generally declined for the Murray-Darling Depression bioregion.
- The Pine Creek bioregion experienced generally below-average *seasonal quality* (based on simulated pasture biomass), despite known years of high rainfall: 6 of the 14 years had wet-season (November to April) rainfall in the top 10% of all long-term recordings. The lower deciles of simulated pasture biomass when rainfall was generally plentiful were most likely related to the limited availability of soil nitrogen because a high proportion of the total nitrogen pool was being held in carryover biomass.

An overall view of *seasonal quality* can be obtained from the summed percentage deviations in simulated pasture biomass. The summed scores for the four bioregions were Desert Uplands –418, Murchison +1034, Murray-Darling Depression +47, and Pine Creek –198.

Seasonal quality (mainly based on decile rainfall) can also be used to help interpret changes in other rangeland indicators (see the following parts of this chapter).

Key points

- Indices of *seasonal quality*, derived from decile ranks of rainfall and plant growth simulation models, were very useful for illustrating patterns of climate variability across Australia's rangelands. In particular:
  - recent rainfall and modelled plant growth expressed as deciles of the long-term record most usefully indicate regional variability in *seasonal quality*
  - an integrated measure of *seasonal quality* over the 14-year reporting period (1992–2005), compared with all previous 14-year periods in the rainfall record, usefully demonstrated medium-term changes in rainfall for each bioregion.
- The reliability of the rainfall records used to calculate these indices of *seasonal quality* must be considered. As noted above, the number of meteorological stations across the rangelands is inadequate for reliably assessing change in many areas; this is particularly an issue for desert regions.
- Even with these limitations in reliability, the usefulness of indices of *seasonal quality* for helping to interpret seasonally adjusted changes in rangelands responses has been demonstrated.

Landscape function

Changes in landscape function assessed at monitoring sites and from road traverses are illustrated in this section of the report. Landscape function defines the capacity of landscapes to regulate (ie capture and retain, not leak) rainwater and nutrients (Figure 3.5). Water and nutrients are the vital resources for plant growth that, in turn, provides food and shelter for fauna.

Functional landscapes have a high cover of patches of perennial vegetation, which are spatially arranged to efficiently capture runoff and resist wind erosion. This role of perennial vegetation patches has been described by Tongway and Ludwig (1997):

> Perennial vegetation exerts a strong influence on the transfer of materials across landscapes, whether by wind or water. For example, when runoff encounters grass clumps its pathway becomes more tortuous. Litter and sediment are trapped or filtered out of the flowing water. Also when flowing water is slowed down by the grass patch it has more time to infiltrate, and the flow itself becomes deeper. Therefore, these processes increase the amount of water infiltrating and being stored within the soil profiles of patches.

This simply means that much of the rain that falls soaks into the soil and is available for plant growth, which in turn can be used for forage for stock, fuel for fire, food and shelter for fauna, bush tucker, and many other purposes.

Figure 3.5 Functional and dysfunctional landscapes in central Australia

Functional: longer-lived shrubs slow overland flows, allowing rainwater to infiltrate the soil surface. Any waterborne sediment is deposited around the shrubs. The persistent cover reduces wind erosion.

Dysfunctional: very low cover and erosion result in leakage of water and soil nutrients from this landscape.

Photos: NT Department of Natural Resources, Environment and the Arts

Functional landscapes are likely to maintain their vegetation cover through variable climatic conditions and recover more quickly from disturbances (eg drought, fire, grazing). Changes in landscape functionality provide useful indicators for assessing the effects of management on rangelands.

Changes in landscape function

Change in landscape function for a monitoring site is shown in Figure 3.6. Over a 31-year period, saltbush species (*Atriplex vesicaria* and other species) have recolonised the paddock area to the left of the fence, considerably improving its ability to conserve rainwater

Figure 3.6 Change in landscape function for an area of the Flinders Lofty Block bioregion, 1965 to 1996

1965

1996

Photos: Pastoral Land Management Group, SA Department of Water, Land and Biodiversity Conservation for plant growth. The much-improved persistent cover provides better protection against wind and water erosion. Shrub density and inferred landscape function appear little changed in the field of view for the paddock to the right of the fence.

Two sets of maps are used to show changes in landscape function at the national level, the first showing overall or 'gross' changes and the second showing changes adjusted for *seasonal quality*. Where data derive from monitoring sites, mapped change applies to the locations of available monitoring sites.

See Box 3.1 for a brief description of data available from pastoral monitoring programs.

Gross change — all seasons

A score indicating the percentage of monitoring sites showing change in landscape function, and the reliability of that score, are mapped for each pastoral IBRA bioregion (in some cases, by sub-IBRA region) (Figure 3.7). This score is based on site-based monitoring for NSW, SA, the NT and WA, and on rapid mobile data collection combined with AussieGRASS model simulations for Queensland (see Box 3.1). Where monitoring data allowed, the percentage change score covered the 1992–2005 reporting period. For NSW, SA, the NT and WA, mapped change applies only to the area represented by monitoring sites.

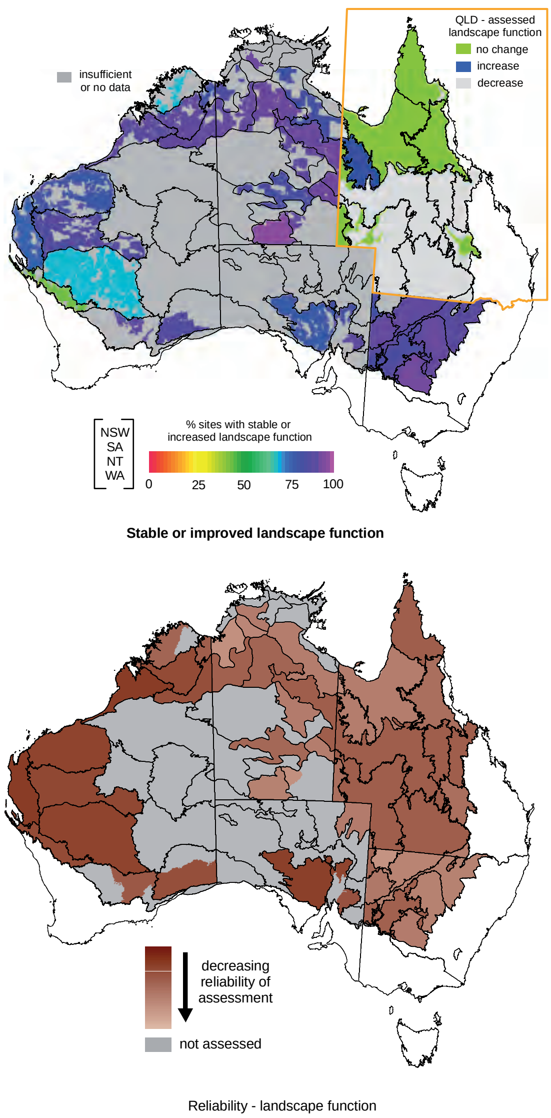
An estimate of the reliability of these scores to accurately report change in landscape function is also mapped (Figure 3.7, bottom). The reliability scores are based on a composite of:

- a site density index (km^2/site)
- a numeric ranking of site distribution within each bioregion or sub-IBRA region
- whether the data are quantitative or qualitative
- the relevance of the data for reporting changes in landscape function (ie their indicator value).

At most monitoring sites within pastoral bioregions in NSW, SA, the NT and WA, landscape function was either stable or had increased (Figure 3.7, top). These findings had moderate to high reliability (Figure 3.7, bottom), except for some subregions in central Australia, the northern Kimberley and the Gulf.

In Queensland, landscape function did not change in northern bioregions (ie Cape York Peninsula,

Figure 3.7 Changes in landscape function, Australia's rangelands, all seasons, and reliability estimates



Top: Changes in landscape function for all seasons across Australia's rangelands.

Bottom: Reliability estimates for those changes.

Note: Non-pastoral areas within each bioregion are masked out (ie not assessed).

Data sources: see Box 3.1. Maps compiled by the ACRIS-MU.

much of the Einasleigh Uplands and the Gulf Plains) but increased across the Mount Isa Inlier (Figure 3.7, top). Landscape function was also stable in parts of the Brigalow Belt South (two sub-IBRAs), Simpson–Strzelecki Desert (two sub-IBRAs) and Channel Country (one sub-IBRA). Reliability was generally moderate for all bioregions reported (Figure 3.7, bottom).

When interpreting maps of change in landscape function, it is important to note that:

- to be mapped, bioregions had to have at least 12 assessed sites
- in some areas, sites are confined to a sub-IBRA, in which case only that part of the bioregion is reported
- sites do not represent all parts of the landscape
- mapping was confined to the pastoral areas in SA, the NT and WA, but in NSW all bioregions were mapped (most of each bioregion grazed).

Seasonally adjusted change

Adjusting changes in landscape function by *seasonal quality* provides a useful longer-term view because changes are corrected for recent-season rainfalls. In their pastoral monitoring programs, most jurisdictions also aim to assess longer-term changes by measuring changes in perennial plants, not ephemerals.

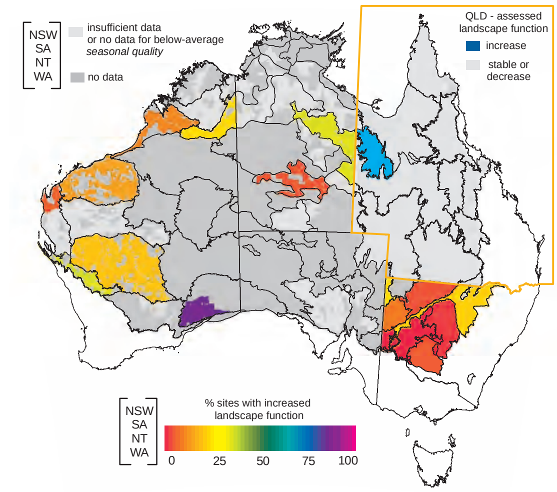
For NSW, SA, the NT and WA, maps illustrating seasonally adjusted changes in landscape function are based on monitoring data from field sites, whereas for Queensland maps are based on a combination of field observations and AussieGRASS simulations.

Figure 3.8 shows those rangeland sites, grouped by bioregion, where seasonally adjusted landscape function increased (top panel) and those where it decreased (bottom panel).

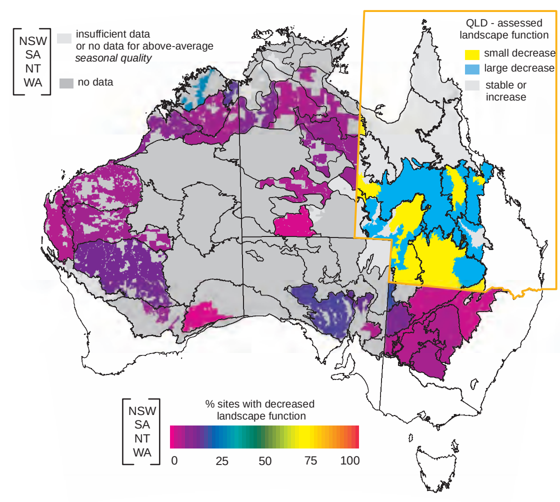
There were seven pastorally important bioregions where 20% or more of monitoring sites assessed following poor *seasonal quality* showed increased landscape function instead of the expected decrease (Figure 3.8, top panel). Notable examples were the Nullarbor 2 sub-IBRA and Yalgoo IBRA. Lesser increases occurred at sites in other bioregions in WA, NSW and the NT. In Queensland, landscape function increased above that expected across the Mount Isa Inlier bioregion.

Within bioregions, generally less than 20% of sites showed loss of landscape function following above-average *seasonal quality* (Figure 3.8, bottom panel). Notably, 29% of reassessed sites in the Northern Kimberley 1 sub-IBRA in WA had decreased landscape function despite better *seasonal quality*; this was probably due to the extensive wildfires that followed wetter years. In Queensland, landscape function decreased below that expected across much of the rangelands, particularly for the Mulga Lands, parts of the Channel Country, Desert Uplands, Mitchell Grass Downs and Gulf Plains bioregions.

Figure 3.8 Seasonally adjusted changes in landscape function for Australia's rangelands



Increase in landscape function following below-average *seasonal quality*



Decrease in landscape function following above-average *seasonal quality*

Note: For NSW, SA, the NT and WA, mapped change applies to the local area represented by monitoring sites. Any value above 0% in the top map is a positive result. The colour scheme is reversed between the two maps so that in each case the blue-purple end of the colour scheme represents the most substantial improvement; for example, where landscape function increased despite below-average *seasonal quality*. See Figure 3.7 (bottom) for the reliability of these changes.

Data sources: see Box 3.1. Maps generated by the ACRIS-MU.

Box 3.1 Rangeland monitoring of landscape function

Each rangeland state and the NT has a monitoring system that allows change in landscape function to be reported with varying rigour. Monitoring systems in WA, SA, NSW and the NT are focused on pastoral land and make assessments at fixed sites. All systems are ground based, and SA and the NT supplement their ground data with remote-sensing data. Queensland uses a combination of repeated ground traverses, modelling and remote sensing.

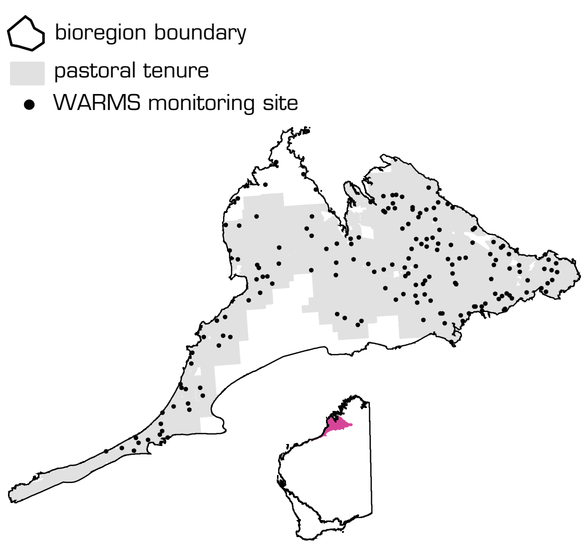
Reliability in reporting change in landscape function is indicated for each region.

- WA reports change from quantitative data collected at Western Australian Rangeland Monitoring System (WARMS) sites. In the northern grasslands, landscape function is indicated by the frequency of perennial grasses (ie percentage presence in quadrats relative to the total number assessed at each site). In the southern shrublands, landscape function is indicated by the density of longer-lived perennial vegetation. Although WA conducts formal landscape function analysis (Tongway and Hindley 2004) at WARMS sites, vegetation data are used in this report to represent landscape function because they are considered more robust and are more consistent with reporting by other jurisdictions.
- NSW uses an index of landscape function based either on frequency and cover of perennial herbage species in grassland vegetation or on cover and density for shrubland vegetation. The frequency and cover data are combined to indicate landscape function; high perennial-herbage frequency combined with high cover indicates increased landscape function.
- SA reporting is based on shrub density measured in fixed transects at sites in the southern sheep-grazed rangelands, and the degree to which remotely sensed grazing gradients of vegetation cover persist following large rainfall events in the north. Higher shrub densities indicate increased landscape function, analogous to WARMS monitoring. Recovery of grazing gradients following substantial rainfall indicates increased landscape function.
- The NT uses the cover and composition (by biomass) of perennial grass species estimated at fixed sites to indicate landscape function. Those estimates are combined into an index of landscape function (higher composition, by biomass, and cover of perennial grasses equate to better landscape function and produce higher index scores). Ground-based assessments are supplemented by remote sensing methods, grazing gradient analysis on pastoral country in the southern NT and vegetation cover trends in parts of the northern savanna.
- Queensland reporting is based primarily on rapid mobile data collection (RMDC), in which vegetation and land condition attributes are collected along road traverses (Hassett et al 2006). Where RMDC data are unavailable or inadequate, changes in landscape function are based on interpretations of AussieGRASS simulations (Carter et al 2003). Stable or increased landscape function is presumed where modelled utilisation of pasture growth is relatively conservative and constant through time, and cover levels are not likely to lead to erosion. Reporting is supported by analysis of changes in groundcover from satellite images (the Multiple Regression Bare Ground Index [MRBGI, version bi1] derived from State-wide Landcover and Trees Study (SLATS) imagery; Scarth et al 2006). Changes in groundcover are interpreted with respect to prior seasonal rainfall and used to support inferred landscape function based on RMDC and AussieGRASS data.

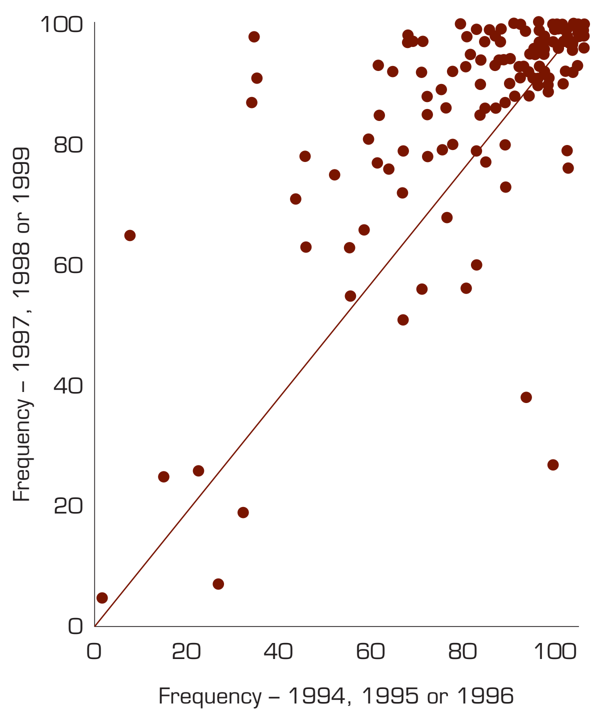
Dampierland IBRA: a regional example of change in landscape function

The average percentage frequency (see definition in Box 3.1) of perennial grasses across all Western Australian Rangeland Monitoring System (WARMS) sites in the Dampierland IBRA increased from 81.8 ± 1.64 to 88.1 ± 1.45 (mean ± standard error) over the 1994 to 2005 period of monitoring (Figure 3.9). From this, it was inferred that landscape function improved on average. The distribution and density of sites across the bioregion provided a moderate to high degree of confidence in this interpretation (see Figure 3.7, bottom), at least in those parts of the landscape where WARMS assessments were made. After accounting for *seasonal quality*, 12% of site-by-year assessments (over three complete cycles) had increased perennial-plant density following below-average rainfall (Table 3.3). A similar percentage of sites (11%) reassessed after above-average rainfall had reduced perennial-grass frequency, interpreted as a decline in landscape function, when an increase was expected. The overall assessment was that, in seasonally adjusted terms, landscape function was either stable or changed in line with seasonal expectations at a majority of sites in the Dampierland bioregion. Where change in landscape function was counter to seasonal expectations, equal proportions of reassessed sites showed gains when a loss was expected, and vice versa. However, there is evidence from elsewhere in WA that areas not monitored by WARMS have different trajectories of change over time (Pringle et al 2006).

Figure 3.9 General improvement in landscape function in the Dampierland bioregion (WA), inferred from increased frequency of perennial grasses measured at the majority of WARMS monitoring sites



Bioregion area: 83 457km²
Area grazed: 73%
WARMS sites: 170
Site density: 359 km²/site



Left: WARMS sites in the Dampierland bioregion

Right: Change in frequency of perennial grasses at WARMS monitoring sites. Each circle represents a site and shows % perennial grass frequency recorded at the first assessment and the second assessment of the cycle. Circles above and to the left of the diagonal 1:1 line show an increase in perennial grass frequency (and indicated landscape function) between the first and second assessments.

Table 3.3 Seasonally interpreted change in landscape function based on three assessment cycles, Dampierland bioregion

Seasonal quality	Number of site-by-year combinations	Decline Freq. <90%	No change Freq. 90–110%	Increase Freq. >110%
Above average	287	11%	63%	27%
Average	90	7%	81%	13%
Below average	52	15%	73%	12%

Note: The light grey cell indicates a likely adverse effect related to grazing management, in that no change or an increase in perennial grass frequency would be expected following above-average *seasonal quality*. The grey cell represents an encouraging result, as a decrease in landscape function would be expected following poor seasonal conditions.

Source: see WARMS in Box 3.1.

Key points

- Reporting of change in landscape function was restricted to areas under pastoral tenure in WA, SA and the NT. Pastoral tenure is more widespread in NSW and Queensland, and reporting is more general.
- Change detected through site-based pastoral monitoring programs applies to the site area only. There is bias in positioning sites, and not all parts of the landscape are sampled.
- WARMS is the only site-based monitoring system that includes direct measurement of landscape function. Elsewhere, where site-based data were available, indices of landscape function were constructed from relevant plant attribute data. Such indices were also used in WA to allow comparisons with the results from other jurisdictions.
- Queensland does not have a site-based monitoring system; where ground data were available, they were collected for different purposes.
- Some derived indices of landscape function remain untested for their efficacy in detecting change, which limits confidence in reporting apparent change in landscape function. In Queensland, rapid traverse assessments provide useful information about status and change in vegetation but are not directly related to landscape function.
- The implementation of Queensland's Rural Lands Lease Strategy should improve that state's capacity to report change in its rangelands. Such reporting will likely include a remote-sensing component based on State-wide Landcover and Trees Study (SLATS) data to estimate change in groundcover (eg differences in grass and soil cover), which is proving to be a useful indicator for a number of purposes (see the Biodiversity theme).
- In the future, some jurisdictions may consider collecting additional data directly related to landscape function as an expansion of their existing pasture-monitoring programs, thereby improving the consistency of landscape function reporting across all rangelands. To improve confidence in reporting, the ACRIS-MC could also facilitate testing of the robustness of different landscape function indices derived from available rangeland monitoring data.

Sustainable management

Sustainable management can be evaluated by assessing changes in:

- critical stock forage
- the species available as forage
- the distance stock travel for water
- the occurrence of exotic weeds.

Grazing of native pastures is the most extensive commercial land use in the rangelands. Managing those native pasture systems to keep them intact and highly functional in the long term is a major challenge. Such management is needed to:

- enable continued production
- prevent further loss of biodiversity, particularly those components vulnerable to total grazing pressure

Figure 3.10 Bladder saltbush (*Atriplex vesicaria*) — a chenopod shrub

Bladder saltbush is a component of critical stock forage in the Riverina bioregion of the NSW rangelands.

Photo: NSW Department of Environment and Climate Change

- assist future marketing of food and fibre by maintaining the 'clean and green' image of Australia's rangeland products
- avoid the need to repair damaged landscapes, which is usually so expensive that rehabilitation may not be economically viable.

Critical stock forage

Change in critical stock forage (ie in the abundance of those plants vital for sustaining livestock production) is one of the most important elements of sustainable management of the rangelands. State and territory pasture-monitoring programs are actively monitoring regional changes in critical plant species.

In monitoring, emphasis is placed on longer-lived 'decreaser' species (ie those known to decline with moderate to heavy grazing) to help reduce the influence of recent seasonal conditions (ie *seasonal quality* effects). Longer-lived decreaser species are typically chenopod shrubs (Figure 3.10) in the southern rangelands and mainly palatable perennial grasses (Figure 3.11) in the northern rangelands, where they are referred to as '2P' grasses (palatable and perennial) or, in Queensland, as '3P' grasses (palatable, perennial and productive). Decreaser species are important indicators of the ability of pastures to sustain livestock production.

Another important indicator of pasture sustainability is the presence of those forage species known to increase with heavy grazing (ie 'increaser' species). A disproportionate increase in those species following good seasons, particularly at the expense of decreaser species, suggests that current grazing practices are not sustainable. Conversely, an improvement in decreaser species and a decline in increaser species, especially after below-average seasons, indicates that current grazing management practices are sustainable.

Figure 3.11 Barley Mitchell grass (*Astrebla pectinata*) — a palatable perennial grass

Mitchell grass is an important component of critical stock forage in the Mitchell Grass Downs bioregion of northern Australia.

Photo: NT Department of Natural Resources, Environment and the Arts

Monitoring levels of forage utilisation can also indicate whether current grazing management practices are sustaining stock. Individual animal performance declines at high forage utilisation rates where pressure is increased on palatable forage species. This is particularly important in much of northern Australia, where cattle are now routinely fed nitrogen-based supplements to increase the digestion and nutritional value of low-quality forage. Levels of pasture utilisation are the basis for pasture monitoring across rangeland bioregions in Queensland.

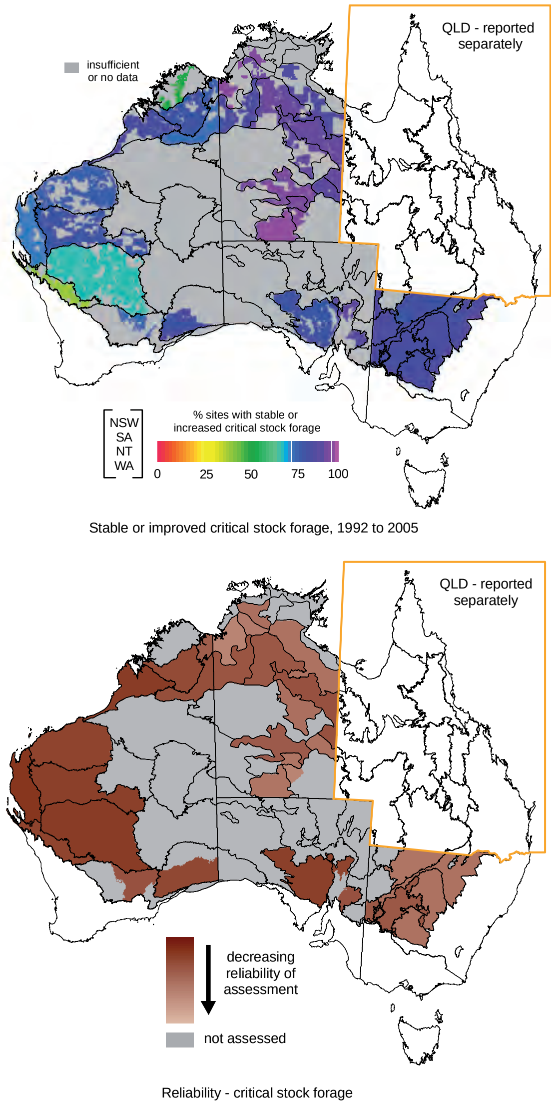
Changes in stock forage: site-based monitoring

As for landscape function, two sets of maps are used to report changes in critical stock forage: overall or gross changes, and seasonally adjusted changes.

Gross change — all seasons

For NSW, SA, the NT and WA, a score that shows site-based changes in the indicator of critical stock forage is mapped (Figure 3.12, top). The score reflects the percentage of monitoring sites reassessed in each bioregion that were either stable or where forage indicators had increased during the 1992–2005 period (see Box 3.2 for details). Mapped change

Figure 3.12 Gross changes in forage species at monitoring sites in NSW, SA, the NT and WA, 1990s to 2005, and reliability in reporting change in critical stock forage



Top: Gross changes in forage species between the 1990s and 2005 recorded at monitoring sites in NSW, SA, the NT and WA.

Bottom: Reliability in reporting change in critical stock forage based on site data from each bioregion.

Note: Bioregions are excluded from reporting where fewer than 12 sites were available for assessment. Where monitoring sites within some IBRA bioregions are confined to particular sub-IBRA regions, reporting is at the sub-IBRA level. Non-pastoral areas within each bioregion are masked out (not assessed).

Data sources: see Box 3.2. Maps compiled by the ACRIS-MU.

Box 3.2 Rangeland monitoring of stock forage

Site-based data used for reporting change in critical stock forage in WA, SA, NSW and the NT are a subset of those used for landscape function, namely:

- WA: Western Australian Rangeland Monitoring System (WARMS) sites. Change in the seasonally interpreted frequency of decreaser (2P) grasses in the northern grasslands and change in the density of longer-lived decreaser shrubs in the southern shrublands. Relative change in the companion measure of increaser species across monitoring sites provides additional information.
- NSW: Rangeland Assessment Program (RAP) sites. Seasonally interpreted change in the frequency of selected 2P grass species at RAP sites.
- SA: Pastoral Monitoring System sites in the southern (sheep-grazed) rangelands. As for WARMS shrubland sites, seasonally adjusted changes in the density of perennial decreaser shrubs are used to indicate management effects on critical stock forage.
- NT: Tier 1 sites. Seasonally interpreted change in the estimated biomass composition of 2P grasses. Composition is corrected for utilisation between the end of the growing season and time of assessment so that grazed sites are not penalised for the effects of short-term utilisation.
- Queensland: AussieGRASS. Modelled rather than site-based data are used, as Queensland has no operational monitoring system to measure species change in the rangelands. Sustainable management is based on AussieGRASS simulations of the relative levels of pasture utilisation at sub-IBRA resolution (see Rickert et al 2000 and Carter et al 2003 for further information on AussieGRASS). Lower levels of spatially averaged utilisation are considered more sustainable. Change in simulated space- and time-averaged utilisation is reported between two periods, 1976–90 and 1991–2005. The two periods show similar climate variability, so the effects of *seasonal quality* on change are accounted for to some extent. Where utilisation averaged over the two periods has remained relatively constant and conservative, as suggested by analyses presented in Hall et al (1998), or has decreased, grazing management is considered to be more sustainable. It is not possible to directly model change in individual species composition from utilisation rates.

applies to the local area represented by monitoring sites. An estimate of the reliability of the scores to accurately report change in stock forage is also mapped (Figure 3.12, bottom). The reliability scores were derived as for landscape function (Figure 3.7, bottom).

Most bioregions had a high proportion of monitoring sites (>70%) that indicated stable or increased levels of the stock forage indicator (Figure 3.12, top). This assessment has moderate or better reliability (Figure 3.12, bottom), although reliability was reduced in parts of central Australia, the northern Kimberley and the Gulf due to a low site density and a clumped distribution of monitoring sites.

Seasonally adjusted change

For NSW, SA, the NT and WA, Figure 3.13 illustrates changes in critical stock forage that have been adjusted for *seasonal quality*. The top panel indicates those regions with an increased percentage of sites with levels of the stock forage indicator relative to that expected after below-average seasons, and the bottom panel indicates where there was a decreased percentage relative to that expected after above-average seasons. An increased percentage suggests that critical stock forage is being sustained. The reliability of these indicators is presented in the bottom panel of Figure 3.12.

The various indicators of critical stock forage increased above levels expected following below-average *seasonal quality* on more than 20% of the sites in a number of regions (Figure 3.13, top), although most regions had too few sites sampled during below-average seasonal conditions to make a judgment. The largest increases were in the Ord Victoria Plain (WA), Yalgoo (WA) and Mitchell Grass Downs (NT) bioregions.

Stock forage decreased following above-average *seasonal quality* at more than 20% of sites reassessed in WA (Figure 3.13, bottom), including the Northern Kimberley NK1 sub-IBRA, Ord Victoria Plain bioregion and Eastern Goldfield sub-IBRA (Coolgardie bioregion). Smaller percentages of WARMS sites (10%–20%) had decreased levels of stock forage in the Central Kimberley, Dampierland, Gascoyne and Murchison bioregions. Smaller percentages (<20%) of reassessed sites within bioregions in the NT, SA and NSW also had levels of stock forage below those expected following good seasons, although many bioregions lacked suitable data for reporting change.

The reported results apply to the local area of sites, not the entire area of each bioregion. For example, there is evidence from WA that parts of the landscape separate from that monitored by WARMS have different trajectories of change over time (Pringle et al 2006).

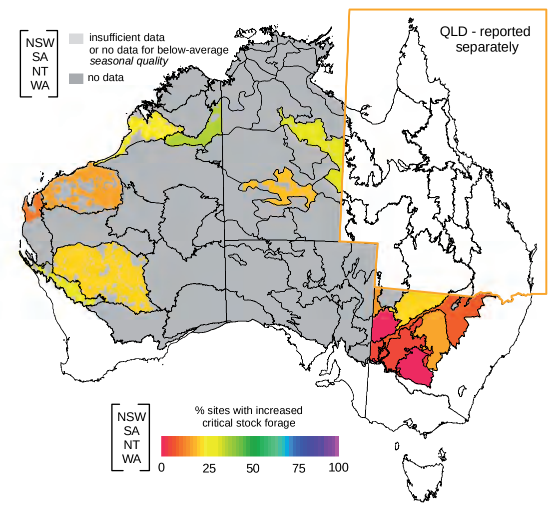
Changes in stock forage: AussieGRASS simulations

In Queensland, changes in stock forage were assessed across rangeland bioregions using estimates of pasture utilisation based on AussieGRASS model simulations (Box 3.2). Mapped results illustrate levels of space- and time-averaged pasture utilisation between 1991 and 2005, and change in pasture utilisation between 1976–1990 and 1991–2005.

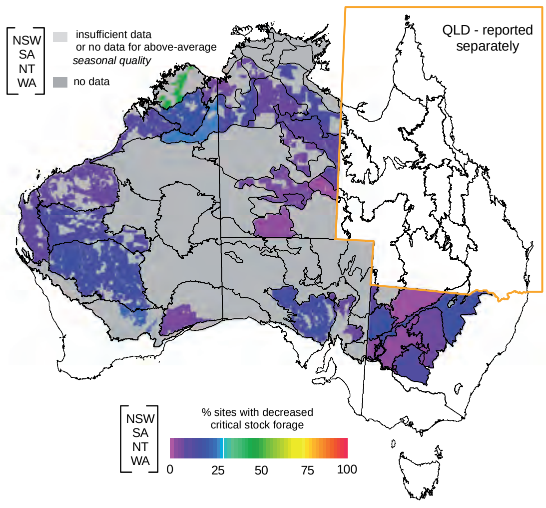
Sustainability of pasture utilisation, 1991–2005

Most of the Brigalow Belt North and South, Cape York Peninsula and Einasleigh Uplands bioregions had utilisation levels below the specified safe threshold (Figure 3.14), which suggests that levels of stock forage were being sustained. Three sub-IBRAs in the Mitchell Grass Downs (Barkly Tableland, Georgina Limestone and Northern Downs), the Simpson Desert and Dieri sub-IBRAs of the Simpson–Strzelecki Dunefields,

Figure 3.13 Seasonally adjusted changes in forage species across rangeland regions



Increase in critical stock forage following below-average *seasonal quality*



Decrease in critical stock forage following above-average *seasonal quality*

Note: Mapped change applies to the local area represented by monitoring sites. Note that the colour scheme is reversed between the two maps so that in each case the blue-purple end of the colour scheme represents the more positive outcome. In the top map, any value above 0% is regarded as a positive result.

Data sources: see Box 3.2. Maps generated by the ACRIS-MU.

and the Wellesley Islands (Gulf Plains bioregion) also appeared to have sustainable levels of pasture utilisation. The reliability of those assessments is presented in Figure 3.15.

Spatially averaged levels of simulated pasture utilisation were considerably above specified safe thresholds, indicating that they were unsustainable, throughout much of this period in the Desert Uplands, Mulga Lands and most of the Channel Country bioregions (Figure 3.14). Two sub-IBRAs of the Darling Riverine Plains (Culgoa–Bokhara and Warrambool–Moonie) and individual sub-IBRAs of other bioregions were also considered to have unsustainable levels of pasture utilisation. The other sub-IBRAs were Donors Plateau (Gulf Plains bioregion), Kynuna Plateau (Mitchell Grass Downs bioregion), Southwestern Plateaus and Floodouts and Mount Isa Inlier (Mount Isa Inlier bioregion), and Strzelecki Desert – Western Dunefields (Simpson–Strzelecki Dunefields bioregion). Levels of pasture utilisation were close to the safe threshold, and hence marginally sustainable, for much of the Gulf Plains and parts of the Mitchell Grass Downs bioregions.

Pest animals, particularly feral goats and kangaroos, contributed substantially to total grazing pressure and high (unsustainable) levels of pasture utilisation in some bioregions, particularly the Mulga Lands.

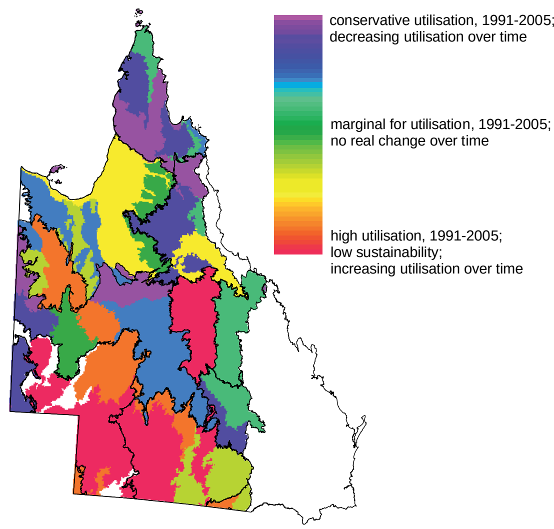
Spatial averaging of utilisation levels across sub-IBRAs conceals local variability. Within sub-IBRAs there were undoubtedly areas (paddocks and properties) with lower (more conservative) and higher (less sustainable) levels of pasture utilisation than that reported as an average over the sub-IBRA.

Changes in pasture utilisation from 1976–1990 to 1991–2005

Pasture utilisation decreased across much of the Cape York Peninsula, Gulf Plains and Mitchell Grass Downs bioregions over this time (Figures 3.14 and 3.16). A number of sub-IBRA regions also had notable decreases, including subregions in the Mount Isa Inlier, Mulga Lands, Darling Riverine Plains, Brigalow Belt South, Einasleigh Uplands and Simpson–Strzelecki Dunefields. Reasons for the difference between the two periods are complex but include better cattle management following the Brucellosis and Tuberculosis Eradication Campaign and a depressed cattle market in the second half of the 1970s, which caused stock to be held rather than sold, leading to prolonged high levels of utilisation.

In contrast, levels of forage utilisation increased between 1976–1990 and 1991–2005 in the Desert Uplands, the Channel Country and Brigalow Belt North bioregions (Figures 3.14 and 3.16), and in part of the Gulf Plains and Cape York Peninsula bioregions. Increased levels of pasture utilisation were likely associated with excessive grazing during periods of below-average rainfall, particularly between 2002 and 2005. Utilisation probably increased in areas where native vegetation was cleared and pastures were converted to exotic species.

Figure 3.14 Sustainable management of stock forage, Queensland, based on AussieGRASS simulations



Data source: John Carter, Queensland Department of Natural Resources and Water

Figure 3.15 Reliability in reporting levels of and changes in pasture utilisation as an indicator of stock forage, based on AussieGRASS simulations

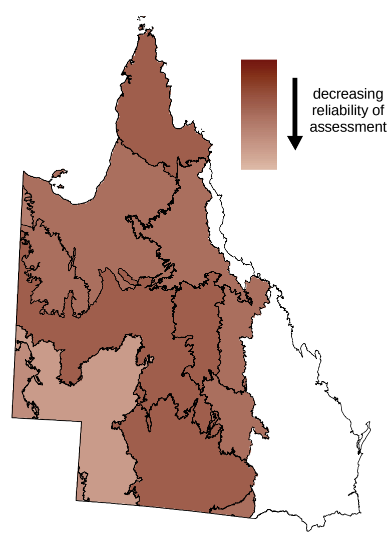
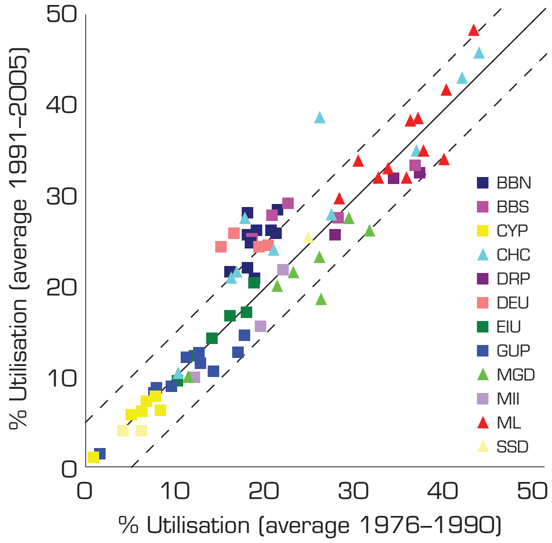


Figure 3.16 Spatially averaged levels of pasture utilisation for Queensland sub-IBRAs, grouped by bioregion



Note: Sub-IBRAs are grouped by bioregion, indicated by colour. The diagonal 1:1 line represents no change between the mean of the two time periods (1976–90 and 1991–2005). The parallel dashed lines represent 5% absolute change from the 1:1 line, so sub-IBRAs plotting above or below those lines had a substantial increase or decrease, respectively, in mean utilisation for the 1991–2005 period compared with 1976–90. Sub-IBRAs of more arid bioregions are shown with the ▲ symbol and have generally lower safe theoretical levels of pasture utilisation. Remaining sub-IBRAs (or bioregions) shown with the ■ symbol are in relatively wetter parts of the rangelands, and most can safely sustain higher levels of pasture utilisation compared with arid bioregions.

Data source: John Carter, Queensland Department of Natural Resources and Water

Caveats on reporting change based on AussieGRASS simulations of pasture utilisation

Interpretation of the forage utilisation changes in Queensland, based on AussieGRASS simulations, should take into account the following limitations:

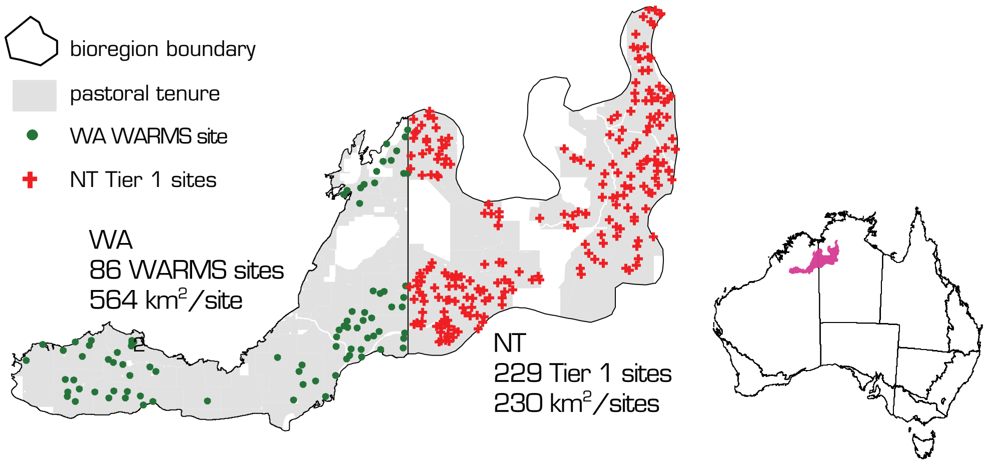
- Survey data on stock numbers sourced from the Australian Bureau of Statistics (ABS), which are essential to AussieGRASS simulations, are possibly inadequate in some areas, especially in the far west and on Cape York Peninsula, where there are few pastoral holdings.
- The safe utilisation level for the Mulga Lands bioregion was set at 20% rather than the 15% quoted in Hall et al (1998) to take into account grazing by macropods and feral animals (mainly goats), which was not included in Hall et al's original analysis.
- Data include conservation reserves and other areas without domestic stock, so actual utilisation rates on commercial holdings will tend to be higher than the average for sub-IBRA regions with significant areas of non-pastoral land.
- Trends in pasture production due to clearing and woodland thickening are likely to be positive and negative, respectively. Their effects are currently not well parameterised in AussieGRASS, and their net effect is uncertain.
- Part of the impact of clearing on pasture production is likely to be transient due to nitrogen dynamics.
- Long-term pasture dynamics resulting from increased atmospheric carbon dioxide levels and nitrogen dynamics resulting from reduced fire frequency have not been captured in this analysis. Their effects may be significant for changes in pasture utilisation.
- Even those sub-IBRAs with simulated levels of *average* utilisation below or close to the specified safe threshold could have problems in some areas because, by definition, half the sub-IBRA area will be running above the mean and half below the mean.

Regional reporting of change in critical stock forage

The Ord Victoria Plain bioregion straddles the WA–NT border, and change in critical stock forage is reported with a combination of WARMS (WA) and Tier 1 (NT) monitoring data (Figure 3.17).

In the WA portion of this bioregion, based on up to three cycles of monitoring at WARMS sites, 76% of reassessed site-by-time combinations had a stable or increased frequency of *decreaser* perennial (ie 2P) grasses over the 1992–2005 period (Table 3.4). The frequency of unpalatable *increaser* perennial grasses declined at 44% of reassessed sites. These two results suggest an improved level of critical stock forage and sustainable management during a period of generally above-average *seasonal quality*.

Figure 3.17 Location of WARMS (WA) and Tier 1 (NT) monitoring sites in the Ord Victoria Plain bioregion



Data sources: see Box 3.2.

Taking account of *seasonal quality*, the percentage of sites with an increased frequency of perennial grasses following *poorer* seasons was better for decreaser (2P) grasses than increaser (unpalatable) species (Table 3.4; 38% compared to 29%). Where decline occurred, it occurred for increaser species at a higher percentage of sites than for decreaser species (36% compared to 25%). Following *better* seasons, a smaller percentage of reassessed sites had a reduced frequency of decreaser species compared with increaser species (26% compared to 48%). These seasonally interpreted results confirm a generally improved level of critical stock forage at WARMS sites. However, this conclusion cannot be extrapolated to the whole of the WA portion of the Ord Victoria Plain bioregion. Pringle et al (2006) have shown in another rangeland region that parts of the landscape separate from those monitored by WARMS have different trajectories of change over time.

Table 3.4 Percentage of reassessed WARMS sites showing change in frequency of decreaser, intermediate and increaser perennial grass species for the WA part of the Ord Victoria Plain bioregion

Seasonal quality	Species group	Decline: frequency < 0.90	No change: 0.90 ≤ frequency < 1.10	Increase: frequency ≥ 1.10
All years	Decreaser	25	43	33
	Intermediate	31	15	53
	Increaser	44	17	39
Above average	Decreaser	26	44	30
	Intermediate	27	15	57
	Increaser	48	15	37
Average	Decreaser	18	43	39
	Intermediate	75	8	17
	Increaser	n.a.	n.a.	n.a.
Below average	Decreaser	25	38	38
	Intermediate	n.a.	n.a.	n.a.
	Increaser	36	36	29

n.a. = not applicable (fewer than 10 sites available)

For the NT portion of the Ord Victoria Plain bioregion, the percentage composition (by biomass) of 2P grasses remained stable or increased at 86% of sites (Table 3.5, data pooled across all initial 2P-grass categories). However, it is not possible for sites with an initial high composition of 2P grasses to show further improvement; nor can sites with a low percentage composition show much further decline. To further investigate grazing effects, 2P-grass composition at the first assessment for each site was subdivided into categories of high, medium and low 2P composition, and subsequent changes were interpreted in relation to those categories.

Following *better* seasons, 2P grass composition *increased* at 39% of sites that had an initial low composition of those species (Table 3.5). 2P grass composition *decreased* further at 6% of sites at that time. For sites with an initial medium composition of 2P grasses, *improvement* and *decline* occurred at an equal proportion (25%) of sites. Of some concern was the *decrease* in 2P grass composition at 24% of sites with a high initial composition of 2P grasses following *better* seasons.

Very few sites were reassessed following below-average *seasonal quality*, so it is not possible to report change when (or if) that group of sites was under greater climatic stress.

The available data for the NT suggest that, after taking account of seasonal conditions, levels of stock forage at monitoring sites have been generally stable or shown a slight improvement and that grazing management was generally sustainable over the 1992–2005 period.

Key points

- Reporting of change is restricted to areas of pastoral tenure in WA, SA and the NT. Pastoral tenure is more widespread in NSW and Queensland, and reporting applies to those states' areas of rangeland more generally.
- Because of their pastoral origins, site-based monitoring programs provide direct evidence of changes in critical stock forage; those data have a moderate to high reliability in reporting change. Change results apply to the local site area and not to the whole of each pastorally significant bioregion.
- Queensland reporting is based on change in time- and space-averaged modelling of pasture utilisation. While this provides complete spatial coverage and retrospective analysis, it is not possible to compare reported change for Queensland directly with that in other jurisdictions.

Table 3.5 Percentage of reassessed Tier 1 sites showing change in composition (by biomass) of 2P grasses for the NT part of the Ord Victoria Plain bioregion

2P grass contribution at time of first assessment	*Seasonal quality*	Decline: >20% decrease in 2P grasses	No change	Increase: >20% increase in 2P grasses
	All years	14	61	25
High 76%–100% of ungrazed pasture biomass	Above average	24	76	0
	Average	10	90	0
	Below average	0	100	0
Medium 41%–75% of ungrazed pasture biomass	Above average	25	50	25
	Average	4	46	50
	Below average	0	100	0
Low 0%–40% of ungrazed pasture biomass	Above average	6	55	39
	Average	24	71	6
	Below average	n.a.	n.a.	n.a.

n.a. = not applicable (fewer than 10 sites available)

- Comparison of changes in critical stock forage across all the rangelands remains a problem. Site-based reporting is more reliable locally, but reporting across a bioregion requires spatial averaging that hides variations within a region (eg half the area is performing better and half poorly, with some of it much more poorly). Furthermore, site-based monitoring can only reflect change in those local areas where monitoring sites are located. Modelling can be valuable, but inferences must be drawn as to what is really happening on the ground, which can only be confirmed by field-based checks.
- Notwithstanding these limitations, monitoring of changes in critical forage available for livestock assists in indicating whether pastoral land management is sustainable.

Pastoral plant species richness

Change in the number of different kinds (ie the richness) of pasture plant species assists in indicating the sustainability of pastoral land management. As a general rule, increased richness of native pasture species indicates grazing land with a positive trend because stock have a greater choice in selecting the most nutritious forage (Figure 3.18). This greater choice translates to increased individual animal performance (Purvis 2004).

Changes in pastoral plant species richness

Information on the richness of pasture plants is recorded from state and territory pasture-monitoring sites. Suitable data are available from WA and NSW but not from SA, Queensland and the NT. The WA and NSW data are presented in two sets of maps to report changes in native plant species richness, the first illustrating overall or gross changes and the second showing changes that have been adjusted for *seasonal quality*. Changes were computed using repeated assessments on pastoral monitoring sites (Box 3.3). An estimate of the reliability of the changes in plant species richness for each bioregion is based on site density, spatial distribution of sites, whether data are quantitative or qualitative, and the suitability of the available data for reporting change in species richness.

Figure 3.18 Central Australian cattle on pasture of perennial grasses and annual herbage species

A diverse pasture of palatable perennial grasses and annual herbage species provides these central Australian cattle with considerable choice to select the most nutritious forage plants.

Photo: CSIRO, Alice Springs

Gross change — all seasons

In WA, native plant species richness was maintained or increased on more than 75% of reassessed sites in all IBRA bioregions or sub-IBRA regions (Figure 3.19, top), except for the VB1 sub-IBRA of the Victoria Bonaparte bioregion, where about 70% of sites were either stable or had increased species richness. All NSW bioregions with enough sites to report change had more than 80% of reassessed sites with maintained or increased plant species richness. The reliability of reported changes for site areas is high in WA and moderate in NSW (Figure 3.19, bottom).

Seasonally adjusted change

Native plant species richness increased following below-average *seasonal quality* for a substantial percentage (≥20%) of reassessed sites (Figure 3.20, top), notably in the Dampierland, Ord Victoria Plain, Pilbara and Nullarbor (NUL2 sub-IBRA) bioregions of WA and in the Darling Riverine Plains bioregion in NSW. However, in many regions too few sites were sampled during below-average seasonal conditions to make an assessment.

Box 3.3 Rangeland monitoring of plant species richness

A species richness score reflecting changes between site assessments can be calculated as:

(number of species found on the site at Date 2) / (number of species at Date 1)

A score greater than 1.0 reflects increased richness, and less than 1.0 indicates decreased richness. This score will mostly range around 1.0, plus or minus ~0.3. The percentage of sites having increased richness versus those having decreased richness can be tabulated, expressed as a percentage change, and mapped.

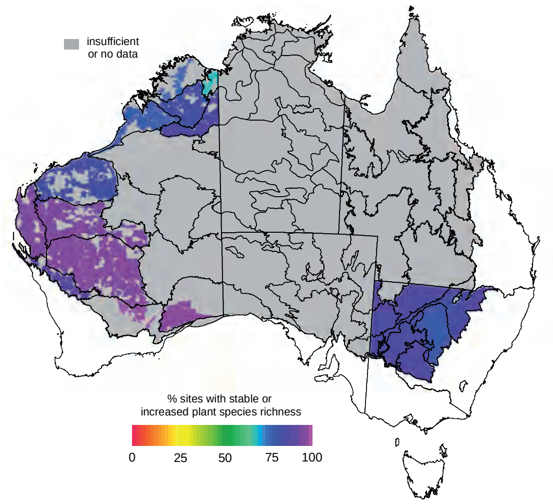
In WA, only perennial plant species are recorded on WARMS sites in order to dampen the effects of seasonal quality. For this analysis, only native plant species were included, so an increase in richness represents an increase only in that component of sustainable management, except in cases where contributing species may be less desirable native woody species.

In NSW, species richness data are based on the number of native herbage species (both perennial and annual) recorded at RAP sites. Sites were assessed before the dominant growing season in each year (spring in the north, autumn in the south), and the data generally reflect the 'worst case' situation (ie before opening rains promoted new germination and an increase in species richness). The principal source of error for RAP sites arises from observers recording groups of species to the genus level only, thereby underestimating species richness.

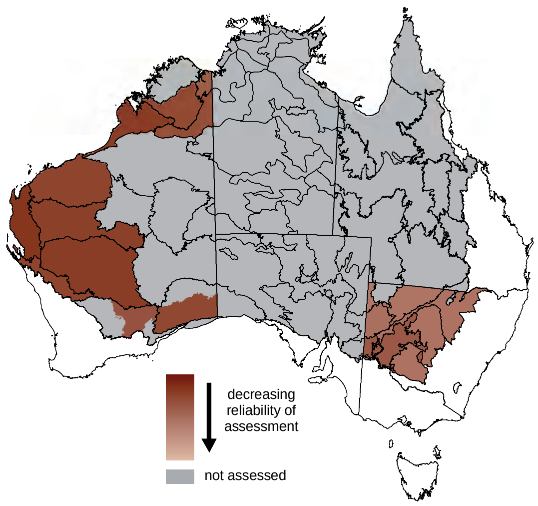
Although species richness is recorded somewhat differently on WA and NSW monitoring sites, changes were reported by presenting the percentage of sites that had changed beyond a specified threshold value. Bioregions were excluded from reporting if they did not have at least 12 sites that had been reassessed.

For SA and the NT, available plant species data were either insufficient or unsuitable for reporting changes in richness.

Figure 3.19 Percentage of sites with stable or increased richness of native plant species and reliability of reporting, by bioregion



Stable or improved species richness of native plant species



Reliability - species richness of native plants

Top: Percentage of sites in each bioregion where richness of native plant species was maintained or increased (based on pasture-monitoring site records).

Bottom: Reliability in reporting change in plant species richness, by bioregion.

Note: Mapped change applies to the local area represented by monitoring sites. For WA, reporting is by sub-IBRA where monitoring sites are confined to particular sub-IBRAs within a bioregion, and non-pastoral areas within bioregions are masked out (not assessed).

Data sources: see Box 3.3. Maps compiled by the ACRIS-MU.

In contrast, plant species richness decreased at sites when an increase was expected because of above-average *seasonal quality* in the Victoria Bonaparte (VB1 sub-IBRA), Dampierland and Northern Kimberley (NK1 sub-IBRA) bioregions (Figure 3.20, bottom), and in the Broken Hill Complex bioregion in NSW.

Key points

An analysis of pasture species richness data revealed that:

- the richness (or diversity) of native plant species was useful for reporting changes in the vegetation available for grazing
- available site-based data are largely restricted to pastoral monitoring sites in WA and NSW, and thus provide a very limited perspective on rangeland-wide change as an indicator of sustainable management.

The demonstrated value of plant richness data to report on changes in grazing management would be further enhanced by an expansion of monitoring capacity.

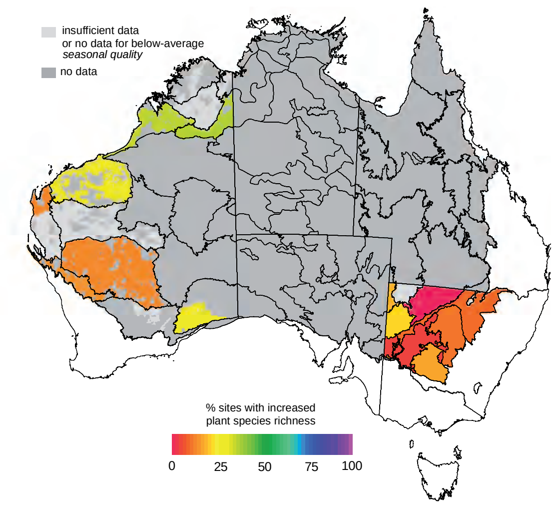
Distance from water for stock

The distance from water for stock is one of the critical elements in sustainably managing the rangelands. Data on the proportional area of sub-IBRAs within 3 km of stock water (Box 3.4) indicate the density or level of waterpoint development. Three kilometres from water is well within the grazing range of sheep and cattle, so that distance is a key surrogate indicator for the pressure that stock impose on the land. Essentially, grazing pressure is a function of distance from water. For a given land type, areas closer to water are subject to far more grazing pressure than water-remote areas because animals stay near water.

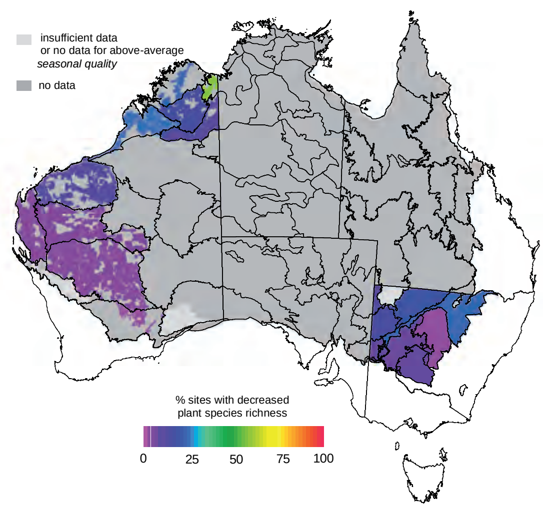
Background

The introduction of pastoralism meant that tens of thousands of artificial waterpoints were installed so that available forage would be within the walking distance of livestock from permanent water (Figure 3.21). Environmental damage is generally found close to water, where stocking and grazing pressures are highest.

Figure 3.20 Seasonally adjusted changes in native plant species richness based on pasture monitoring records



Increase in plant species richness following below-average *seasonal quality*



Decrease in plant species richness following above-average *seasonal quality*

Top: Percentage of sites in each bioregion where there was an increase in the species richness measure despite antecedent below-average *seasonal quality.*

Bottom: Percentage of sites in each bioregion where there was a decline in species richness despite antecedent above-average *seasonal quality*.

Note: Mapped change applies to the local area represented by monitoring sites. The colour scheme is reversed between the two maps so that in each case the blue-purple end of the colour scheme represents the more desirable outcome. For the top map, any value above 0% indicates a favourable outcome. Reliability is indicated in Figure 3.19 (bottom).

Data sources: see Box 3.3. Maps compiled by the ACRIS-MU.

Figure 3.21 Liquid gold

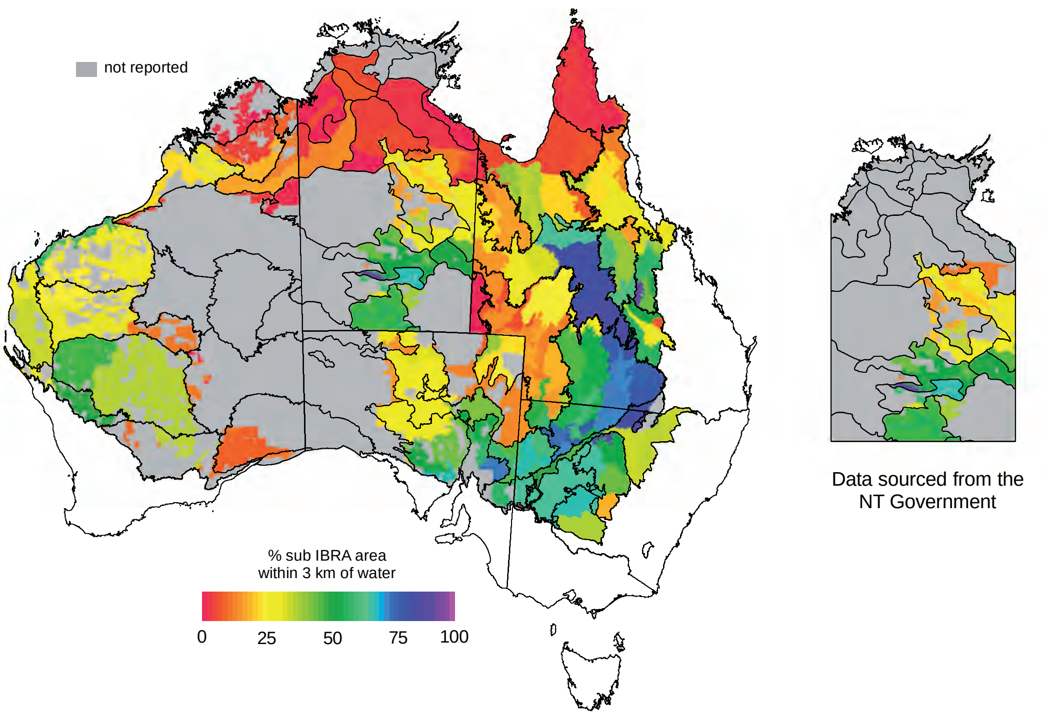
Adding waterpoints brings water closer to better feed and increases animal production but can be detrimental to biodiversity.

Photo: Jonathan Condon

Factors that control the distance from water that livestock will graze include the type and class of stock; the palatability and nutritional value of forage; the salinity of the drinking water; physical barriers that hinder grazing access; the ambient temperature; and the time of year. During the wet season in the north and during winter months in the south, livestock are able to survive either without free-standing water or by drinking from ephemeral pools, claypans and other depressions. During those wetter periods, stock can graze much further from permanent water. Therefore, there is no hard and fast threshold distance from water beyond the range of grazing animals; as a general rule, sheep will graze out to about 5 km from water and cattle to about 8 km.

A strategic distribution of waterpoints will spread livestock over an area, lowering grazing pressure and decreasing the risk of environmental damage near water. This involves making water available closer to the better feed, rather than forcing stock to walk to feed on a more-or-less daily basis. Overall grazing

Figure 3.22 Percentage of sub-IBRA area within 3 km of stock water in pastorally productive rangelands



Note: If less than 25% of a bioregion's area is grazed, sub-IBRAs within the region are not mapped. In WA, SA and the NT, mapped results apply only to lands with pastoral leases.

Data sources: see Box 3.4. Maps: ACRIS-MU.

Box 3.4 Water in the rangelands

In SA and the southern NT, water available for stock was calculated as the area within 3 km of waterpoints (bores, tanks on pipelines, dams and some natural sources). The SA database includes the locations of larger natural waters that are significant for grazing, especially in the northern pastoral lands. Distance from water was converted to area by accounting for fences and other natural barriers (eg salt lakes, mountain ranges) that restrict grazing access. This area represents distance from water for stock, not straight-line access as for birds.

In SA, the database of waterpoint and fence infrastructure is held and maintained by the SA Department of Water, Land and Biodiversity Conservation. In the southern NT, the waterpoint and fences database is maintained by the NT Department of Natural Resources, Environment and the Arts. Data were available for the pastoral country in SA and the Alice Springs and Barkly pastoral districts in the NT. Because ages of most waterpoints were unknown, it was not possible to report changes in the area within 3 km of stock waterpoints.

In WA, the area 3 km from the digitised locations of waterpoints (bores, tanks on pipelines, dams and some natural sources of water) was calculated without regard for fencelines and other natural barriers that restrict grazing access, and so represents the straight-line distance from water. This method was used because many waters are near a fence, especially a corner, and water is typically available in all adjoining paddocks; and some fences in the southern rangelands are now in disrepair and no longer provide an effective barrier to stock movement. For WA, these calculations were done for pastoral land only, so that the maps of the percentage of sub-IBRA area within 3 km of water refer to the percentage of pastoral land within the sub-IBRA. Watered-area data were supplied by the WA Department of Agriculture and Food. For WA, it is possible to report gross changes in watered area from the mid to late 20th century, but not over the 1992 to 2005 period.

In NSW, Queensland and the northern NT, data on bores and dams were extracted from Geoscience Australia's Geodata Topo 250K vector product (Series 3, June 2006). These data were screened to remove disused and other non-functional waterpoints, such as those with excessively saline water. The proportional area of sub-IBRAs within 3 km of waterpoints was then calculated. As for WA, this calculated area did not take account of fences; nor is it possible to report change in watered area.

With the exception of SA, these analyses do not include rigorous checking of the locations of all natural waters. Such waters can provide additional sources of water for stock, particularly following good rains. This is particularly the case in the early dry season for northern bioregions.

pressure is only reduced where livestock numbers are maintained as waterpoints are added. If stock numbers are increased, overall grazing pressure will rise.

An increased density of waterpoints also means that the potential for spelling country is improved with the ability to turn off waters at certain times. The extent to which this potential is realised varies considerably, as stock will often walk considerable distances to graze known areas of more palatable or nutritious forage. Additional fencing to control animal movements may be required to effectively spell country by fencing animals out of paddocks.

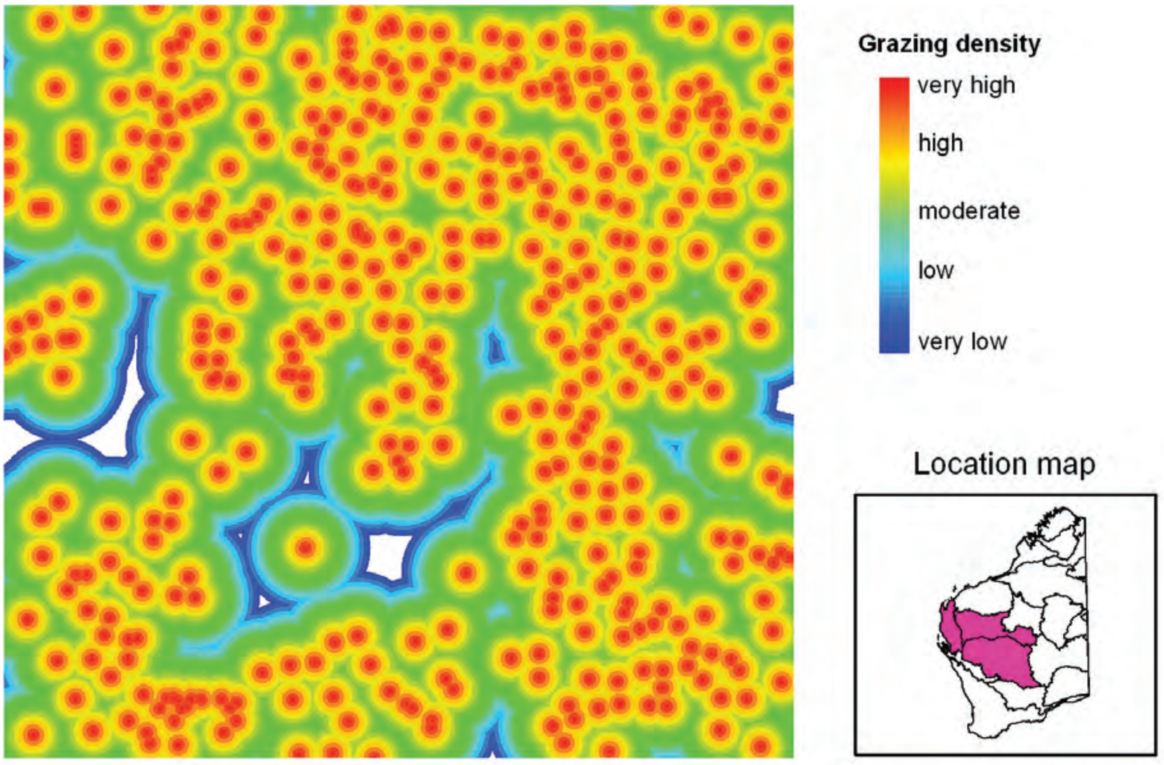
Ready access to water creates both winners and losers in terms of biodiversity. Biodiversity is generally better protected in areas remote from water and, from this perspective, increased density of waterpoints poses a threat to biodiversity (see the Biodiversity theme in this section of the report).

Water for stock: current status

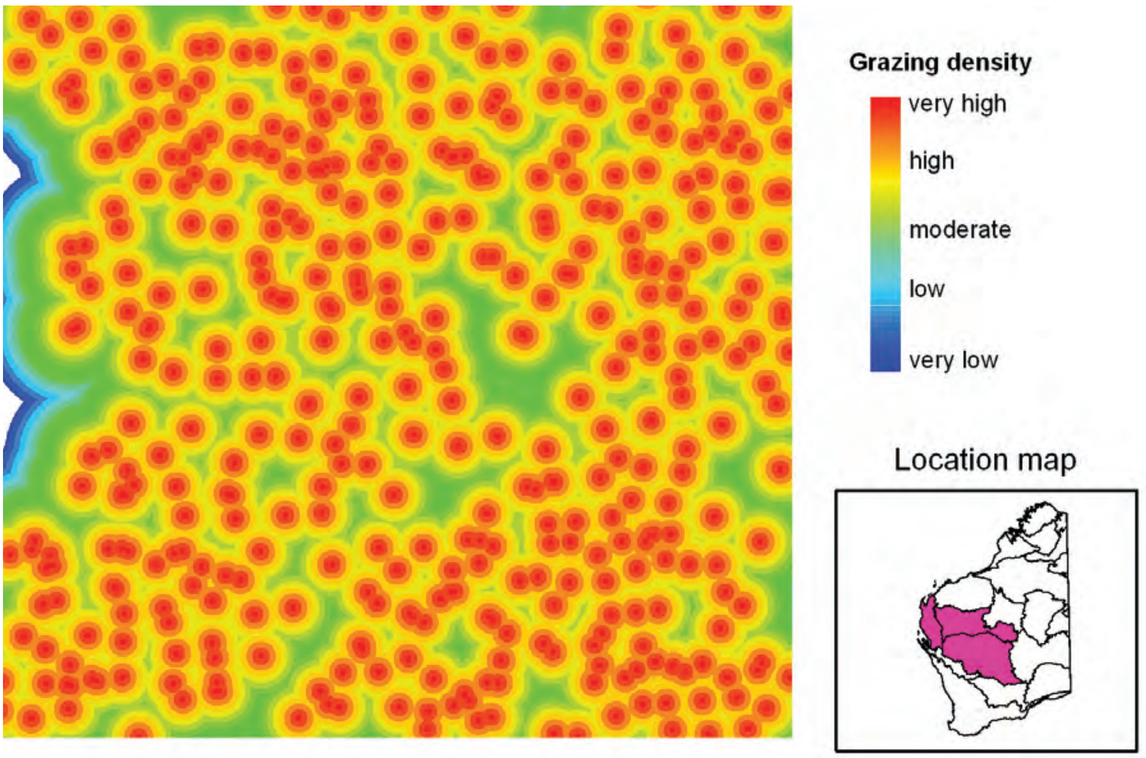
Across Australia's rangelands, there are regional differences in the proportional area within 3 km of stock waterpoints (Figure 3.22). In SA, sub-IBRAs in the southern rangelands (ie the Riverina, Flinders

Figure 3.23 Change in waterpoint density for a sample area in the Gascoyne–Murchison region, WA, circa 1950 to circa 1990

Distance from permanent water circa 1950 for a sample of the Gascoyne–Murchison region



Distance from permanent water circa 1990 for the area shown above



Data sources: Watson et al (2005a). Maps produced by the WA Department of Agriculture and Food.

Lofty Block, Murray-Darling Depression, Broken Hill Complex and Gawler bioregions) are much more intensively watered than those of the interior.

In the southern NT, sub-IBRAs within the MacDonnell Ranges, Burt Plain and Finke bioregions have the highest waterpoint densities, with densities decreasing towards the 'desert' bioregions (ie Tanami, Simpson–Strzelecki Dunefields) and to the north. In the northern NT, there is generally a low percentage (<10%) of sub-IBRA area within 3 km of artificial sources of stock water. This probably reflects the increased abundance of naturally occurring permanent and semipermanent water.

In WA, sub-IBRAs with the highest percentage area within 3 km of water include Roebourne (Pilbara IBRA, 59%), Tallering (Yalgoo IBRA, 51%) and Western Murchison (Murchison IBRA, 49%). The percentage of sub-IBRA area within 3 km of artificial water sources decreases from west to east towards the deserts (and including the Nullarbor bioregion) and to the north (the Kimberley), where there is a greater abundance of natural waters.

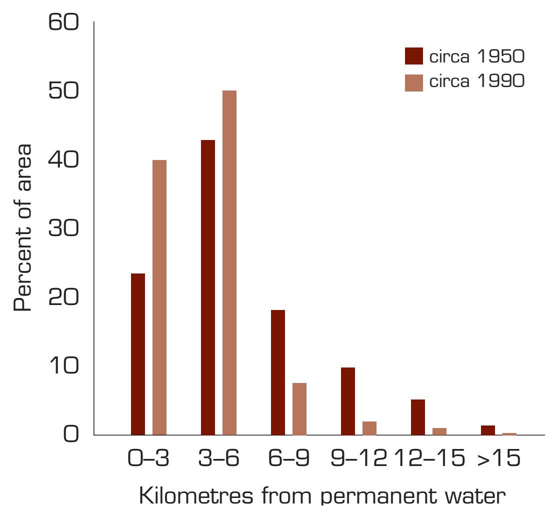
In NSW, a high percentage of the area of most sub-IBRAs is within 3 km of stock water, with the highest percentage in the Mulga Lands. The lowest density of stock waterpoints is in the Simpson–Strzelecki Dunefields.

In Queensland, the density of stock waterpoints is highest in the centre (sub-IBRAs of the Mitchell Grass Downs and Mulga Lands bioregions) and decreases to the north and west. There is a greater availability of natural water sources in the north (Cape York and Gulf country), which reduces dependence on bores and dams for watering stock. Surface waters are more plentiful across parts of the Channel Country bioregion following floods.

The percentage of sub-IBRA area within 3 km of stock water is probably understated for much of the Great Artesian Basin in western Queensland and northwestern NSW. Large areas were formerly watered by bore drains from freely flowing bores. Those bores are being progressively rehabilitated and capped to regulate their flow, and bore drains are being replaced with piped water as part of the Great Artesian Basin Sustainability Initiative.[13]

[13] See http://www.daffa.gov.au/natural-resources/water/great-artesian-basin (accessed 3 July 2007) or http://www.nrw.qld.gov.au/water/gab/gabsi.html (accessed 3 July 2007)

Figure 3.24 Percentage area at different distance classes from water, for a sample area in the Gascoyne–Murchison region, WA, circa 1950 to circa 1990



Data and graph: Watson et al (2005a)

Change in the availability of water for stock

In the absence of detailed and accurate information on when waterpoints were established, it is not possible to report changes in the availability of water for stock over the full 1992–2005 reporting period. However, data available for a few areas, such as the Gascoyne–Murchison region in WA, can be used to show how the distribution of stock waterpoints has changed through the 20th century.

During World War II, the then WA Department of Lands and Surveys collated information on pastoral leasehold infrastructure. Maps showing that infrastructure were released through the 1950s at a scale of 1 inch to 10 miles (1:633 600). The maps provide an opportunity to compare waterpoint distribution from around 1950 with waterpoint distribution around 1990, for example, in the Gascoyne–Murchison region (Figure 3.23).

In the sample area (Figure 3.24), there was less land at greater distances from water and more land close to water in the 1990s than in the 1950s. This pattern was found across all land types, although the change was most pronounced in the more highly productive and fragile systems. On only one land type (the resilient and low-productivity 'Sandplains and occasional dunes with spinifex grasslands' type) was stock waterpoint distribution largely unchanged since the 1950s (Watson et al 2005a).

Key points

An analysis of waterpoint data found the following:

- Distance data were directly available from state and territory agencies for pastorally tenured land in WA, SA and parts of the NT. Distance from stock water elsewhere was calculated using other nationally available waterpoint data.
- It is not possible to report change in the watered area (at least not in the short term), as most waterpoints are not attributed for age. Providing this necessary attribute would require considerable investment, and it is unlikely that an improved ability to report change in either waterpoint distribution or watered area can be achieved in the short term.

These findings raised important issues:

- Waterpoint data were sourced from state/territory agencies and from national sources. Where the two sets of data overlapped, there were considerable differences, and the state/territory data appeared to be more current, accurate and reliable.
- The distribution and management of stock waterpoints has important implications for conflicts between increasing livestock production, sustainable resource use and improving the conservation of biodiversity.
- For future investments in waterpoint data acquisition and analyses, it would be useful to be able to report waterpoint distributions for sustainable management of both stock and biodiversity. Perhaps the most important issue is how grazing is managed near waterpoints, rather than the number and distribution of waterpoints.

Invasive weeds

There is limited capacity to report the effects of invasive weeds on sustainable management because information to report changes in weed distributions and abundances across the rangelands is scarce. Some information (eg maps of weed distributions) is available on the world wide web.

Background

According to the ABS (2006), the most commonly reported natural resource management (NRM) issue and activity on Australian farms is 'weeds and pests'. The CRC for Australian Weed Management estimated that the cost of weed control in the rangelands between 1997 and 2004 was approximately $80 million (Grice and Martin 2005).

Introduced weeds can reduce grazing value, may be poisonous to livestock, may contaminate agricultural produce and are expensive to control. They can also alter and degrade habitats and threaten biodiversity. Control of weeds and habitat restoration is costly, so restricting the spread of existing populations and preventing further invasions is a high priority.

Sources of information

Updated information on invasive weeds is available for a select number of weeds against the following national indicators:

- extent, density and distribution
- impact on assets (both productive and ecological assets)
- extent of active management.

These weeds include the Weeds of National Significance (WoNS), the list of weeds that were nominated for assessment as WoNS but did not make the shortlist (WoNS candidates), the National Environmental Alert List and the Agricultural Sleeper list.[14]

The Biodiversity section of this report provides additional information on Australia's rangeland weeds, including identification of 11 important invasive species as 'transformer weeds' in a number of different rangeland ecosystems (Table 3.8).

Examples of invasive weeds

Draft maps of the distribution and density of invasive weed species have been produced at a national scale of 1:100 000. For example, the extent and distribution of mesquite (*Prosopis* spp.) and parkinsonia (*Parkinsonia aculeata*; Figure 3.25) have been mapped at that scale (Figure 3.26). Where data are available, finer resolution

[14] NLWRA website: http://www.anra.gov.au (accessed 3 July 2007); Weeds of National Significance website: http://www.weeds.org.au/natsig.htm (accessed 3 July 2007).

Figure 3.25 Parkinsonia (*Parkinsonia aculeata*) infestation

Parkinsonia currently infests over 8000 km^2 of land, mainly along watercourses, in WA, Queensland and the NT. Left untreated, it displaces native vegetation and reduces access to land and waterways.

Photo: Colin G Wilson and the Department of the Environment, Water, Heritage and the Arts

maps have been produced at 1:25 000 and 1:50 000 scale and are available from individual jurisdictions.

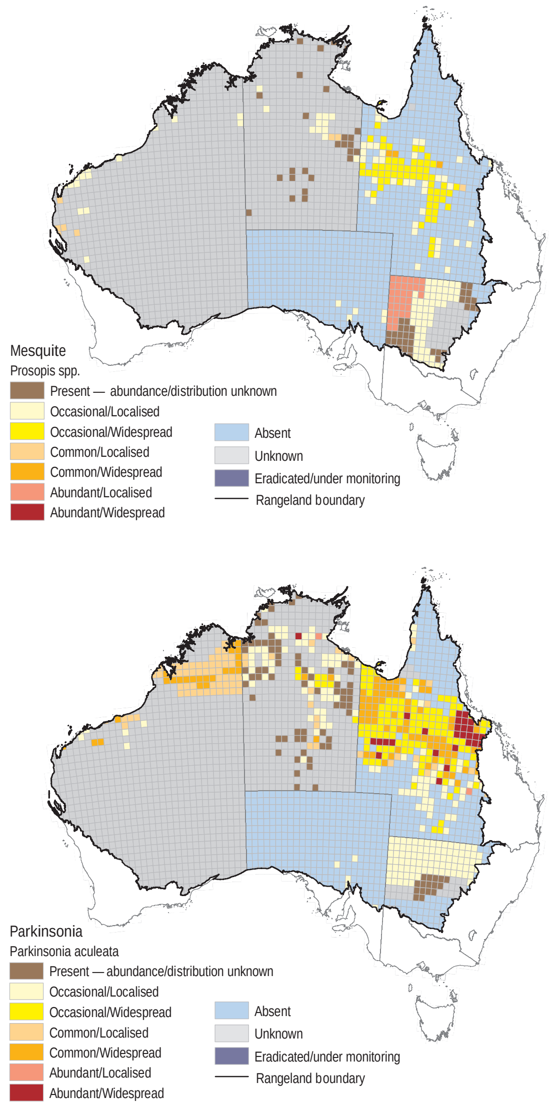
Maps of weed distributions will help governments, land managers and regional groups determine priorities for action and monitor the impact of weed management action on the distribution and density of particular invasive species. If additional weed species are identified as being important in the rangelands, they can also be included in future assessments and mapped at the relevant scale.

Invasive weed management

At the national scale, the Natural Heritage Trust and the National Landcare Program have invested heavily in weed research and management, with resources being used by regional NRM and Landcare groups to control both weeds of production and weeds that impact on environmental assets.

Management actions and associated resource condition targets for 'invasive species' are being established under the National Monitoring and Evaluation Framework by regional groups. Establishing methods for measuring and mapping changes in the extent, density and impact of weed species is being undertaken by the National Land & Water Resources Audit (NLWRA)

Figure 3.26 Distribution and extent of mesquite (*Prosopis* spp.) and parkinsonia across Australia



Top: Mesquite

Bottom: Parkinsonia

Source: NLWRA, July 2007

in collaboration with all states and the NT through the Australian Weeds Committee.

Key points

- The available data on the distribution of invasive weeds are usually not at scales adequate for effective control programs, and this report has been unable to report directly on the effects of weeds on sustainable management. It is very difficult and costly to obtain comprehensive and accurate data on the locations and extent of weed infestations over areas as vast as the rangelands.

- Future work to improve data and information on weeds in the rangelands could include:
  - identification of specific species of weeds considered to be important to rangelands communities and the identification of their distribution and extent
  - more frequent monitoring (for example, annual or biannual reporting on the change in extent and distribution of particular weeds to support decision making where weeds are threatening productive and environmental assets)
  - linkage of national and regional reporting of the extent of particular weeds to improve efficiencies of data collection and reporting.

Total grazing pressure

Across Australia's rangelands, grazing pressure on native pastures comes not only from livestock, but also from native animals such as kangaroos and exotic animals such as feral goats. These three components of total grazing pressure (TGP) — the densities of domestic stock, kangaroos and feral herbivores — are described briefly in this report. More information is available in Fisher et al (2004).

Livestock densities

Livestock density is known to be a useful indicator of sustainable management (Harrington et al 1984). In Australia's rangelands, the density of livestock (the numbers of sheep and cattle per unit of land area) is the one component of TGP directly under the influence of pastoral management. The two components of stock densities — the inherent productivity or capacity of the land to carry stock (ie long-term carrying capacity) and the number of stock on the land relative to recent seasonal conditions (ie *seasonal quality*) — are illustrated by the Mitchell grasslands (Figure 3.27). The Mitchell Grass Downs bioregion has a high capacity to carry stock, but stock numbers are usually reduced by managers during periods of below-average rainfall or poor *seasonal quality*.

Figure 3.27 Cattle grazing Mitchell grass, Barkly Tableland (NT)

Cattle in the Barkly Tableland (NT), part of the Mitchell Grass Downs bioregion.

Photo: NT Department of Natural Resources, Environment and the Arts

Change in livestock density

In the period from 1993 to 2004, livestock densities were relatively stable on pastoral leases of rangeland IBRA regions (Figure 3.28), compared with the large differences in densities occurring between IBRA regions. In other words, the stocking density for a specific lease within a region changed little over the years compared to the inherent differences in livestock-carrying capacities across the entire rangelands. The eastern margin had the highest livestock densities over the years, while areas in the centre had the lowest.

Notable changes in relative livestock densities in some bioregions from 1993 to 2004 can be illustrated by examining percentage changes compared to the average of previous years (1983–1991)(Figure 3.29). For example, livestock densities generally increased in the Pilbara (Figure 3.30), Pine Creek, Daly Basin, Victoria Bonaparte, Sturt Plateau, Mount Isa Inlier, Gascoyne and Davenport–Murchison bioregions. Densities generally decreased in the Riverina (Figure 3.30), Broken Hill Complex, Cobar Peneplain, Murray-Darling Depression, Flinders Lofty Block and Yalgoo bioregions.

Box 3.5 Data on livestock numbers

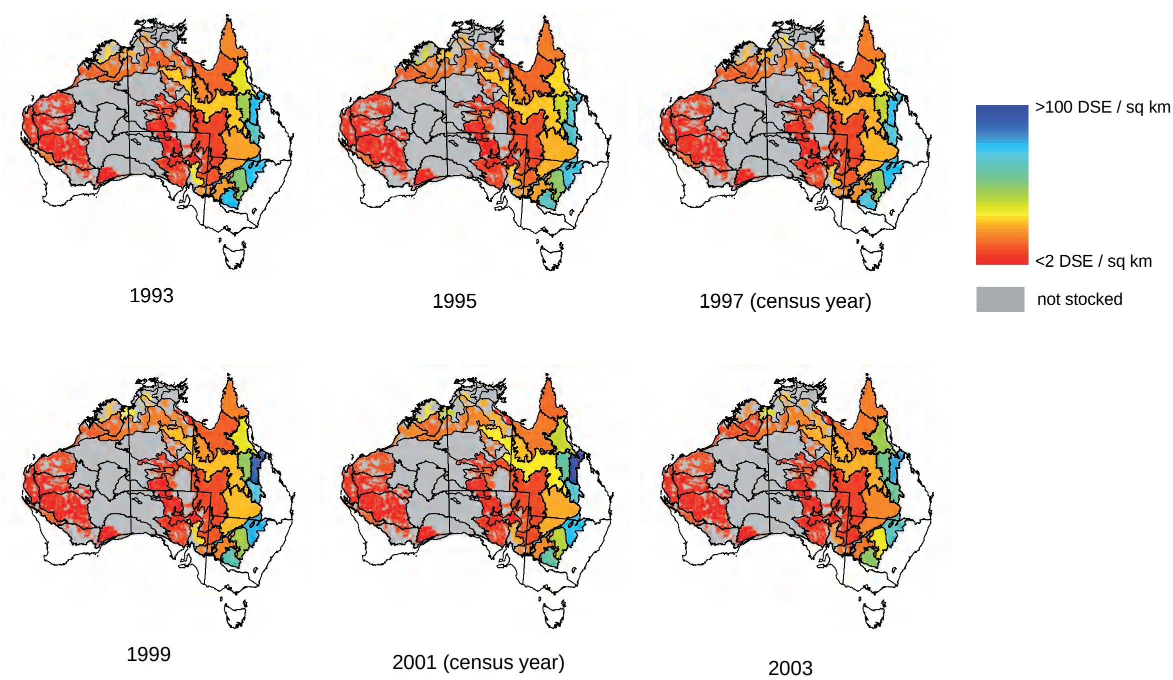
The ABS conducts annual assessments of domestic stock (sheep and beef cattle) numbers on pastoral leases, with a complete Agricultural Census every five years and sample surveys in intervening years. The ABS compiles and reports survey data by statistical local area (SLA).

The Queensland Department of Natural Resources and Water uses ABS data on livestock numbers in AussieGRASS simulations. For the 1983–2004 period, livestock densities for rangeland bioregions were calculated using land use and tenure data provided by the NLWRA. Livestock densities are not reported for bioregions where less than 25% of the area was grazed or where there were fewer than five leases.

The reliability of the ABS survey data is important when interpreting and reporting changes in livestock densities at the bioregional level. Five-yearly censuses covered all livestock producers, but intervening surveys only sampled a small proportion of pastoralists. Data reliability is obviously higher in the years of census (1997 and 2001). Where properties are very large, they may extend across more than one bioregion, resulting in relatively poor correspondence between SLAs and bioregions and reduced data reliability.

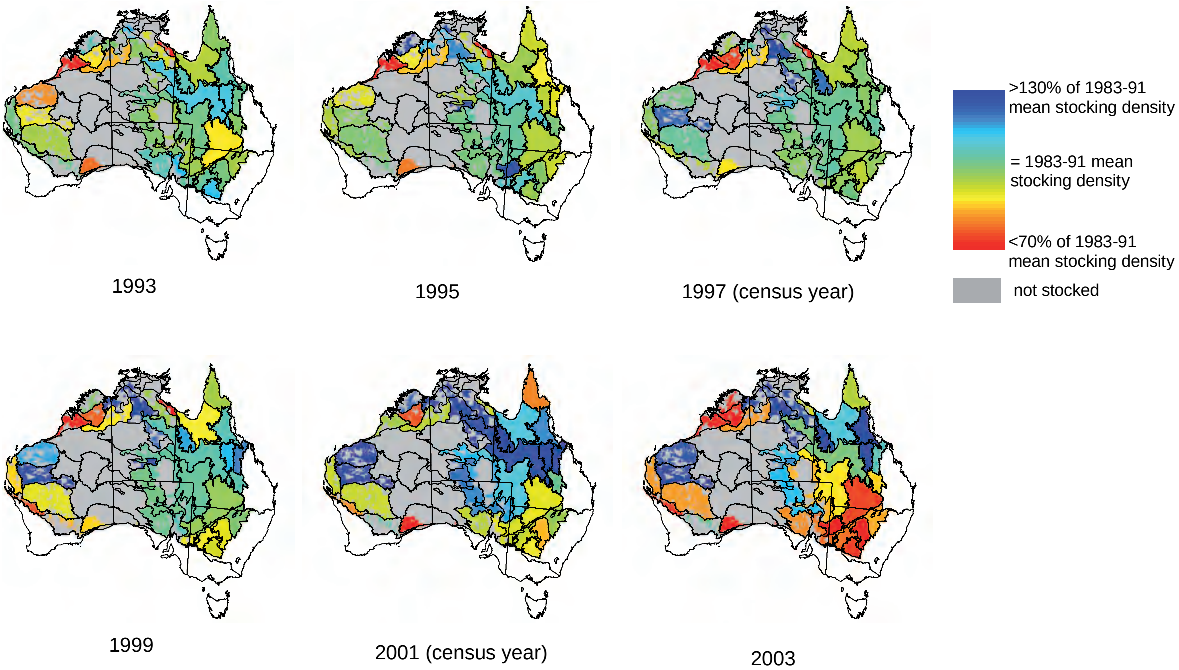
In WA and SA, the reliability of ABS-sourced data was verified by livestock data collected by pastoral land boards. The ABS-sourced and land board data were found to be broadly similar for the main pastoral bioregions in SA. In WA, the data also generally agreed, but some discrepancies were found, for example in the Kimberley and Yalgoo bioregions. Because comparative data were lacking for many rangeland regions, it is not possible to provide a reliability score for every bioregion.

Figure 3.28 Stocking density for selected years, 1992 to 2003 (DSE/km^2)



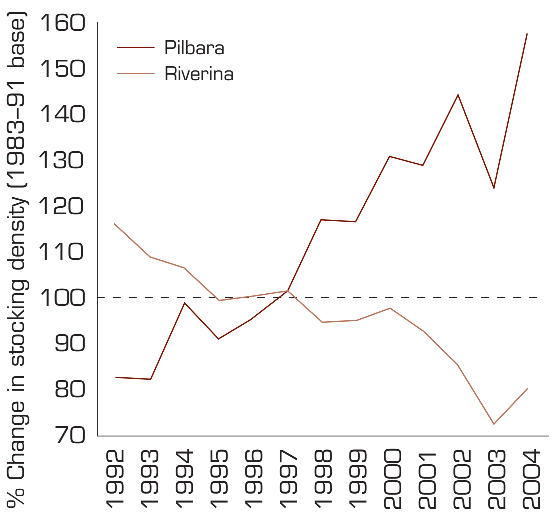
Maps compiled by the ACRIS-MU from ABS and QDNRW data.

Figure 3.29 Changes in livestock densities for rangeland bioregions, selected years from 1993 to 2003, compared with mean stocking density from 1983 to 1991 (%)



Maps compiled by the ACRIS-MU from ABS and QDNRW data.

Figure 3.30 Change in livestock densities, grazed area of Pilbara and Riverina bioregions, 1992 to 2004 (%)



Note: Change is calculated relative to the average stocking density of each region for the 1983–91 period (dashed line).

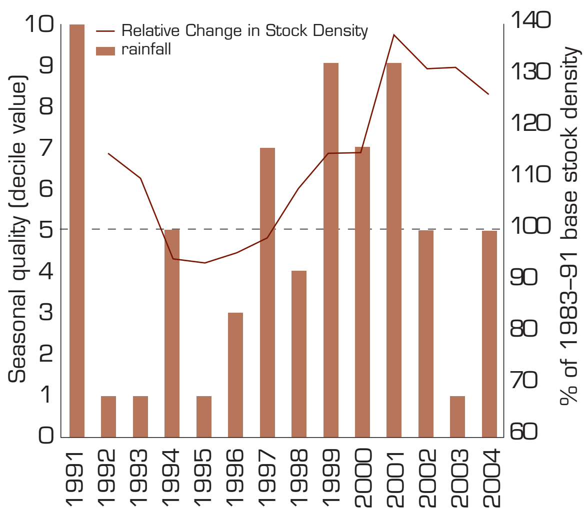
Graph compiled by the ACRIS-MU from ABS and QDNRW data.

These changes are broadly related to better seasons in the north and much of the west of the continent and drier conditions in the southeast and the southwest parts of the rangelands, particularly in more recent years. Expansion of cropping probably also accounted for declining stocking density in the southeast (for example, the Riverina, Darling Riverine Plains and Cobar Peneplain bioregions all had a lower percentage of grazed area in 2004 than in 1992).

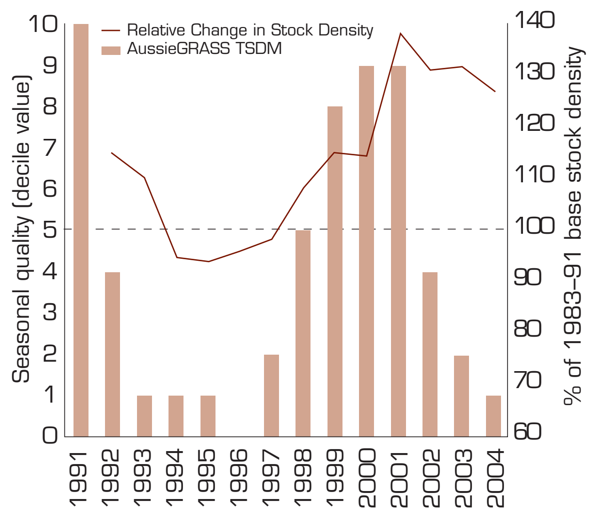
Livestock density adjusted for *seasonal quality*

To achieve sustainable production, rangeland managers generally decrease livestock numbers during a run of below-average rainfall seasons, and increase numbers again during a run of above-average seasons; they adjust for *seasonal quality*. How quickly pastoralists make such adjustments across a region is important, particularly when *seasonal quality* is declining. Data for the Desert Uplands bioregion, for example, demonstrate the extent to which bioregion-scale indicators of *seasonal quality* and stocking density are linked (Figure 3.31). Deciles of rainfall and AussieGRASS simulated TSDM have a general relationship with changing livestock densities.

Figure 3.31 Change in relative stock density related to indicators of *seasonal quality*, Desert Uplands bioregion, 1991 to 2004, and relative to long-term record (1890–2005)



Indices are deciles of rainfall.



Indices are deciles of AussieGRASS simulated pasture biomass (TSDM).

Data: QDNRW and ABS. Graphs: ACRIS-MU.

Livestock densities in the bioregion declined substantially between 1992 and 1994 to about the 1983–91 average (Figure 3.31; dashed line). This decline was in line with the below-average annual rainfall in 1992 and 1993, along with substantially lower levels of simulated pasture biomass. After 1997, livestock densities increased appreciably up to 2001 with a run of years with higher *seasonal quality*. Contrary to expectation, livestock densities declined only slowly between 2001 and 2004, whereas *seasonal quality* dropped dramatically with the return of drier years. This suggests a mismatch between the management of stock numbers and seasonal conditions. The difference confirms that *seasonal quality* provides a useful adjustment when interpreting changes in stock numbers in this bioregion of northeast Queensland.

This example shows that single datasets (in this case, on stock numbers) provide useful information, but fully interpreting changes requires multiple datasets (eg land management practices, cattle prices, and infrastructure such as additional waters and fencing that may allow more stock to be safely carried).

Key points

- Sheep and cattle are important components of TGP in the pastoral areas of Australia's rangelands.
- There were regional differences in stocking density across the rangelands. The differences largely relate to the underlying inherent primary productivity of pastoral bioregions.
- Stock density followed *seasonal quality* in many of the pastorally important bioregions, but there were contrasting trends in other regions. This report has used the average of available data prior to the reporting period as a base to provide a relative index of change.
- The reliability of findings remains an issue because accuracy was reduced where concordance procedures between component SLAs and bioregions were tenuous (eg small sample size, poor spatial correspondence between the two regionalisations). In some areas, jurisdictional data on cattle and sheep numbers differed considerably from the ABS's sample survey data; numbers are more reliable in full-census years.

Figure 3.32 Kangaroos — a significant addition to total grazing pressure in the southern rangelands in some years

Kangaroo numbers (reds, eastern and western greys) vary considerably according to seasonal conditions.

Photo: Arthur Mostead

- Unmanaged herbivores such as kangaroos and goats contribute significantly to TGP in many regions. There are good data for kangaroo densities in some regions, but the contribution of feral herbivores cannot be easily determined.

Kangaroo densities in rangelands

Kangaroos are an important component of TGP in much of Australia's rangelands, particularly the southern rangelands (Figure 3.32). Kangaroo populations increased after European settlement with the development of stock waterpoints. Dingo control has also allowed kangaroo populations to increase.

Four species of kangaroos are harvested in Queensland, NSW, SA and WA, with offtake based on survey numbers and quotas established by the states and territories and agreed by the Australian Government under the *Environment Protection and Biodiversity Conservation Act 1999* (the EPBC Act):

- Red kangaroos (*Macropus rufus*) are harvested in Queensland, NSW, SA and WA.
- Eastern grey kangaroos (*M. giganteus*) are harvested in Queensland and NSW.
- Western grey kangaroos (*M. fuliginosus*) are harvested in NSW, SA and WA.

Kangaroo numbers decline during droughts, but recover rapidly after a drought breaks. For example, the 1981–83 drought reduced kangaroo populations in harvested areas to almost half the estimated pre-drought population, but they recovered to exceed pre-drought figures within seven years (Anon 2006).

Kangaroo densities are reported for rangeland bioregions in Queensland, NSW and SA where regular surveys have been conducted (see Box 3.6). Kangaroo numbers are expressed as dry sheep equivalents (DSE) per square kilometre so that their contribution to TGP can be assessed relative to livestock.

Change in kangaroo density

There were considerable year-to-year variations in kangaroo densities across rangeland bioregions over the 1993–2003 period (Figure 3.33), and in kangaroos' contribution to TGP relative to livestock. For example, the Broken Hill Complex bioregion in both NSW and SA often had kangaroo densities greater than 10 DSE/km^2; those densities were 80%–160% of livestock (sheep and cattle) DSE in the region. At times, kangaroos contributed more to TGP than did livestock.

In the Mulga Lands bioregion, kangaroo densities in the Queensland portion were approximately half those in the NSW portion until 1997, but then increased to exceed NSW densities by 2003; those densities were 40%–70% that of livestock. These results show that kangaroos contribute significantly to TGP, their contribution being higher in the more arid, predominantly sheep-grazed, bioregions where livestock densities are lower. Overall, surveyed bioregions in NSW and southern Queensland had higher kangaroo densities than bioregions in SA and in the more northern Mitchell Grass Downs bioregion in Queensland.

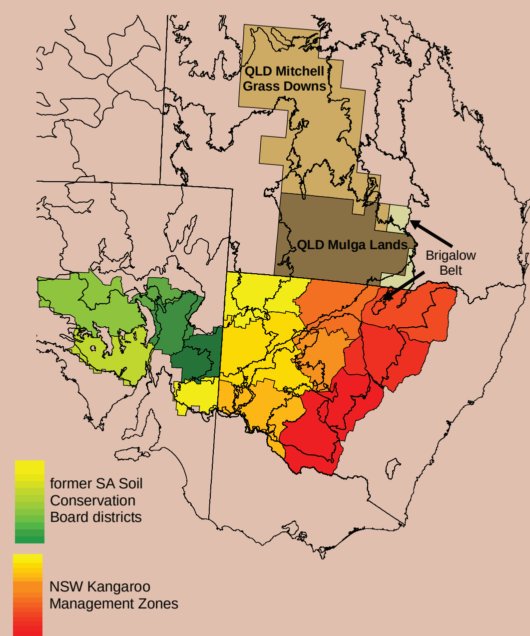
Box 3.6 Data on kangaroo numbers

Each state monitors its kangaroo populations on an annual basis, and harvest quotas are generally set at between 15% and 20% of the estimated population of each species. From 1980 to 2003, Queensland, NSW and SA have used yearly aerial surveys with fixed-wing aircraft to monitor kangaroo numbers in an area greater than 1.2 million km^2 (see map).

These data have recently been comprehensively analysed and reported by Pople (2006), and provided for this report as corrected estimates of population size and density (number per km^2), by species, for different management zones. Western NSW has a number of 'kangaroo management zones'; in SA, the zones are the former Soil Conservation Board districts; in Queensland, zones approximate bioregions.

The ACRIS-MU converted kangaroo density data from management zones to those bioregions predominantly covered by the various zones (map). Kangaroo densities were then transformed to DSEs for comparison with domestic stocking densities on the basis of information in Wilson (1991) (one red kangaroo = 0.6 DSE; one eastern or western grey = 0.5 DSE).

Regions surveyed for kangaroo numbers



Source: Pople (2006)

There were also relatively large percentage shifts in kangaroo densities compared to the 1984–91 period (Figure 3.34). For example, densities in the Gawler bioregion in SA in 1995 and 2000 were notably higher (>150%) than the average for the 1984–91 period (Figure 3.35). Densities then declined below the average by 2003. A general reversal of this pattern occurred in the Mulga Lands of Queensland, where kangaroo densities were well below the 1984–91 average until after 1998, reaching a peak in 2002, then declining to the average in 2003.

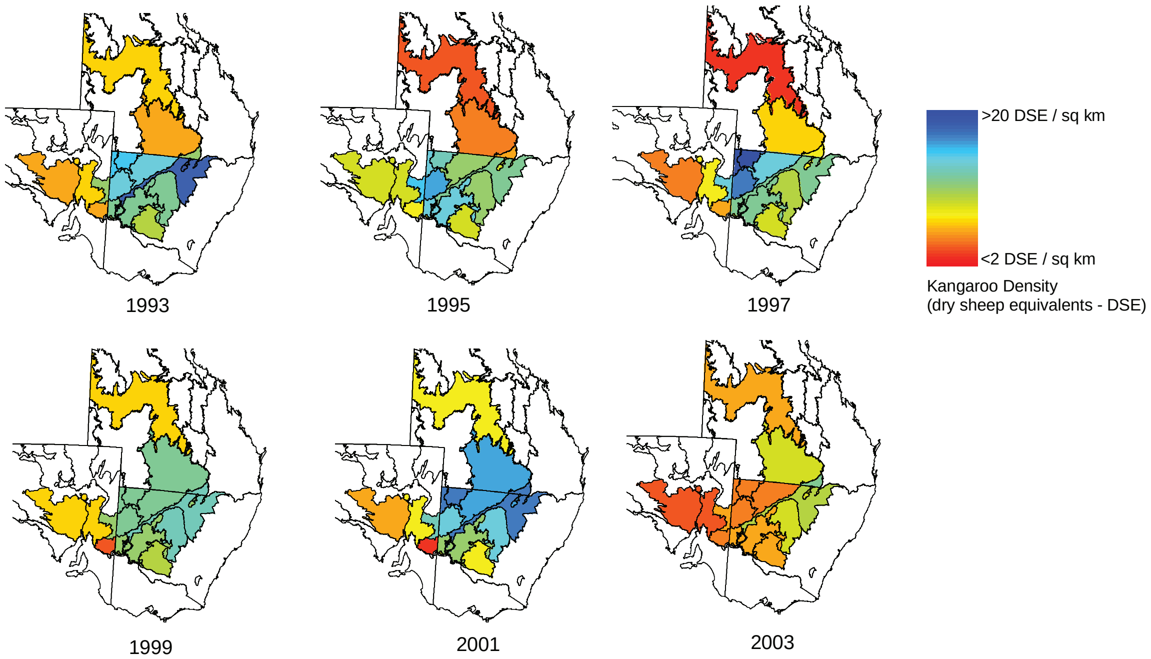
Kangaroo density adjusted for *seasonal quality*

Kangaroo numbers respond to runs of above-average and below-average rainfall (*seasonal quality*), typically lagging by about one year. For example, kangaroo densities in the Broken Hill Complex bioregion declined, as expected, in line with below-average *seasonal quality* in the 2001 and 2002 seasons (Figure 3.36), and then remained low in both NSW and SA in 2003 despite the wet year, probably due to a lag effect. This pattern was consistent for both deciles of rainfall (Figure 3.36, left panel) and AussieGRASS simulated pasture biomass (right panel).

Key points

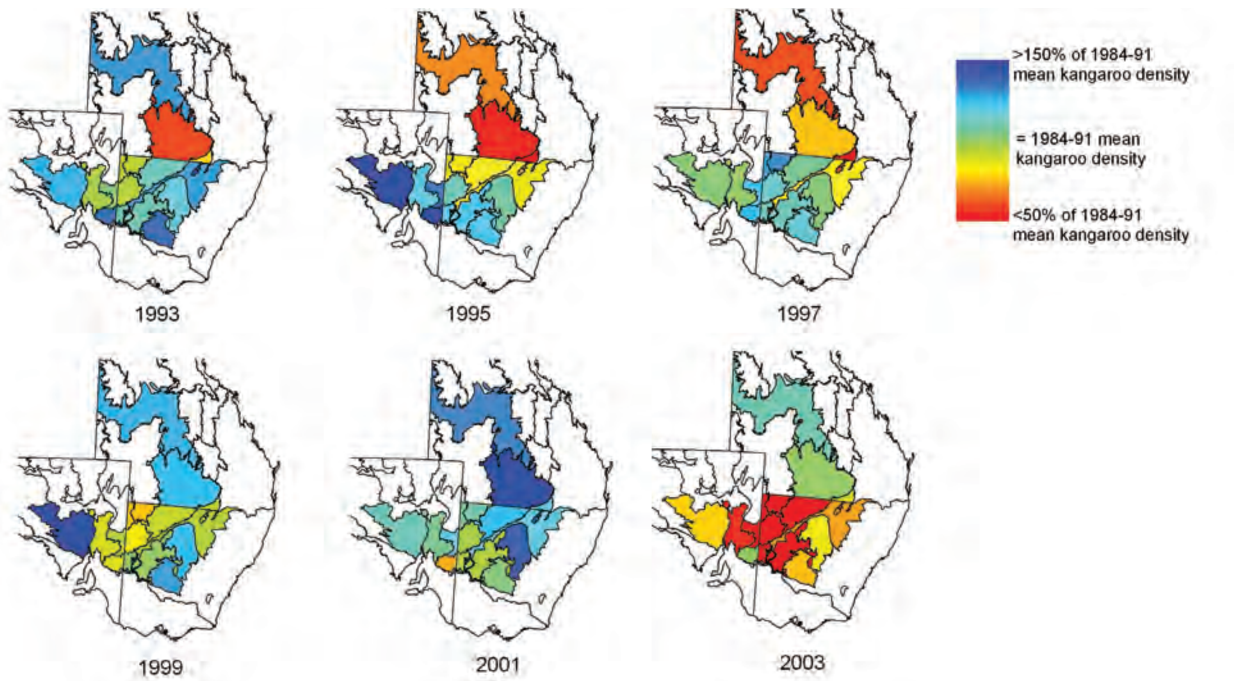
Systematic surveys of kangaroo numbers have been conducted across much of the sheep-grazed eastern rangelands (SA, NSW and southwest Queensland) for more than 20 years. These data have been comprehensively analysed (Pople 2006), and the report was kindly made available to the ACRIS Management Committee.

Figure 3.33 Combined densities of red, eastern grey and western grey kangaroos, southeastern rangeland bioregions, two-year intervals, 1993 to 2003 (DSE/km^2)



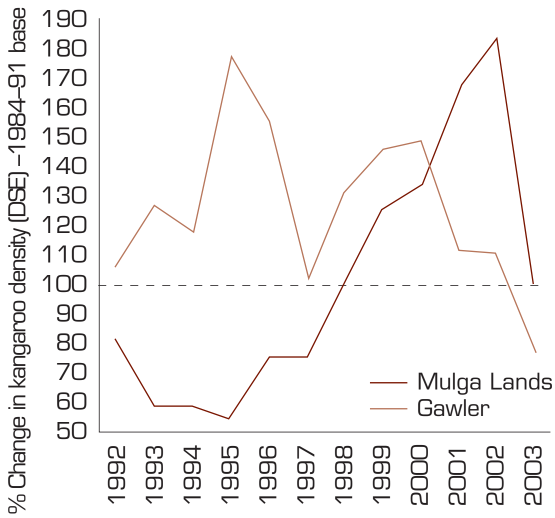
Source: compiled by the ACRIS-MU using data from Pople (2006)

Figure 3.34 Change in density of kangaroos, two-year intervals, 1993 to 2003, relative to mean density for 1984–1991 period (%)



Source: compiled by the ACRIS-MU using data from Pople (2006)

Figure 3.35 Change in combined density of three kangaroo species, Gawler and Queensland Mulga Lands bioregions, 1992 to 2003 (%)

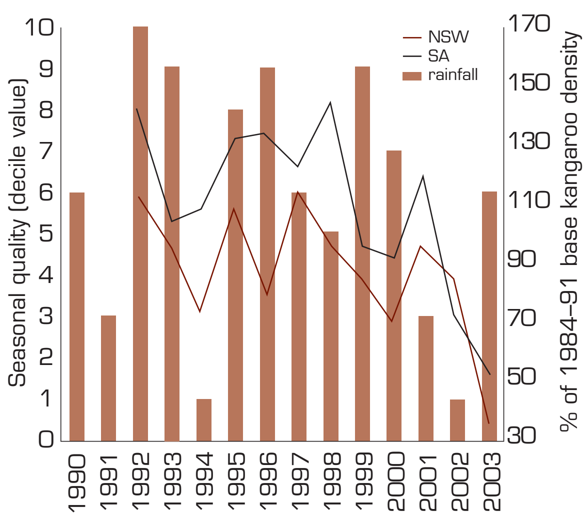


Note: Change is expressed relative to the average density for each region for 1984–1991.

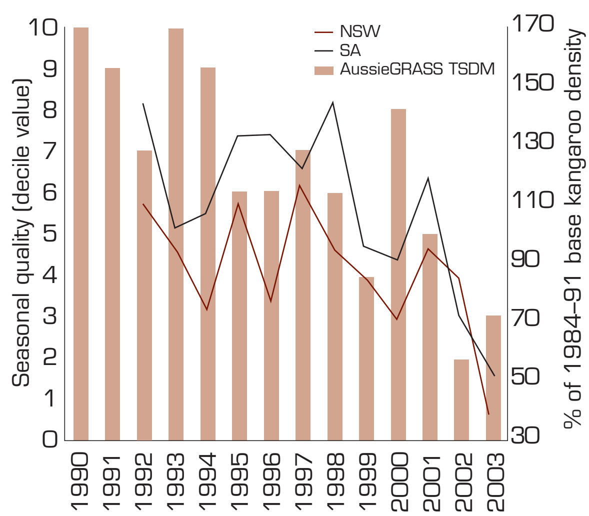
Data source: Pople (2006). Graph: ACRIS-MU.

- Kangaroo populations (red, western grey and eastern grey species) contribute substantially to TGP in parts of Australia's rangelands.
- Kangaroo numbers have increased across much of the rangelands in response to increased waterpoint density and distribution. Dingo and wild dog control in sheep grazing areas has undoubtedly assisted this increase.
- There were large changes in kangaroo densities in response to seasonal conditions during the 1992–2003 period (50%–150% variation on the average for the preceding eight years). Kangaroo numbers declined substantially in prolonged droughts.
- Kangaroo populations are monitored in parts of the WA rangelands, but those data were not available to ACRIS. In future, it would be very useful to include all possible kangaroo density data in ACRIS reporting.

Figure 3.36 Changes in kangaroo densities in relation to rainfall and AussieGRASS-modelled indicators of *seasonal quality*, NSW and SA portions of Broken Hill Complex bioregion, 1990 to 2003 (%)



Indices are deciles of rainfall.



Indices are deciles of AussieGRASS simulated pasture biomass.

Data sources: Pople (2006) and QDNRW. Map: ACRIS-MU.

Feral animals

Feral herbivores such as goats, horses, donkeys and camels contribute to TGP because they are known to alter, damage and compete for pastures, and to damage habitats for native flora and fauna (Figure 3.37). This group of animals is part of what are broadly described as 'invasive vertebrate pests'.

Background

Norris and Low (2005) reviewed the management of feral animals and their impact on biodiversity in the rangelands. Their review covered 39 species of feral animals in the rangelands (22 mammals, 14 birds, 2 reptiles and 1 amphibian). It also identified at least 10 species of fish that have established wild populations in the rangelands. According to these authors, 'apart from the loss of mammals, feral animals in the rangelands have degraded vast tracts of habitat, promoted invasion by serious weeds, and pose an ongoing threat to threatened plants and animals'. Feral animals also cause large economic losses by destroying crops and livestock and degrading landscapes.

Sources of feral animal information

National information is being collated by the NLWRA for selected vertebrate pests against the following national indicators:

- distribution and abundance of significant invasive vertebrate pests
- impacts of significant invasive vertebrate pests.

A number of invasive animal species have been assessed against these indicators (Table 3.6) and maps of their distributions are available on the NLWRA website[15] — for example, the distribution of camels and cane toads (Figure 3.38). Draft maps are currently available at a national scale of 1:100 000, but the aim is to produce maps at scales of 1:25 000 and 1:50 000 when data are available.

Feral animal management

The ABS (2006) reported that the most commonly reported NRM issues on Australian farms are weeds and pests. The Natural Heritage Trust and the National Landcare Program have invested heavily in pest management, with resources being used by regional groups, land managers and Landcare groups to manage invasive vertebrate species.

The Australian Vertebrate Pest Committee is establishing methods to measure changes in the extent, abundance and impact of vertebrate pest species in collaboration with all states and the Northern Territory through the NLWRA.

15 http://www.anra.gov.au (accessed 3 July 2007)

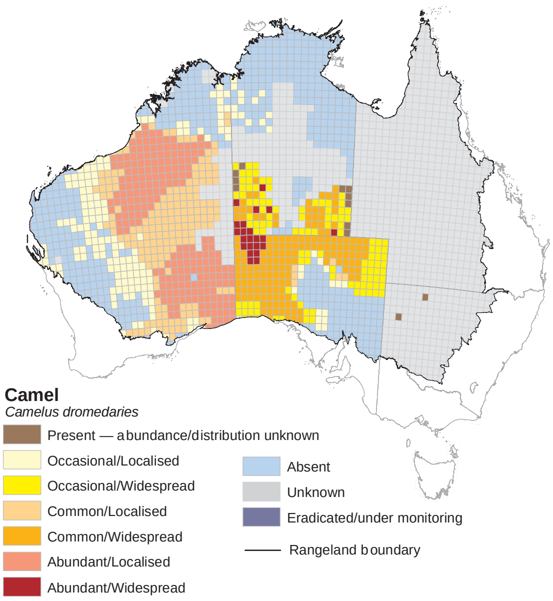
Figure 3.37 Feral goats (*Capra hircus*)

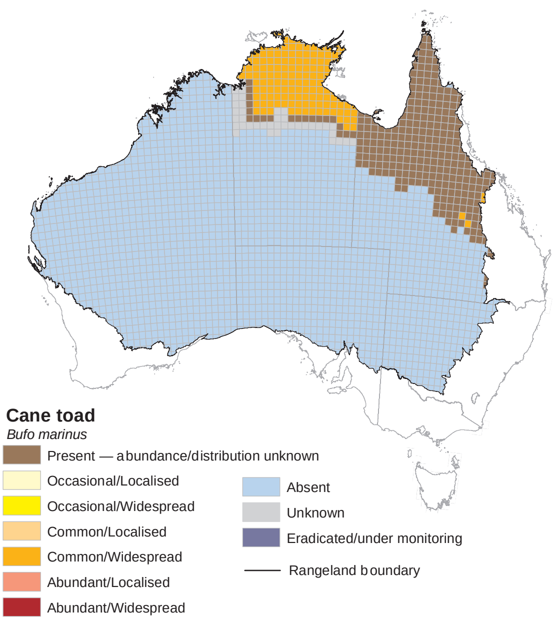
Feral goats contribute significantly to total grazing pressure in parts of the southern rangelands (southwest Queensland, NSW, SA and WA).

Key points

- Nationally consistent mapping of the extent and distribution of feral animals and other invasive vertebrate pests is currently on a broad scale and has limited use at a management scale. The aim is to build an information system for invasive species that is standards based for data and information and able to incrementally report at finer scales as required.
- In the future, the system would be useful for:
  - identifying specific feral animal species considered important to rangelands communities and monitoring their extent and abundance

Figure 3.38 Distribution of camels (*Camelus dromedarius*) and cane toads (*Bufo marinus*), Australia





Top: Distribution of camels

Bottom: Distribution of cane toads

Source: NLWRA, July 2007

– annual or biennial reporting on change, particularly where feral animals are threatening productive and environmental assets.

Table 3.6 Invasive animal species that have been assessed against national indicators

Common name	Latin name
Rabbits	*Oryctolagus cuniculus*
Foxes	*Vulpes vulpes*
Feral pigs	*Sus scrofa*
Feral goats	*Capra hircus*
Common carp	*Cyprinus carpio*
Cane toads	*Bufo marinus*
Starlings	*Sturnus vulgaris*
Feral cats	*Felis catus*
Wild dogs; dingoes	*Canis lupus familiaris; Canis lupus dingo*
Deer	
Fallow	*Dama dama*
Red	*Cervus elaphus*
Sambar	*Cervus unicolour*
Rusa	*Cervus timorensis*
Hog	*Axis porcinus*
Mapped only where data available	
Horses	*Equus caballus*
Donkeys	*Equus asinus*
Buffalo	*Bubalus bubalis*
Camels	*Camelus dromedarius*
Banteng	*Bos javanicus*
Red-eared slider turtle	*Trachemys scripta elegans*

Fire and dust

While fire and dust were not identified as separate themes by the ACRIS-MC, information on fire and dust generation relates closely to the Landscape function theme and the Sustainable management theme.

By reducing the cover of vegetation patches, fire affects how well landscapes retain resources (Tongway and Ludwig 1997). Fire is clearly an important factor in managing grazing lands; palatable vegetation consumed by fire is not available as forage, while the presence of fuel provides opportunities to burn to control woody thickening and promote grass growth as part

Figure 3.39 Burning in the Top End, NT

Photo: CSIRO Sustainable Ecosystems

of managing the grass–tree balance. Heavy dust in the air during wind storms can indicate source areas with low vegetation cover and poor soil surface condition (McTainsh 1998); these conditions may also imply that TGP may not be sustainable.

Fire

Fire has shaped the ecology of Australia's rangelands, particularly its vegetation. Fires are known to burn vast areas of rangeland, especially across northern Australia (Dyer et al 2001) (Figure 3.39). Such fires can occur frequently (eg every year in the Top End of the NT) and can be intense (late dry-season fires tend to be very hot).

Fires were, and continue to be, used by Indigenous people to manage vegetation, and for other purposes such as hunting wildlife. Small areas were typically burned during times of the year when fires were cool (late wet and early dry seasons in northern Australia). European settlers infrequently burned country, largely because potential fuels were used as forage for their livestock. When wildfires did occur in settled country, they tended to be in the hotter

Figure 3.40 Burning in central Australia

Fuel loads in much of the central and southern rangelands are related to prior rainfall. Spinifex (*Triodia* and *Plectrachne* spp.) is particularly flammable, and patch burning can reduce the risk of extensive wildfire.

Photo: Bruce Rose and the Department of the Environment, Water, Heritage and the Arts

Box 3.7 Monitoring fire scars in the rangelands

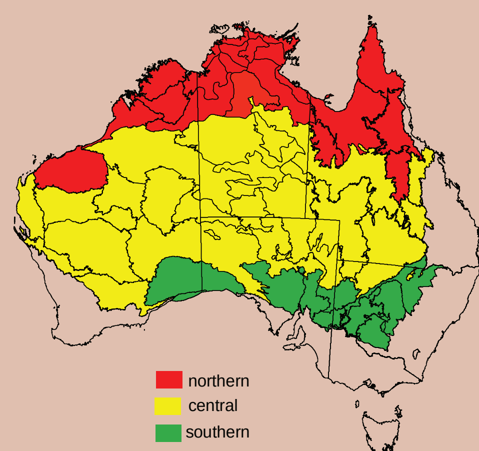
The extent of fire scars has been mapped on a monthly basis using satellite imagery covering most of Australia's rangelands. The satellite data have been acquired by the WA Land Information Authority (Landgate), and fire-scar maps are available on its website. Landgate provided statistics on the monthly and annual extent of fire scars in each rangeland bioregion, by sub-IBRA region, between 1997 and 2005. In this report, fire frequency is a spatial averaging of the number of times an area (pixels in a satellite image) burned over that nine-year period (see Box 3.8 for sample calculations).

At the regional scale, fire data were highly reliable (based on ground checks, and taking into account the difficulties in mapping small fires with the 1-km resolution of the Advanced Very High Resolution Radiometer). 'Cooler' burns may be difficult to detect, particularly where there is tree cover and the crown is not burned (eg woodlands). These limitations in mapping fire scars are less critical for regional reporting than for local evaluations.

Fire intensities were evaluated as being hot or cool depending on the month in which the fire occurred.

Geographic grouping of bioregions for categorising fire intensity

Regional grouping	Fire intensity	Months
Northern	Hot	August to December
	Cool	January to July
Central and southern	Hot	December to March
	Cool	April to November



months and were both extensive and intense (ie 'hot' fires, as opposed to 'cool' fires).

Fire records in the rangelands

Across much of Australia's rangelands, the extent, intensity and frequency of fire have changed markedly over the past 100 years or more. The changed fire regimes have caused a number of management problems. For example, in many semiarid rangelands, less fire has promoted an increase in shrubs (both native and exotic), often referred to as 'woody weeds'. Planned fires are now recognised as an important tool for managing woody vegetation.

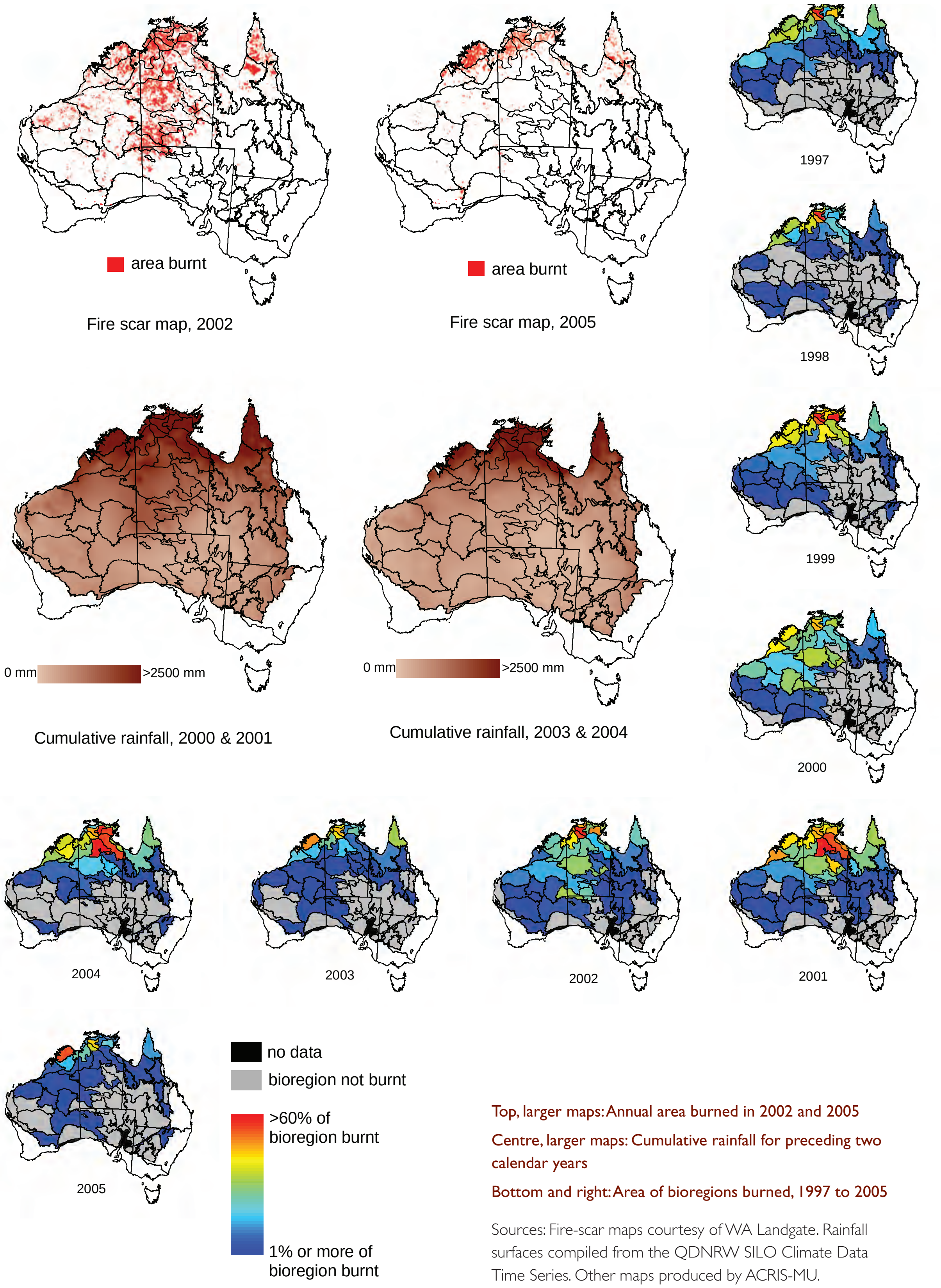
When intense or 'hot' fires sweep across the rangelands, they leave blackened landscapes (fire scars), which can be identified and mapped from satellite imagery (Box 3.7).

Three aspects of fire markedly affect the rangelands: extent, intensity and frequency. Changes in annual area burned are reported for the period 1997–2005, and, to the extent possible, changes in fire intensity and frequency.

Fire extent

Over 50% of the northern savannas of Australia can burn each year, largely because fuels tend to build rapidly in those regions of higher rainfall. In the arid and semiarid interior, fires are more episodic, being related to prior rainfall (Figure 3.41). For example, widespread fires in central Australia in 2002 were clearly linked to above-average rainfalls in the two previous years, 2000 and 2001. In southern rangelands, widespread fire is usually sparse or absent.

Figure 3.41 Area burned, 2002 and 2005; cumulative rainfall for preceding two calendar years; area of bioregions burned between 1997 and 2005



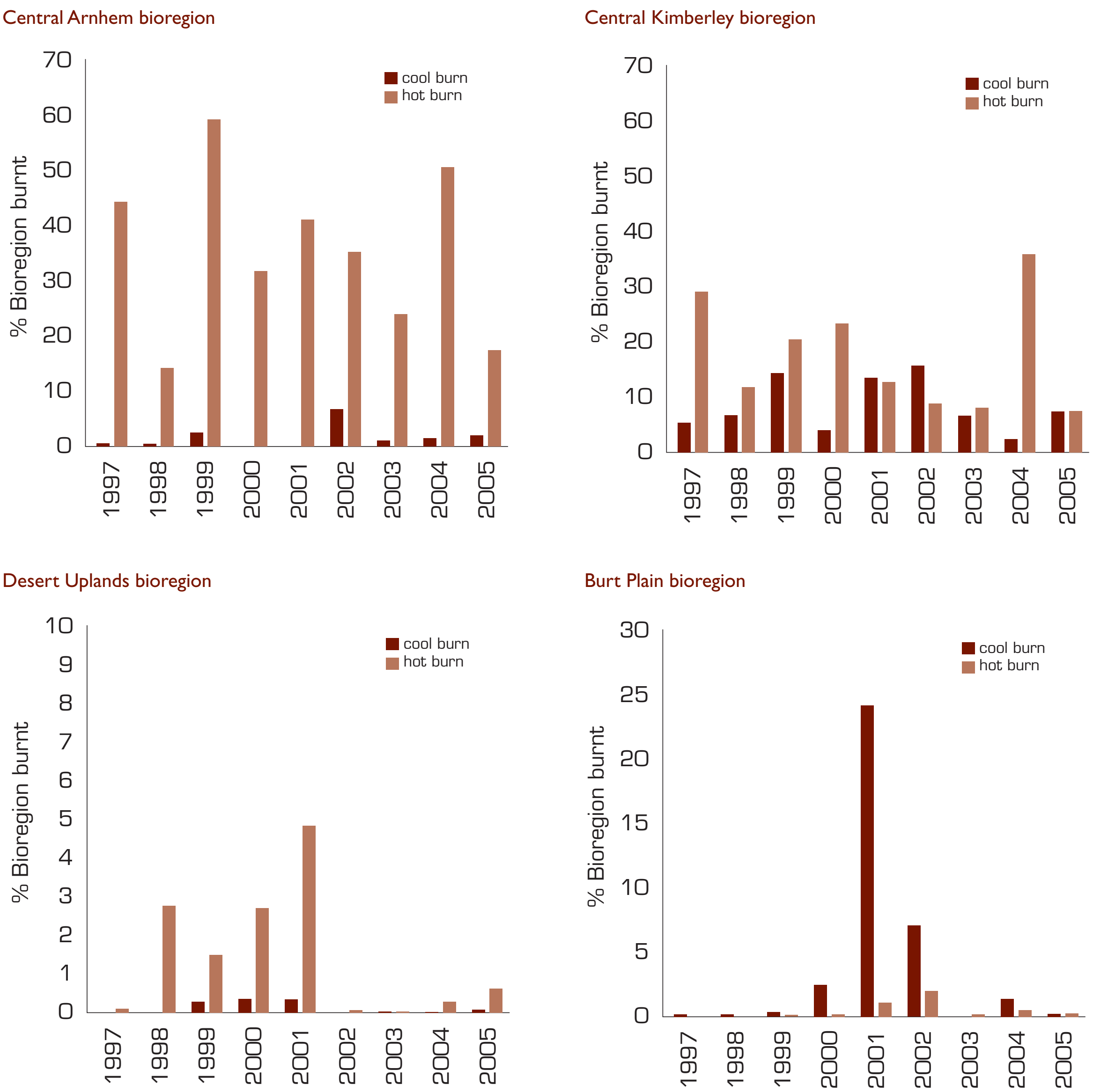
Top, larger maps: Annual area burned in 2002 and 2005

Centre, larger maps: Cumulative rainfall for preceding two calendar years

Bottom and right: Area of bioregions burned, 1997 to 2005

Sources: Fire-scar maps courtesy of WA Landgate. Rainfall surfaces compiled from the QDNRW SILO Climate Data Time Series. Other maps produced by ACRIS-MU.

Figure 3.42 Rangeland fire-intensity zones and percentage areas of selected bioregions burned by 'hot' and 'cool' fires, 1997 to 2005



Data: WA Landgate. Graphs: ACRIS-MU.

Fires were extensive across northern rangelands between 1997 and 2005 (Figure 3.41) and extended into central Australia and the western deserts in 2002. Figure 3.41 shows that most of the southern and southeastern bioregions were either not burned or had a very low incidence of fire between 1997 and 2005.

Fire intensity

Fire intensity was defined by month of burn (Box 3.7). Four bioregions were selected to illustrate differences in fire intensities across Australia's rangelands (Figure 3.42). Extensive 'hot' fires occurred every year in the northern bioregions, Central Arnhem and Central Kimberley, although the proportions of areas burned

Box 3.8 Fire frequency in the rangelands

Fire frequencies over the 1997 to 2005 period for each rangeland bioregion were calculated using the following diagrams supplied by the WA Land Information Authority (Landgate).

Assume that a 3 × 3 array of pixels and lines represents the area extending across a region (represented as a tabular array). Burnt pixels were represented by the value '1' and unburnt pixels by '0'. In 1999, two-thirds of the array was burnt; in 2000, a little more than one-third was burnt. The fire frequency across the two years is calculated by summing pixel values.

Year 1999		
0	1	1
0	1	1
0	1	1

Year 2000		
0	0	0
0	1	1
0	1	1

Fire Frequency		
0	1	1
0	2	2
0	2	2

Two examples of calculating fire frequencies for a region are presented.

In Example 1, the region is represented by four pixels within the solid line.

0	1	1
0	2	2
0	2	2

The average fire frequency for this region is (2 + 2 + 2 + 2) / 4 = 2.0

In Example 2, the region is represented by six pixels.

0	1	1
0	2	2
0	2	2

The average fire frequency for this region is (0 + 0 + 2 + 2 + 2 + 2) / 6 = 1.3

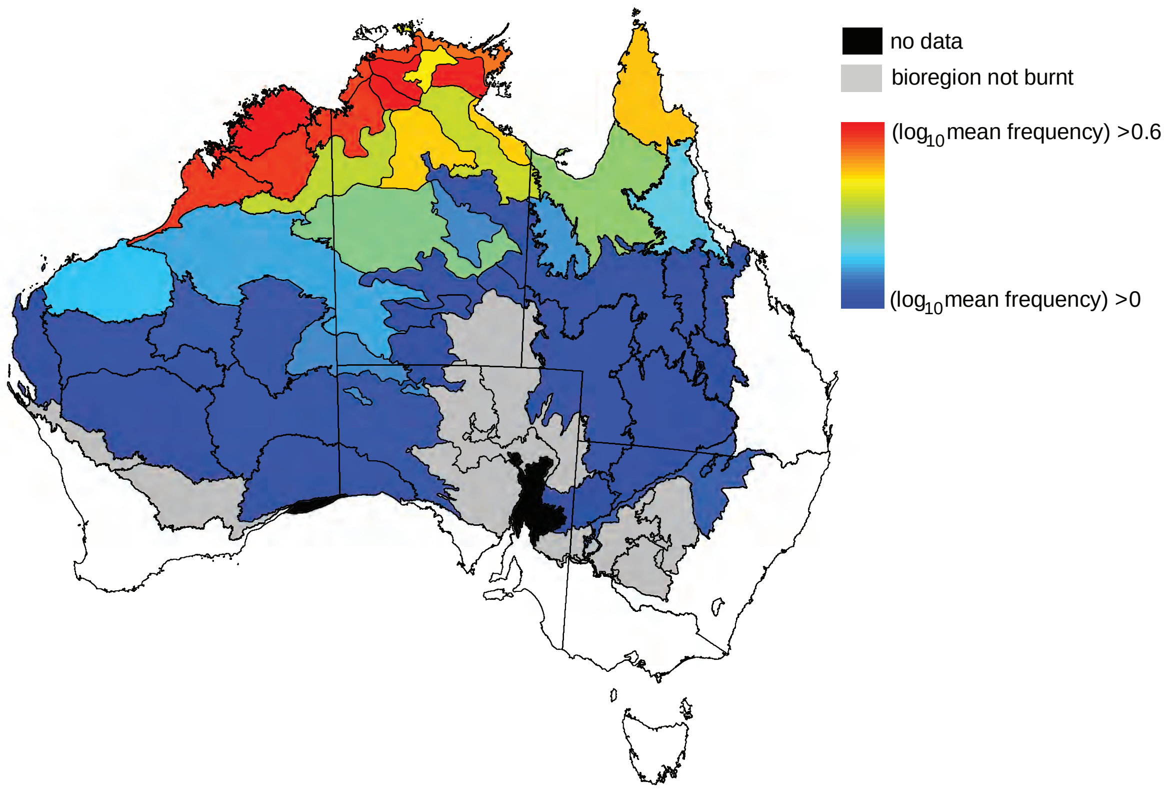
The spatially averaged fire frequency data for bioregions have a large and skewed range. Average fire frequency is relatively high in the north and very low in the south. To improve mapping detail for northern bioregions, where very large areas were burned in most years, the frequency data were $\log_{10}$ transformed by the ACRIS-MU (Figure 3.43).

with 'cool' and 'hot' fires were more balanced in the Central Kimberley bioregion than in Central Arnhem. Hot fires also dominated the Desert Uplands bioregion, but the area burned varied greatly from year to year. Fire was episodic in the Burt Plain bioregion, occurring mainly in 2001 with smaller areas burned in 2000, 2002 and 2004.

Fire frequency

For each rangeland bioregion, fire frequency was calculated as the number of times each area burned between 1997 and 2005 (see Box 3.8 for sample calculations). Overall, northern rangelands burn frequently and those in southern areas burn infrequently (Figure 3.43). For example, in NSW and SA, the Riverina, Murray-Darling Depression and

Figure 3.43 Mean fire frequency for bioregions burned, 1997 to 2005, values mapped as $\log_{10}$



Data: WA Landgate. Maps: ACRIS-MU.

Flinders Lofty Block bioregions had no or negligible fire scars evident over the 1997–2005 period.

Key points

The national database of mapped fire scars produced by WA Landgate is of critical value to the ACRIS-MC in reporting fire extent, intensity and frequency for the rangelands. National coverage is from 1997.

Fire-scar maps from 1997 to 2005 show where fires occurred and how fire frequency varied considerably:

- Fire was widespread and frequent in much of northern Australia. Much of it was uncontrolled and occurred in the late dry season, when fires are more extensive and very intense.
- In the semiarid and arid parts of central Australia, particularly the western deserts, extensive fire was episodic and followed sequences of wetter years.
- Fire was generally minimal and infrequent across most of the southern rangelands.

How fire can be managed for different purposes is an important issue, particularly in northern regions where fire frequencies and intensities are high. Controlled burns are increasingly being used early in the dry season to reduce fire hazard in some regions, notably in the Sturt Plateau, Pine Creek and Daly Basin bioregions of the NT. Programs to re-establish Indigenous burning practices across other regions have been set up. The West Arnhem Land Fire Abatement Project, for example, is a partnership between Aboriginal traditional owners, the Northern Land Council, the NT Government and Darwin Liquefied Natural Gas. Its goal is to strategically manage fire across 28 000 km^2 of western Arnhem Land to reduce greenhouse gas emissions as an offset for Darwin Liquefied Natural Gas.[16]

In some regions, the issue is reduced fire frequency, which has implications for the management of

16 http://www.savanna.cdu.edu.au/information/arnhem_fire_project.html (accessed 3 July 2007)

woody thickening in much of the pastoral country in the eastern, central and parts of the western rangelands. Woody thickening is a major issue in semiarid eucalypt and acacia woodlands in the eastern rangelands, and for the northern tropical savannas.

A much longer fire record would help to reliably determine whether fire management is changing in those rangeland regions where fire was formerly very extensive.

Dust

In Australia's rangelands, and worldwide, wind erosion has been accelerated by factors that reduce vegetation cover, such as grazing and fire. The level of dust in the air is a useful indicator of wind erosion (Figure 3.44).

Many meteorological stations record atmospheric dust levels in dust storm events. Regional differences in dust levels are related to soil type and natural levels of vegetation cover, but dust levels higher than expected for the seasonal conditions (ie *seasonal quality* effects) may be due to grazing-induced low vegetation cover.

Dust records in the rangelands

In Australia, a Dust Storm Index (current version, DSI_3) has been developed to evaluate the occurrence and severity of dust storms (McTainsh 1998). DSI values have been related to climatic events such as droughts, and have been proven to be a useful indicator of rangeland conditions during droughts.

Maps of DSI_3 data covering the rangelands (Box 3.9) were provided by G McTainsh (Griffith University, Queensland). Two sets of maps are used to illustrate dust storm patterns across rangeland bioregions: maps of average dust storm patterns for the 1992–2005 period, and maps for selected high and low dust storm years.

Dust Storm Index maps

Highest annual values for DSI_3 between 1992 and 2005 were observed in the arid rangelands (Figure 3.45). The Simpson–Strzelecki Dunefields and Channel Country bioregions, and parts of the Stony Plains and Mulga Lands, had mean DSI_3 values greater than 3; those data were of medium to high reliability over most of these bioregions.

Figure 3.44 Approaching dust storm

ACRIS uses a Dust Storm Index to report the occurrence and severity of dust storms as an indicator of wind erosion.

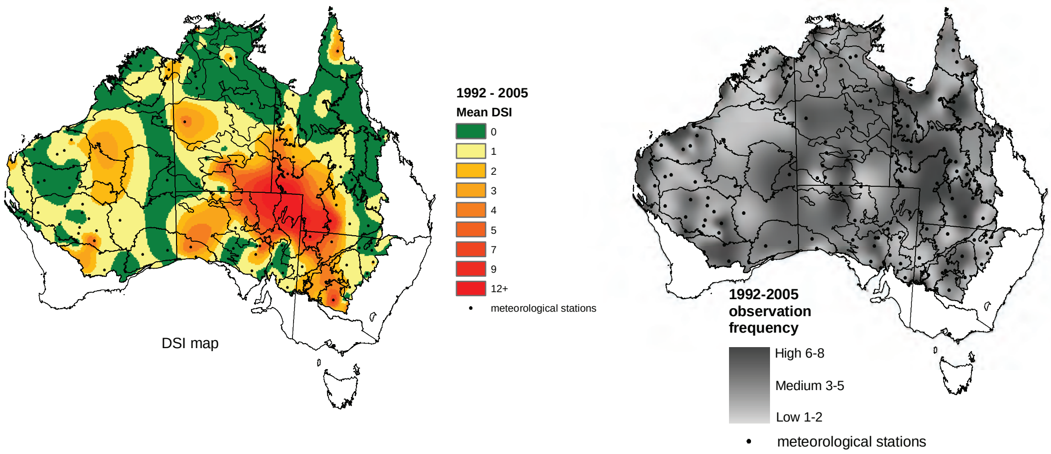
Photo: Hans Bossem

Box 3.9 Dust Storm Index data and calculation

DSI_3 values are calculated from dust storm events recorded at meteorological stations maintained by the Bureau of Meteorology. A number of different wind erosion event-types are evaluated by the bureau, ranging from severe dust storms to local blowing dust. The intensity of these event-types can be approximated by the extent to which they reduce visibility. DSI_3 is a composite measure of the weighted contributions of local dust events, moderate dust storms and severe dust storms. These three types of dust storm events are weighted in order of decreasing severity ('severe' times 5, 'moderate' times 1 and 'local' times 0.05) and summed to calculate a DSI_3 value for each recording station at each point in time. Values are spatially interpolated among stations and integrated over time to provide annual DSI_3 maps (McTainsh et al 2007).

The reliability of the dust storm patterns in DSI_3 maps for the rangelands depends on the observation frequency at each recording station.

Figure 3.45 Mean DSI_3 values, 1992 to 2005



Note: Higher values indicate higher levels of wind erosion. Dots show the locations of Bureau of Meteorology stations. The greyscale image on the right shows the frequency of meteorological observations, an indicator of DSI_3 reliability.

Data and maps: G McTainsh, Griffith University, Queensland

Two calendar years (1992 and 2005) had relatively high and widespread levels of dust storm activity over the 1992–2005 period (Figure 3.46). There was a notable reduction in the reliability of DSI_3 patterns by 2005 because of a decline in observation frequencies at BoM stations between 1992 and 2005. The establishment of a DustWatch network of volunteer observers (Leys et al, in press), using simplified BoM observation protocols, is aimed at reversing this trend. When interpreting the DSI_3 maps, it should be remembered that the atmospheric dust observed at a meteorological station may have originated elsewhere and crossed a regional boundary. The low density of BoM recording stations in some bioregions may also mean that dust has been transported a considerable distance before it is recorded.

Spatially averaging DSI_3 data over large bioregions can conceal considerable spatial patterning within each bioregion. The Mulga Lands bioregion, for example, had a distinct west-to-east reduction in DSI_3 values in 2005 (Figure 3.46).

Dust Storm Index and *seasonal quality*

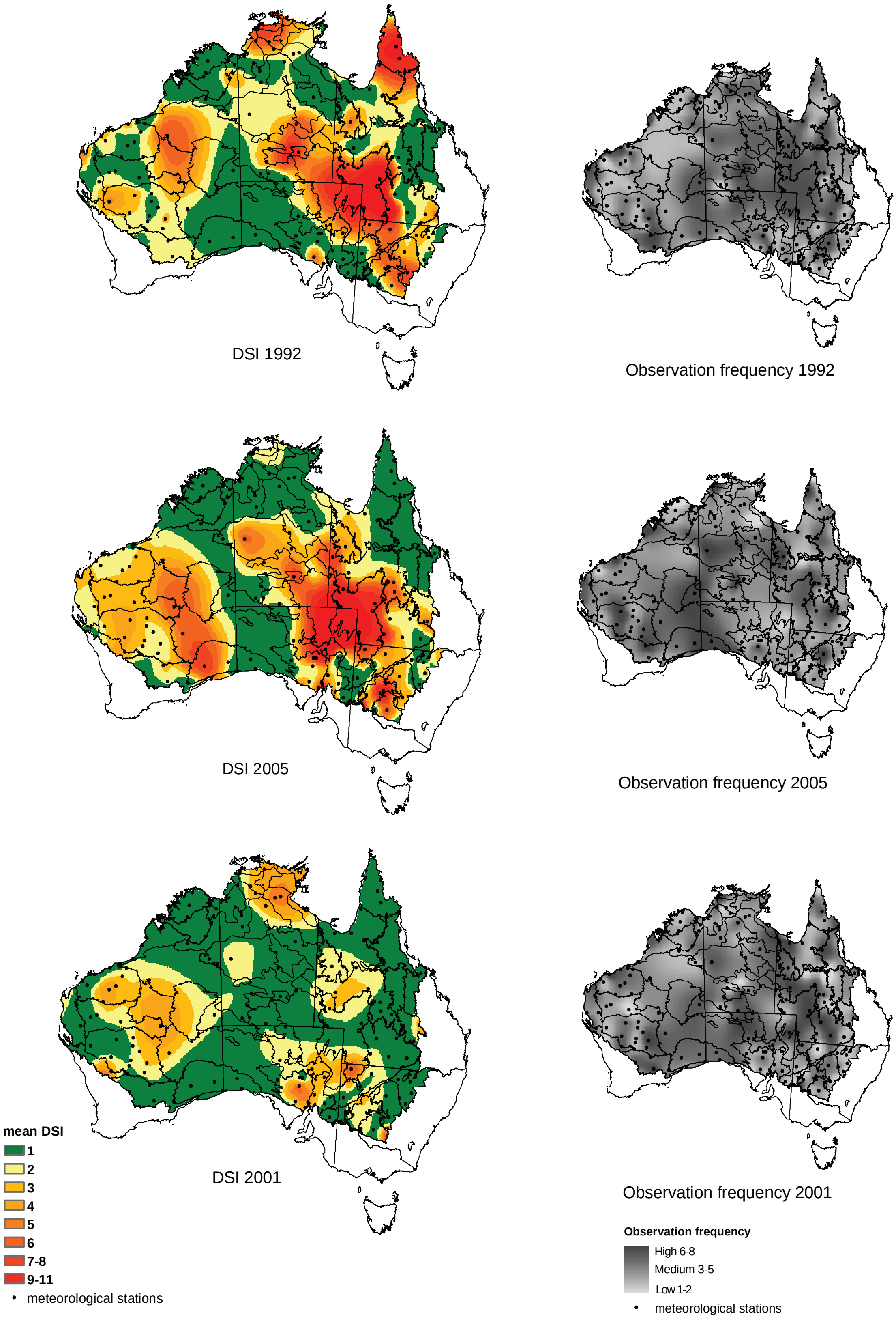
As expected, dust storms markedly increased in bioregions in years with rainfalls well below the long-term (1890–2005) average, for example, in the Channel Country and Mulga Lands bioregions (Figure 3.47). DSI_3 values increased abruptly in the driest years (1994 and 2002) and progressively declined during wetter years.

For those bioregions in and surrounding the Simpson Desert, it appears that one very dry year can precipitate a large increase in observed dust levels, presumably because vegetation cover has declined below a threshold that adequately protects and stabilises the soil surface against wind erosion. This result is consistent with the field-based measurements of wind erosion in the Channel Country by McTainsh et al (1999). A sequence of years with above-average rainfall may then be required to increase cover sufficiently to reduce levels of erosion activity.

Key points

- Atmospheric dust is a useful indicator of landscape function because dust levels are affected both by soil surface conditions (wind erodibility) and by the amount of vegetation cover. When adjusted for recent *seasonal quality*, the DSI indicates how well the rangeland area is being sustainably managed.
- The Dust Storm Index allows regional changes in dust levels to be reported.

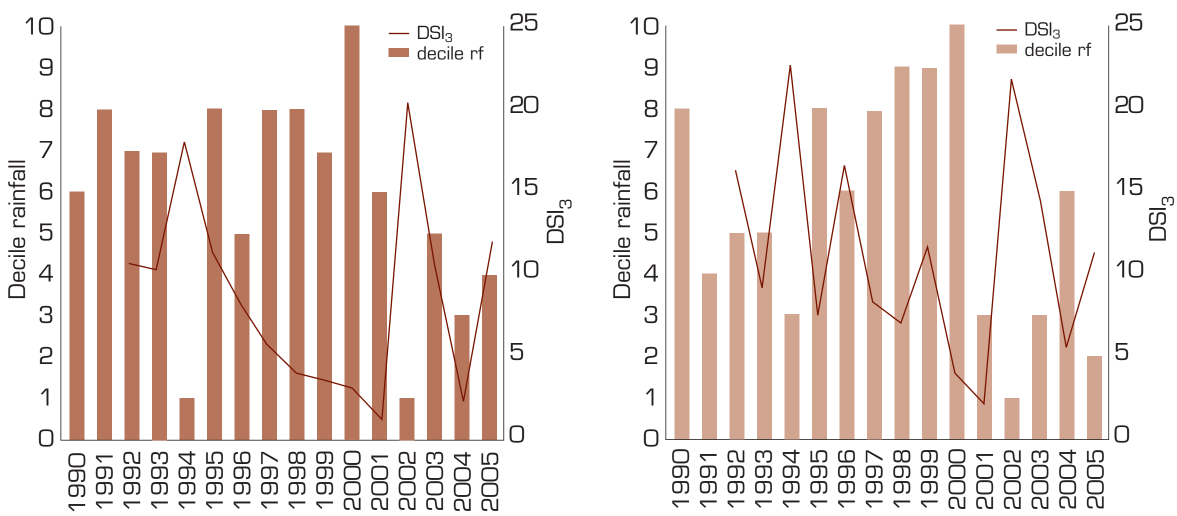
Figure 3.46 Selected years with relatively high and low levels of DSI_3



Note: Dots show the locations of BoM stations. The greyscale images show the frequency of meteorological observations for each year.

Data and maps: G McTainsh, Griffith University, Queensland

Figure 3.47 Annual DSI_3 values and decile rainfalls, Channel Country and Mulga Lands bioregions, 1990 to 2005



Note: Rainfall deciles were calculated for each bioregion by spatially averaging yearly rainfalls estimated by SILO (http://www.bom.gov.au/climate/silo) compared to the long-term (1890–2005) record. Rainfalls in 1990 and 1991 are included to allow for any temporal lag in DSI_3 values in following years.

DSI_3 data: G McTainsh, Griffith University, Queensland. Graphs: ACRIS-MU.

- Medium-term (10+ year) changes in dust levels in relation to climate, vegetation change and management across broad regions of the rangelands need to be better understood. Future work by McTainsh and colleagues to relate DSI_3 values over a longer period to seasonal conditions and known changes in vegetation has the potential to improve reporting capacity.

Water resources

The National Water Commission has undertaken a baseline assessment of Australia's water resources (NWC 2007ab) according to its obligations under the National Water Initiative. The objective of the assessment was to make information on the condition of and pressures on Australia's water resources relevant to a range of stakeholders, resource managers and decision makers in the first year of the National Water Initiative. The assessment (Australian Water Resources 2005, or AWR 2005) is the most recent attempt to report on the quantity, quality, use, allocation and management of surface water and groundwater resources since the Australian Water Resources Assessment (NLWRA 2001b).

AWR 2005 and associated information is available from the National Water Commission, including information on water availability, river and wetland health, and water use.[17] Therefore, data and information on water quality and quantity in the rangelands have not been collated separately for this report; nor has there been any specific monitoring of water resources in the rangelands for the report.

Reporting boundaries

AWR 2005 revised the mapped management boundaries used by the states and territories to manage and report on surface water and groundwater.

- Surface water resources have been divided into 12 drainage divisions, 246 river basins and 340 surface water management areas.
- Groundwater resources have been divided into 69 groundwater provinces and 367 groundwater management units.

[17] http://www.nwc.gov.au; specific information on water availability, river and wetland health, and water use is at http://www.water.gov.au.

Figure 3.48 Irrigated agriculture — an important component of regional rangeland economies

Irrigated agriculture is important to regional rangeland economies (see the Socioeconomic theme in this chapter). Further analysis of groundwater – surface water interactions is required in many areas to determine the extent to which current water extractions are sustainable.

Photo: Arthur Mostead

For maps of surface and groundwater resources, see the Australian Water Resources website.[18]

Individual datasets for catchments and groundwater management areas can also be viewed at the website. While information on quantity and quality remains a national water accounting issue, water balances and other data are available for a number of management areas in the rangelands.

Key points

The National Water Commission baseline assessment has raised some important issues for the rangelands:

- Further mapping and analysis of the extent of groundwater – surface water interactions and the impact that increased groundwater extractions may have on stream flow and the environment are required (Figure 3.48). Upstream extractions of water from inland rivers for irrigation can affect the health of the whole river system.
- Definitions of sustainable yield or a surrogate, both for surface waters and for groundwaters, are needed nationwide (Figure 3.49).

[18] http://www.water.gov.au/KeyMessages/SurfaceAndGroundWaterManagementBoundaries/index.aspx?Menu=Level1_1_3 (accessed 16 August 2007)

Figure 3.49 Water for cotton, Bourke, NSW

Upstream extractions of water from inland rivers for irrigation can affect the health of the whole river system.

Photo: Liz Poon

Figure 3.50 Snappy gum (*Eucalyptus brevifolia*)–spinifex (*Triodia basedowii*) habitat

Photo: Graeme Chapman

- Analysis of natural stream flows and groundwater levels before water resource development is necessary to allow us to understand the impact of such development on flows and levels, and to identify the potential for double accounting of groundwater and surface water resources.
- Improving information on water quality (particularly groundwater quality) will be particularly important in the rangelands.

Biodiversity

Globally and nationally, concern about the state of Australia's biodiversity is growing, especially in the light of obvious declines in remote but utilised environments, such as arid and semiarid rangelands.

Because of the challenges in assessing change in biodiversity, the ACRIS-MC's Biodiversity Working Group has selected 10 indicators as the most useful for inclusion in this report. The 10 were chosen from previous evaluations of more than 50 biodiversity indicators (Smyth et al 2003, Hunt et al 2006). Their selection was based on criteria such as providing a national view of change, being regularly monitored, providing reliable interpretations, and having the potential for future use (Table 3.7).

Assessing change in biodiversity requires repeated measurement or monitoring of changes in species populations, gene pools and biological communities. Figures 3.50 and 3.51 show examples of diverse biological communities in the rangelands where it is important to understand change in biodiversity.

Monitoring all the attributes of biodiversity is a complex task. According to Hunt et al (2006), an effective monitoring system must include the following principles:

- Identify the reasons for monitoring and how the information is to be used.
- Identify who is responsible for doing the monitoring, and for collating, analysing and storing the data.
- Identify and prioritise the risks to biodiversity values … focus on the land uses that are occurring and potentially driving the changes in biodiversity values

Figure 3.51 Bluebush (*Maireana sedifolia*) country near Silverton, NSW

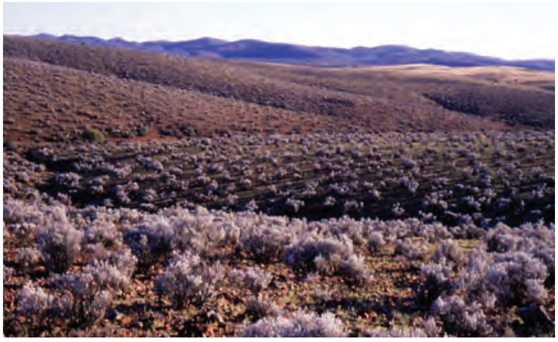


Photo: Liz Poon

- Define what you are monitoring … structural, compositional and functional elements.
- Identify appropriate indicators … what will be monitored and how.

The 10 selected indicators are not listed in order of priority or according to their feasibility or likelihood of being monitored (see Table 1 in Hunt et al 2006 for this perspective). However, the Biodiversity Working Group has noted for each indicator whether it:

- currently or potentially can provide a national view
- is being, or has the potential to be, regularly monitored
- currently provides reliable and consistent information, or needs further development for ACRIS.

Protected areas

Changes from 2000 to 2004 in the extent of protected area within each rangeland bioregion are recorded in the Collaborative Australian Protected Areas Database (CAPAD). The 2006 data were not available for this report. The changes between 2000 and 2004 provide a critical indicator of how Australia is tracking in its quest to improve the conservation of its biodiversity. Establishment of conservation areas on private lands is covered in Chapter 5.

For many years, the Commonwealth and states and territories have been active in establishing a system of parks or reserves to protect habitats for biota. Protected areas form part of the National Reserve System.

Within CAPAD, protected areas are grouped into different conservation categories (eg national parks, conservation reserves, nature parks, heritage sites, remote areas, natural areas). The categories follow the International Union for Conservation of Nature (IUCN) classification system[19], with categories I to IV meeting the requirements of the National Reserve System. The IUCN categories are:

IA *Strict Nature Reserve* — managed mainly for science

IB *Wilderness Area* — managed mainly for wilderness protection

II *National Park* — managed mainly for ecosystem conservation

III *Natural Monument* — managed for specific natural features

IV *Habitat/Species Management Area* — mainly for conservation

V *Protected Landscape/Seascape* — managed for conservation

VI *Managed Resource Protected Area* — managed for sustainable use.

There are also private areas held by non-government organisations such as the Australian Wildlife Conservancy and Bush Heritage Trust. Indigenous protected areas may not be recognised as being formally protected over the long term under state/territory or Commonwealth legislation (see Chapter 5) due to tenure arrangements such as limited-term leases, or to contracted arrangements limited to the life of the funding programs.

One requirement for a protected area is that it must contribute to the principles of CAR: comprehensiveness, adequacy and representativeness.

- *Comprehensiveness* is a measure of how many of the different regional ecosystems located within a bioregion are protected within that bioregion.
- *Adequacy* refers to the capacity of protected areas to sustain protection of biodiversity values.
- *Representativeness* is an assessment of whether the variation in regional ecosystems is covered in the protected area system.

[19] See http://www.environment.gov.au/parks/iucn.html.

Table 3.7 Biodiversity indicators selected by the ACRIS-MC Biodiversity Working Group

No.	Description[a]	National view by IBRA bioregions	Regularly monitored and reported	Development for ACRIS monitoring and reporting[b]
1	Protected areas designated to conserve habitats for biodiversity: number by bioregion	Yes	Yes, to Collaborative Australian Protected Areas Database (CAPAD)	Information on whether protected areas are progressing towards CAR (comprehensiveness, adequacy and representativeness)
2	Threatened species and biotic communities: numbers listed by bioregion	Yes	Yes; listed under the *Environment Protection and Biodiversity Conservation Act 1999*	Consistent use of IUCN 'threatened' categories and further evaluations of the status of species and communities
3	Habitat loss and fragmentation due to tree clearing: % by sub-IBRA regions	Potentially	Potentially, but no consistent method or reporting	Consistent methodology and strengthened linkages to biodiversity
4	Distribution of artificial waterpoints to indicate impact on habitats	Potentially	No; data irregularly updated and reports incomplete	Improved accuracy and regularity of analyses, and reports on waterpoints
5	Surveys and records for fauna: numbers across regions	Potentially	Potentially, but reporting is irregular and incomplete	Coordination of a regular and consistent form of reporting fauna records
6	Surveys and records for flora: numbers across regions	Potentially	Potentially, but reporting is irregular and incomplete	Coordination of a regular and consistent form of reporting flora records
7	Transformer weeds: invasive exotic plants that modify habitats for native biota	Yes	No; information focuses on Weeds of National Significance	Improved information on rangeland transformers, such as exotic grasses
8	Wetland distribution and condition	Yes	Potentially, but reporting is irregular	Continued development of remote sensing methods to map wetlands
9	Habitat condition: extent and type of groundcover as habitat for biota — based on remote sensing	Potentially	Potentially, but as yet no consistent method or reporting	Consistent methodology and strengthened linkages to biodiversity
10	Bird species composition and distribution	Yes	Yes, but dependent on Birds Australia Atlas surveys and reporting	Improved coverage of rangeland regions by Birds Australia surveys

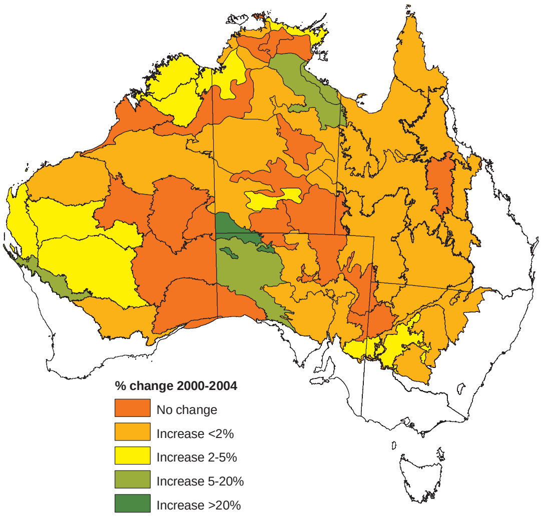
[a] See indicator subsections below for details.

[b] See subsections for additional recommended developments.

Progress on adding protected areas: 2000–2004

Change in the area protected within each rangeland bioregion from 2000 to 2004 can be expressed and mapped as a percentage change (Figure 3.52). There were small increases in the percentage area protected for most rangeland bioregions, with significant expansion in the Central Ranges (NT and SA) and Great Victoria Desert (SA) (Figure 3.53). Lesser increases (2%–5%) occurred in the Murray-Darling Depression and MacDonnell Ranges IBRAs, in several WA bioregions and in the Top End of the NT. Approximately 50 000 km^2 of pastoral lease country has been purchased by the WA Government for conservation, but those areas are not yet formally reserved. This change in land use represents significant progress towards CAR, particularly in the Gascoyne–Murchison region.

Figure 3.52 Change in the protected areas within each rangeland IBRA bioregion, 2000 to 2004 (%)



Note: WA reports on protected areas that meet the minimum standards of the National Reserve System, which includes land acquired for conservation and land that is in the process of being formally reserved.

Data: Queensland, NSW, SA and the NT — CAPAD, Department of the Environment, Water, Heritage and the Arts; WA: WA Department of Environment and Conservation. Map: ACRIS-MU.

Figure 3.54 shows changes in the extent of protected areas each year.

Significant areas were added to CAPAD in SA and the NT between 2000 and 2002. Although the areas added between 2002 and 2004 were smaller, they were widely dispersed across the rangelands. This contributed to the principles of CAR by providing a more comprehensive, adequate and representative reserve system to protect areas of habitat for biodiversity.

Key points

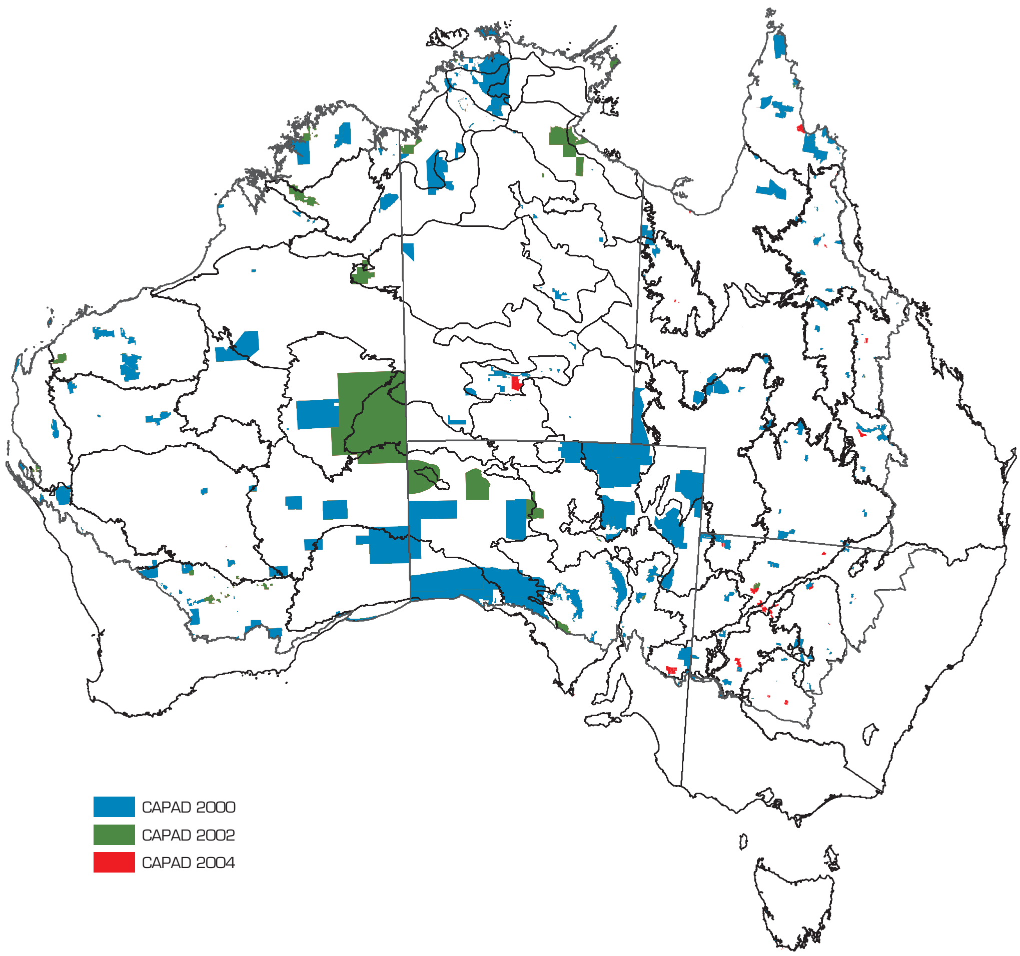
- Analyses of the CAPAD information and separate data for WA showed that most rangeland bioregions increased their percentage of protected area; in central Australia, some made notable additions.
- A number of concerns were identified:
  - Once protected areas are acquired, their locations are fixed, and their effectiveness in conserving biodiversity in the face of increased climate variability is uncertain.
  - Data relating to protected areas in CAPAD do not always meet the minimum standards of the National Reserve System.

Figure 3.53 Marble gum (*Eucalyptus gongylocarpa*) over spinifex (*Triodia basedowii*) on dune, Great Victoria Desert bioregion

Location: Anne Beadell Highway, Mamungari Conservation Park

Photo: Jeff Foulkes, SA Department for Environment and Heritage

Figure 3.54 Change in the extent of protected areas within the rangelands, 2000 to 2004



Data: Queensland, NSW, SA and the NT — CAPAD, Department of the Environment, Water, Heritage and the Arts; WA: WA Department of Environment and Conservation. Map: ACRIS-MU.

– Although protected area data in CAPAD have some limitations, they are updated on a bioregion basis every two years and provide a very valuable national-scale indicator of changes in Australia's efforts to conserve habitat for biodiversity.

Number and status of threatened species/communities

This section reports change in the numbers of declared threatened species in rangeland bioregions. Caution is required when interpreting some changes because they may be due to taxonomic revisions and improved information on threatened status. Data on threatened ecological communities are also reported, although those data are more limited.

Previous studies have found that Australia's rangelands have lost a substantial number of plant and animal species. The populations of some taxa have changed greatly:

> … the terrestrial mammal fauna … has suffered catastrophic decline in many rangeland areas. This loss has particularly affected larger dasyurids and rodents, bandicoots and smaller macropods … The bird fauna of many rangeland regions has suffered regional extinctions and pronounced change … Declines appear to be continuing across much of the rangelands. (Woinarski et al 2000a)

Other taxa have probably changed little, and some have increased in distribution and abundance:

> There is less evidence for change in the reptile, frog and invertebrate faunas of the rangelands, but this needs qualification because of the even poorer historic baseline information … some species have

Box 3.10 Sources of information on threatened species and communities

State/territory	Agency/department	Website
NSW	Environment and Conservation	http://www.threatenedspecies.environment.nsw.gov.au/index.aspx (accessed 19 March 2007)
NT	Natural Resources, Environment and the Arts	http://www.nt.gov.au/nreta/wildlife/animals/threatened/specieslist.html (accessed 19 March 2007)
Qld	Environmental Protection Agency / Queensland Parks and Wildlife Service	http://www.epa.Qld.gov.au/nature_conservation/wildlife/threatened _ plants_and_animals/ (accessed 19 March 2007)
SA	Environment and Heritage	http://www.environment.sa.gov.au/biodiversity/threatened.html (accessed 19 March 2007)
WA	Environment and Conservation	http://www.dec.wa.gov.au/ (accessed 19 March 2007)

> increased … favoured by the provision of artificial water sources and by vegetation change associated with pastoralism. Examples include crested pigeon, galah and large kangaroos. (Woinarski et al 2000a)

A number of the processes likely to cause species losses, such as droughts, longer-term climate changes, pastoralism and introduced pests such as rabbits, foxes and feral cats, have been identified (Woinarski et al 2000a, Smyth et al 2003, Fisher et al 2004, Smyth and James 2004).

Those processes threaten ecological communities with restricted distributions, such as mound spring communities, and continue to threaten animal and plant species and communities in the rangelands more generally. It is essential to keep track of whether numbers of threatened species are stable or declining.

Listings and data sources

State and territory agencies have identified threatened species and communities under the relevant legislation of their jurisdictions (Box 3.10). That information is used to regularly update a national EPBC database, which is maintained by the Australian Government as part of the EPBC Act.[20] State/territory and national databases provide ecological descriptions of threatened communities and taxonomic information on threatened species. State and territory agencies also identify the processes threatening species and communities and develop recovery plans.

A status category is assigned to each threatened species and ecological community. In general, state/territory databases combine three IUCN categories to define species or communities as 'threatened': 'critically endangered', 'endangered' or 'vulnerable'.[21]

The national EPBC database also uses these three IUCN categories to list species or communities as 'threatened'. Specifically, the EPBC categorises species as 'extinct', 'extinct in the wild', 'critically endangered', 'endangered', 'vulnerable' or 'conservation dependent'. Species listed as conservation dependent are not identified as of national environmental significance ('protected matters') under the EPBC Act.

Some data on species extinctions across rangeland bioregions are available (Woinarski et al 2000a, Smyth and James 2004). For example, based on data available at the end of 2005 for the NT, 21 mammal species have likely become extinct in both the Finke and Great Sandy Desert bioregions, whereas only one mammal

20 http://www.environment.gov.au/epbc (accessed 19 March 2007)

21 http://www.iucnredlist.org/info/categories_criteria (accessed 19 March 2007)

species is known to have become extinct in the Arnhem Plateau bioregion (Alaric Fisher, Natural Resources, Environment and the Arts, NT, pers comm, 2007).

A new approach to assessing the condition of ecological communities has been proposed by the Threatened Species Scientific Committee[22] (Beeton et al 2006). That approach recognises the impact of degradation through the use of condition classes that describe areas of an ecological community with similar conservation values. The definition of an ecological community listed under the EPBC Act will now include information on the condition classes. The new approach applies to areas that contain degraded examples of listed ecological communities that may be rehabilitated. This adds to the credibility of the listings and will assist regional bodies in developing appropriate management responses.

Numbers of threatened species, by bioregion

The number of EPBC threatened plant species across rangeland bioregions has been mapped (Figure 3.55) using the most recent information (mostly 2006) available from state/territory agencies. This information will be used to update the national EPBC database.

The high number of threatened plants seen in the Cape York Peninsula bioregion has been confirmed by Landsberg and Clarkson (2006):

> Cape York Peninsula … contains some of Australia's highest concentrations of species that are rare, endemic or thought to be threatened with extinction. Sixty-seven of its plant species are currently listed as threatened …

Numbers of threatened species tend to be higher in many of those rangeland bioregions bordering areas used for both farming and pastoralism — areas often referred to as the 'sheep–wheat belt'.

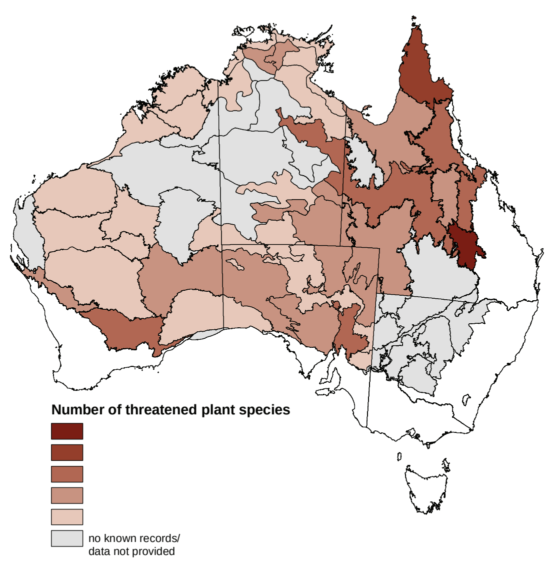
Comparison of the 2006 data with those from the 2001 rangelands report (NLWRA 2001a, p 46, Figure 13) shows that important changes have occurred (although the data for 2001 were by IBRA subregion, so numbers mapped will tend to be lower, making direct comparison difficult). Information was far more extensive in 2006, with very few bioregions having 'no known records' for threatened plants (Figure 3.55). Comparing the 2006 and 2001 maps also reveals that the numbers of threatened plants have increased in some areas, for example in the rangeland bioregions bordering or mixed with farming areas in southwestern WA. In contrast, few changes in the numbers of threatened plants have occurred in bioregions of the Kimberley and Arnhem Land.

Using the latest information from state/territory agencies, numbers of threatened terrestrial vertebrate species can also be mapped (Figure 3.56).

Data are from 2006, and can be compared to similar numbers in the 2001 rangelands report (NLWRA 2001a, p 47, Figure 14). This comparison again illustrates that data were more complete in 2006, with no bioregions designated as having 'no known records'. It appears that bioregions along rangeland margins where grazing and farming mix had an increased number of threatened vertebrate fauna species, as was the case for threatened plants.

The numbers of threatened vertebrate species can also be viewed by taxonomic group. The numbers of threatened bird species appear to be highest in the northeastern rangeland bioregions (Figure 3.58). As an example, the golden-shouldered parrot (*Psephotus chrysopterygius*; Figure 3.57) once occurred over most of Cape York Peninsula but is now restricted to two populations in the central part of the bioregion. The

Figure 3.55 Numbers of threatened vascular plant species across rangeland bioregions



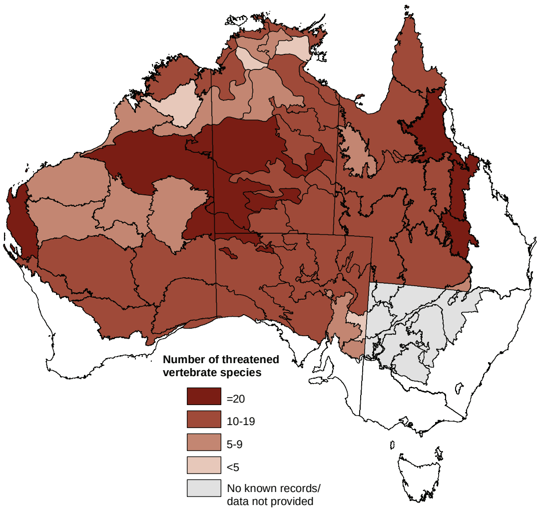
Source: Australian Government EPBC database, http://www.environment.gov.au/epbc (accessed 19 March 2007). Map: ACRIS-MU.

22 http://www.environment.gov.au/biodiversity/threatened/committee.html (accessed 19 March 08)

species only occurs in tropical savannas, where it nests in termite mounds. Its diet appears to be limited to seeds of annual and perennial grasses in the savannas. The parrot is listed as 'endangered' and continues to be threatened because:

> A shortage of food occurs annually in the early wet season and this can be made worse by a lack of burning and intense cattle and pig grazing. Altered fire patterns and grazing have also resulted in an increase in the density of woody shrubs which, it is thought, increases the vulnerability of the parrots to predators. (Garnett and Crowley 2003)

Figure 3.56 Numbers of threatened vertebrate species across rangeland bioregions



Source: Australian Government EPBC database, http://www.environment.gov.au/epbc. Map: ACRIS-MU.

Figure 3.57 Golden-shouldered parrot (*Psephotus chrysopterygius*) on a termite mound, Cape York Peninsula, Queensland

Photo: Queensland Environmental Protection Agency / Queensland Parks and Wildlife Service

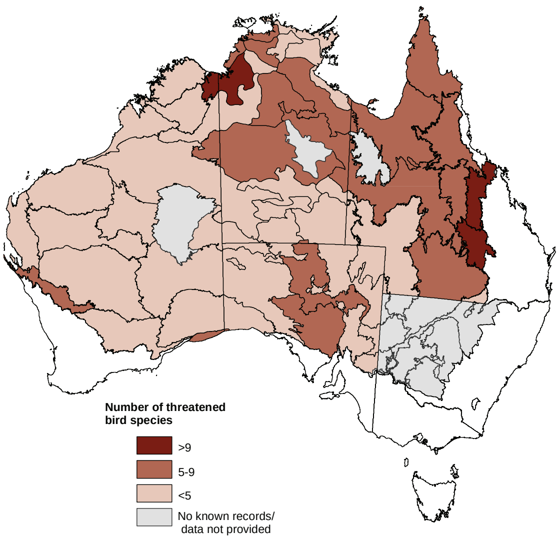
The numbers of threatened mammal species are generally highest in the arid interior (Figure 3.59). The numbers of threatened reptiles, amphibians and fish as a group tend to be higher in certain regions around the margins of the rangelands (Figure 3.60), but the available data for those taxa are few.

Numbers of threatened ecological communities

Information on threatened communities is inconsistent and incomplete. However, Neagle (2003) has collated a comprehensive report on threatened ecological communities and species for South Australia. This report covers seven rangeland bioregions in central and eastern SA. Three bioregions on Aboriginal lands in western SA will be covered in a later report. Although a peppermint box woodland and scented mat-rush and hard mat-rush grasslands are listed as threatened in SA's rangelands, the major threat is to mound springs in the Great Artesian Basin (GAB) in northeast SA (Figure 3.61). In the rangeland bioregions of Queensland, GAB springs are also listed and protected as threatened ecological communities.[23]

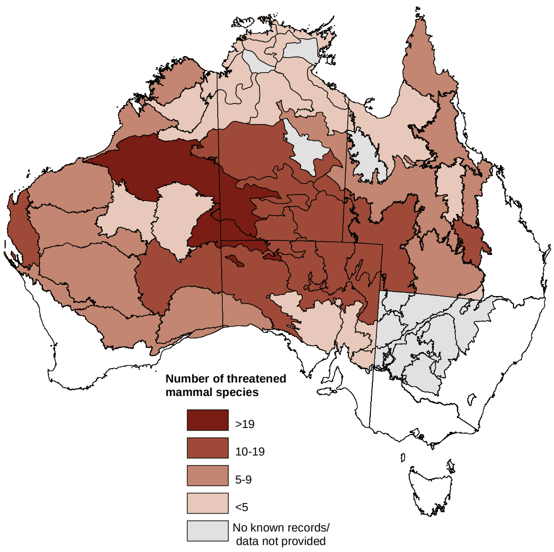
[23] http://www.epa.qld.gov.au/wetlandinfo/site/factsfigures/SummaryInformation/springs.html (accessed 24 March 2007)

Figure 3.58 Numbers of threatened bird species across rangeland bioregions, 2006



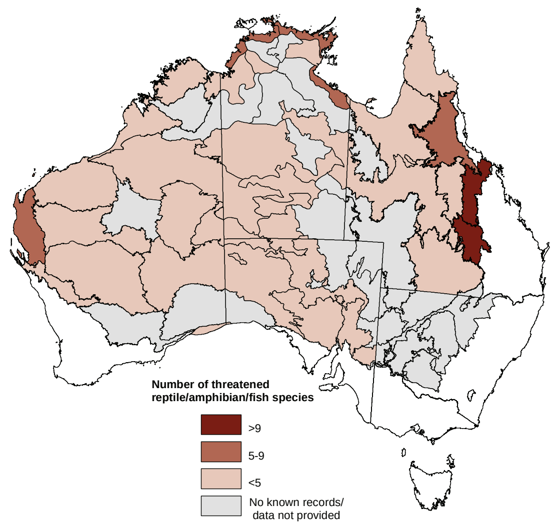
Source: Australian Government EPBC database, http://www.environment.gov.au/epbc. Map: ACRIS-MU.

Figure 3.59 Numbers of threatened mammal species across rangeland bioregions, 2006



Source: Australian Government EPBC database, http://www.environment.gov.au/epbc. Map: ACRIS-MU.

Figure 3.60 Numbers of threatened reptile, amphibian and fish species across rangeland bioregions, 2006



Source: Australian Government EPBC database, http://www.environment.gov.au/epbc. Map: ACRIS-MU.

All threatened regional ecosystems in rangeland bioregions in Queensland, not just springs, have been tabulated (Table 2 in Accad et al 2006). Of a total of 34 threatened (endangered) regional ecosystems, 26 occur within the Brigalow Belt South and North bioregions. All other rangeland bioregions have three or fewer threatened regional ecosystems.

Figure 3.61 Mound spring vegetation, SA, following exclusion of stock

Photo: Pastoral Land Management Group, SA Department of Water, Land and Biodiversity Conservation

Case study: status and management of mound springs as a threatened community

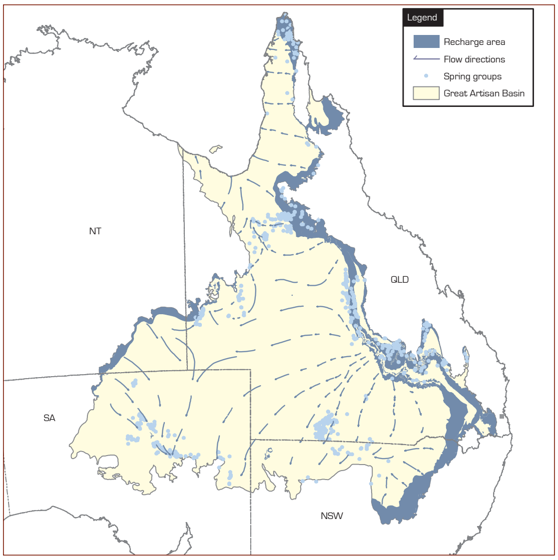
Artesian or free-flowing springs are rare and unusual environments, and therefore have significant ecological and social values. In Australia, the GAB underlies much of Queensland and parts of the NT, SA and NSW (Figure 3.62), or about one-fifth of the continent. Clustered in the GAB are a number of active artesian springs, but the number still free-flowing has declined by almost 40% since 1900. Many springs have become inactive and damaged, according to Fensham and Price (2004):

> … as a result of groundwater extraction that has greatly reduced the artesian pressure of the basin … many of the remaining spring wetlands have been eradicated by mechanical excavation or degraded by stock trampling, pig rooting or the use of exotic grasses for ponded-pasture.

Active, undamaged springs in the GAB are rare and have high conservation values; many have endemic flora and fauna. However, managing artesian springs in the basin has proven difficult:

> … high value spring wetlands occur on tenures where management is not directed towards conservation … but primarily towards cattle (or occasionally sheep) production enterprises. Some of these sites are secure under current management … A strategy … of a bore-capping program and using legislative instruments in conjunction with landholder liaison to ensure that the high priority spring wetlands … are immune from threatening processes. (Fensham and Price 2004)

Figure 3.62 Great Artesian Basin, free-flowing springs



Map: Adapted from GABCC (2000). © Queensland Government

Controlling flows from artesian bores is now part of a cooperative initiative to manage the GAB.[24]

Key points

- Based on information in the national EPBC database and the most recent (2006) information from state/territory agencies contributing to the database, analyses and mapping have shown that the numbers of threatened species in 2006 differed greatly across rangeland bioregions. For example, the Brigalow Belt in Queensland had over 50 threatened plant species, whereas most other bioregions had fewer than 10.
- Caution is required when interpreting some changes that may be due to taxonomic revisions and improved information on threatened status.
- The numbers of threatened flora species are considered low for some WA bioregions because a large number of flora taxa ('priority flora') that occur in the rangelands are regarded as under some form of threat or are in decline. However, there is as yet insufficient information to confirm their conservation status (Mark Cowan, WA Department of Environment and Conservation, pers comm 2007).
- Information allowing a national view on threatened ecological communities is currently sketchy and incomplete, and this report only includes regional case studies.

Habitat loss by clearing

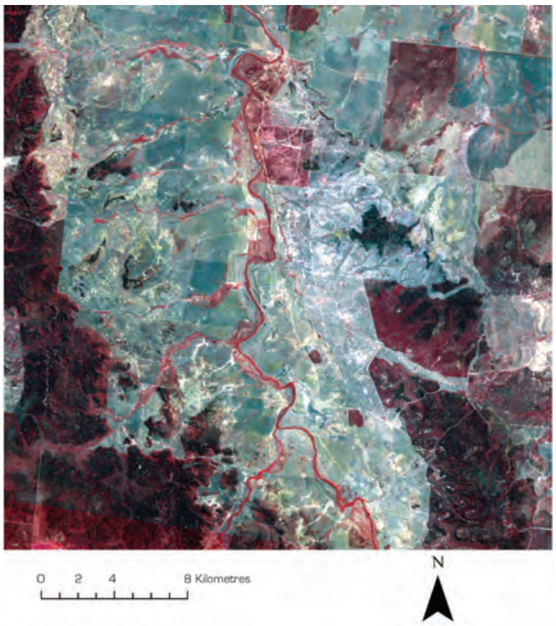
Broadscale land clearing is recognised as one of the more significant threats to biodiversity, although it occurs in a limited portion of Australia's rangelands.

Wilson et al (2002) presented data documenting the state of clearing in Queensland (as of 1999) by IBRA bioregions and sub-IBRA regions, and noted that:

> [t]he majority of Queensland has relatively continuous native vegetation cover (82% remnant native vegetation remaining in 1999). The productive soils of the southern part of the Brigalow Belt, lowlands in Southeast

24 http://www.nrw.qld.gov.au/water/gab/gabsi.html (accessed 24 March 2007)

Figure 3.63 Landsat TM image showing clearing of woody vegetation south of Alpha, central Queensland, 2002



Note: Remnant vegetation shows as darker reds and browns (TM band 2, blue; TM Band 3, green; TM band 4, red).

Source: Geoscience Australia. Map: ACRIS-MU

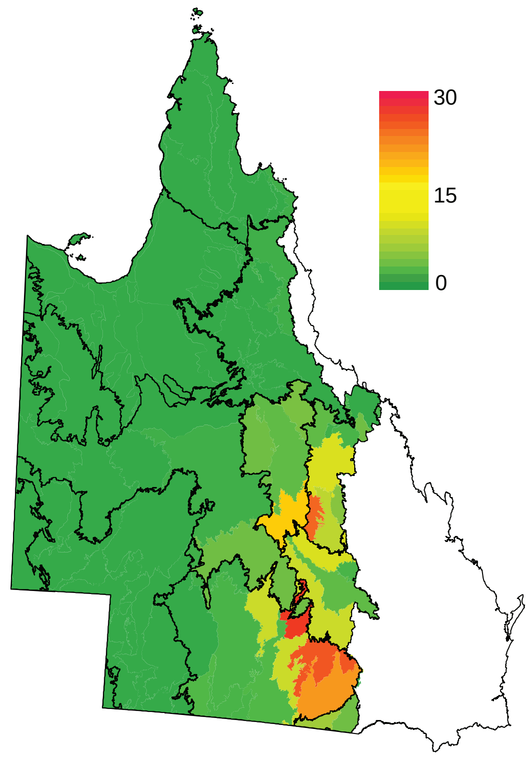
> Queensland, New England Tableland and Central Queensland Coast have been, however, extensively cleared with 7–30% of remnant vegetation remaining.

Habitat loss and fragmentation, and its effect on biodiversity, are an extremely important issue for Indigenous people because they greatly value the diversity of habitats, wildlife and vegetation:

> … people living on country and harvesting wildlife [defined to include trees and bush materials such as fibre, fruit and seed] produce important sources of foods with associated economic and health benefits … Where Indigenous people live on their country, ecological and wider benefits are generated via favourable fire regimes, control over weed infestations, and potentially through feral animal harvesting. (Altman and Whitehead 2003)

Because woodlands and forests typically occur in landscapes with higher and more reliable rainfall, areas with substantial tree and shrub cover tend to occur around the boundaries defining the more arid and semiarid rangelands, notably in eastern Queensland

Figure 3.64 Area of woody vegetation cleared, sub-IBRA regions in the rangeland bioregions of Queensland, 1991 to 2003 (%)



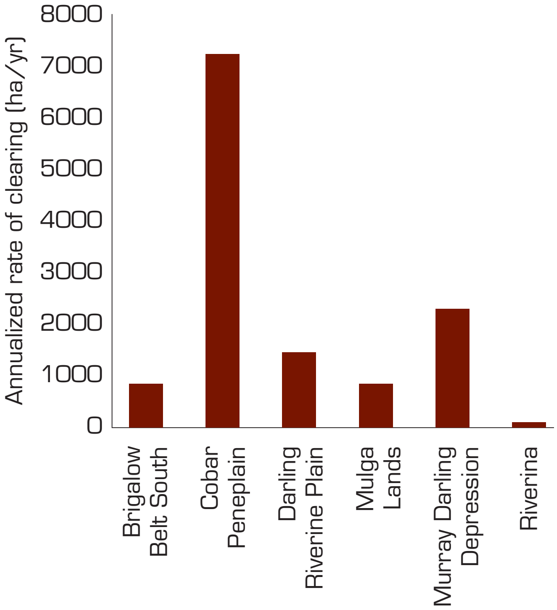
Source: SLATS, Natural Resource Sciences, QDNRW. Map: ACRIS-MU

and eastern NSW. In SA and most of WA, habitat loss due to clearing is a minor issue because only a few rangeland areas have high tree cover. In the NT, tree clearing is only an issue for a few bioregions in the Top End.

Data sources and definitions

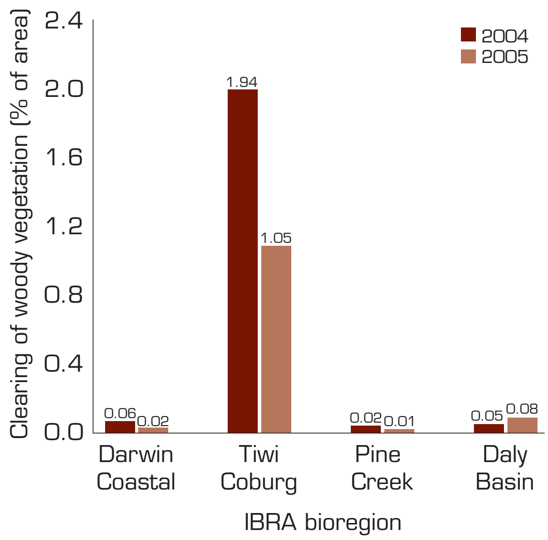
Queensland's SLATS has used Landsat TM imagery to estimate the percentage of each sub-IBRA region cleared (DNRM 2005) (Figure 3.63). Based on SLATS analyses, notable increases in the percentage area of woody vegetation cleared from 1991 to 2003 were evident in a few rangeland regions (Figure 3.64), for example in eastern and northeastern areas of the Mulga Lands bioregion and in southwestern sections of the Brigalow Belt North bioregion. In other rangeland bioregions of Queensland, there has been little change in the percentage area of woody vegetation between 1991 and 2003.

Figure 3.65 Annualised rate of clearing, NSW rangeland bioregions, 2004 to 2006 (ha/year)



Source: Science Services Division, NSW Department of Environment and Climate Change

Figure 3.66 Rate of clearing, Top End bioregions of NT, 2004 and 2005 (%)



Source: NT Department of Natural Resources, Environment and the Arts

A SLATS approach using satellite imagery and analysis techniques has also been applied to estimate changes in clearing, defined as an *annualised rate of woody vegetation change*, between 2004 and 2006 in NSW rangeland bioregions (Figure 3.65). For these SLATS-type analyses, woody vegetation was defined as 'woody communities with 20% crown cover or more (eg woodlands, open forests and closed forests) and taller than about 2 metres' (DNR 2007).

'Annualised rates' of clearing are defined as annual rates of woody vegetation change due largely to cropping, pastoralism and thinning but also to rural and major infrastructure development, fire scars and forestry (DNR 2007).

As noted in a 2005 report by the NT Department of Natural Resources, Environment and the Arts, the NT also updates its estimates of land clearing using 'Landsat satellite imagery [with] an accuracy scale of 1:100 000 mapping on the ground. The data were generated from a range of band ratio techniques, including NDVI and difference imaging to highlight areas of cleared land' (DNRETA 2005). The report provides an estimated update on the total area cleared in each IBRA bioregion. As of September 2005, the Daly Basin bioregion had the highest percentage of total woody vegetation clearing (10.9%, largely for agriculture and horticulture), followed by Darwin Coastal (4.7%, mostly infrastructure), Pine Creek (2.7%, mining), and Tiwi–Cobourg (2.1%, plantation forestry). The bioregions in the semiarid and arid rangelands had very little clearing (usually <0.5%).

Recent clearing of woody vegetation is essentially limited to a few northern bioregions (Figure 3.66). The largest area cleared was in the Tiwi–Cobourg bioregion in 2004 (about 2%), largely due to Indigenous forestry developments.

Case studies: habitat loss and fragmentation effects on biodiversity in central Queensland bioregions

There are several examples of how clearing has adversely affected biodiversity in central Queensland bioregions:

- Woinarski et al (2006) attributed a number of statistically significant declines in woodland and forest fauna to the loss and fragmentation of habitats caused by high rates of vegetation clearance in central Queensland (the study area was not all in the rangelands). The extent of native vegetation declined from 87% to 41% between the mid-1970s and 2001–02.

- A companion study (Hannah et al 2007) found that 'bird species richness (at the scale of a 1-ha quadrat) was least in cleared areas (8.1 species), then regrowth areas (14.6 species), then uncleared woodlands (19.9 species) … At a whole of patch scale, richness increased with fragment size.'
- In the same region, Ludwig and Tongway (2002) documented significant changes in fauna due to altered vegetation structure and function resulting from patterns of tree clearing and thinning ('when savannas are cleared of trees and woody debris … open woodland fauna abundance declined whereas grassland fauna … increased in abundance').

Key points

- Loss and fragmentation of habitats for biota remains an issue in rangeland regions with significant amounts of woody cover.
- A number of different kinds of rangeland taxa were shown by case studies to be affected by habitat loss and fragmentation due to tree clearing.
- Significant changes in woody cover occurred in only a limited number of rangeland IBRA bioregions and sub-IBRA regions.
- In addition to clearing of remnant native vegetation, factors changing woody cover include woody thickening and thinning, and reclearing of woody regrowth.

Stock waterpoint effects on biota

This component of the Biodiversity theme examines water-remoteness — that is, the distance from permanent or semipermanent water, which is known to strongly influence biodiversity in Australia's rangelands (see, for example, James et al 1999). Because natural surface water is scarce and mostly ephemeral, the development of the pastoral industry in the Australian rangelands has depended on the installation of tens of thousands of artificial waterpoints to provide stock with more land close to water.

The density of waterpoints is also examined under the Sustainable management theme, where the emphasis is on the provision of water for livestock as a factor in sustaining production. Here the emphasis is on how the density of stock waterpoints affects biodiversity in areas remote from water. The data sources are the same (see Box 3.4).

Effects of distance from waterpoints on biodiversity

Distance from waterpoints is known to affect rangeland biodiversity:

> There appears to be a consistent message of warning coming from … different authors in different regions: widespread provision of artificial water in previously dry landscapes is potentially threatening to many species through many of the mechanisms identified in this paper. (James et al 1999)

In general, grazing pressure declines with distance from water, so that impacts of grazing and trampling on vegetation structure, vegetation composition, ecosystem function and habitat quality become less pronounced with increasing distance. The spread of permanent water across landscapes also facilitates the spread of native species that are water dependent or favour disturbed areas; those species then impact on other species through competitive interaction. Waterpoints may also facilitate the spread of feral grazers and large macropods, adding to total grazing pressure and attracting native and introduced predators.

Studies along gradients of distance to water in several rangeland ecosystems, such as mulga woodlands and chenopod shrublands (Landsberg et al 2003) and

Figure 3.67 Long-tailed planigale (*Planigale ingrami*)

The long-tailed planigale is Australia's smallest marsupial. It is common in the black-soil grasslands of northern Australia, although research in the Barkly Tableland (Mitchell Grass Downs bioregion) has shown that its population declines under heavy grazing pressure.

Photo: Alaric Fisher, NT Department of Natural Resources, Environment and the Arts

Figure 3.68 Crested pigeon (*Ocyphaps lophotes*)

The crested pigeon has benefited from an increased water supply in the rangelands.

Photo: Geoffrey Dabb

Mitchell grasslands (Fisher 2001), have demonstrated that a significant portion (typically in the range 10%–30%) of species in each taxonomic group are 'decreasers'; that is, they become less abundant closer to water (Figure 3.67). Lightly grazed areas are therefore core habitat for those species, and decreases in the area of water-remote land can result in decline in their range and abundance and, potentially, extinction at local, regional and eventually national scales (Biograze 2000). Determining which species are entirely dependent on areas with little or no grazing pressure is difficult, because such species may be rare (and therefore difficult to adequately sample), and because undisturbed 'reference' sites are difficult to locate in many rangeland regions and ecosystems (Landsberg et al 2003).

Another part of the biota can be identified as 'increaser' species (that is, they become more abundant closer to water). Many increasers are species already widespread and common within the rangelands (eg galah, crested pigeon; Figure 3.68).

The exact nature of the relationships between distance from water, grazing pressure and impacts on biodiversity depends on a large number of factors, including the age of waterpoints, types of stock, stocking history, seasonal conditions, the distributions of different soil and land types within paddocks, and the sensitivity of different biota. It is generally considered that most grazing impact occurs within a 5 km grazing radius of water for sheep and an 8 km radius for cattle, although livestock will walk considerably further from water at times. Beyond 8 km, grazing pressure is generally light and intermittent, and land may be considered 'water-remote'.

Distance from stock waterpoints has been shown to be a useful indicator for pressure on biodiversity in drier rangelands. A decrease over time in the total area of water-remote land is likely to be an indicator of negative impact on grazing-sensitive biota.

Data on water-remote land

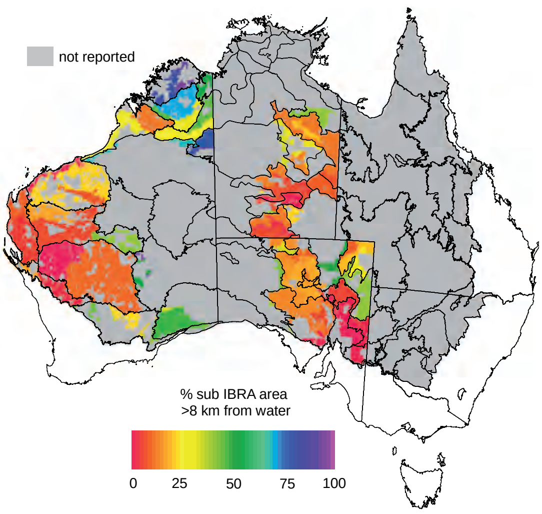
Based on available data on the distribution of stock waterpoints across the rangelands (see Box 3.4), the area remote (>8 km) from water was calculated as a proportion of the area of each rangeland sub-IBRA region.

Less pastorally productive bioregions tend to have a greater percentage of their area more than 8 km from water (Figure 3.69). In WA, a high percentage of area is water-remote on pastoral leases in the Tanami P1 subregion (79%), and also in the Nullarbor (NUL2 subregion; 49%), where finding suitable groundwater is very difficult and the limestone karst makes it difficult and expensive to sink dams. Similarly, in the NT, 30% of the analysed area of the Tanami P3 and 23% of the Simpson–Strzelecki Dunefields P1 (SSD1) subregions were water-remote. In SA, the sub-IBRA with the highest proportion of water-remote land was the Western Dunefields (SSD5, 42%).

Changes in water-remoteness

Data on the age of waterpoints, such as those for the southern Alice Springs pastoral district, illustrate how the remoteness of water has changed over the past 100 years (Figure 3.70). Waterpoint ages (from year of establishment) for ~48 500 km^2 were updated from a grazing gradient analysis (Bastin et al 1993). Early waterpoints (pre-1900) were largely semipermanent waterholes and springs along the major rivers and mountain ranges, supplemented by distantly spaced wells. Large proportions of both pastorally productive sub-IBRAs (eg Finke P1) and pastorally less valuable country (eg Simpson–Strzelecki Dunefields P1) were remote from water (Figure 3.71). This situation had changed little by the late 1930s, but in the next 20 years substantial infilling of previously non-watered areas occurred on pastorally more productive country; new bores were drilled and dams sunk.

Figure 3.69 Percentage of each sub-IBRA more than 8 km from stock waterpoints (water-remote), rangelands in WA and parts of SA and the NT

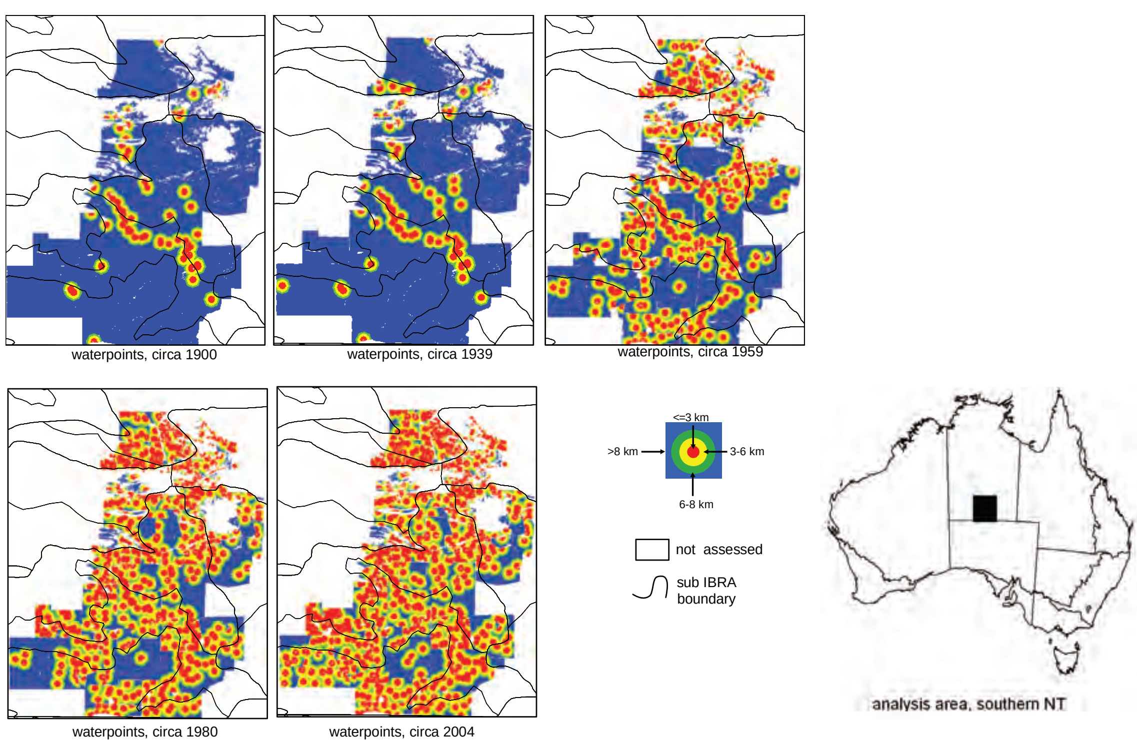


Note: Areas outside pastoral leases are not included.

Data sources: see Box 3.4. Maps compiled by ACRIS-MU.

Over the next 50 years, there were two main reasons for further waterpoint development. The extended and severe 1959–65 drought saw many drought-relief bores drilled under a subsidy scheme. Although development of new waterpoints continued more slowly thereafter, the next major development began in the late 1970s with the national Brucellosis and Tuberculosis Eradication Campaign. The campaign led to more fencing to form smaller, more manageable paddocks (with some additional water supplies), mainly during the 1980s. Further waterpoint development since then has been largely through water reticulation from existing supplies (ie polythene pipe, tanks and troughs), although some additional bores have been drilled and dams sunk. The most recent assessment of waterpoint density (in 2004) placed 43% of Finke P1 sub-IBRA within 3 km of water, with 14% still remote (>8 km) from water (Figure 3.71). The corresponding proportions for the less pastorally valuable Simpson–Strzelecki Dunefields P1 sub-IBRA were 32% close to water (0–3 km) and 26% remote from water.

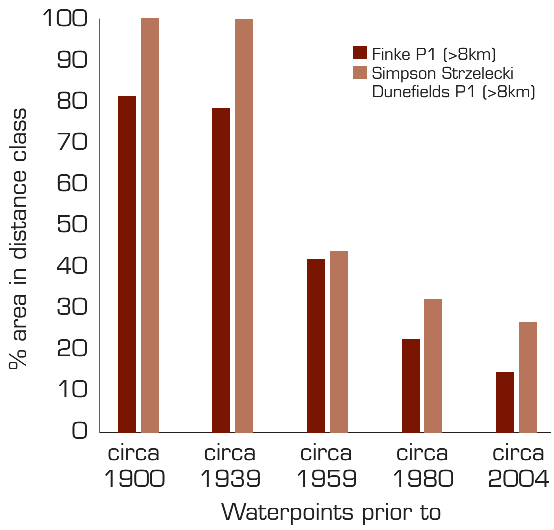
Figure 3.70 Changes in waterpoint density and distance from water, sample area in the NT, circa 1900 to circa 2004



Note: Sample area of 48 500 km^2 in the southern Alice Springs pastoral district, NT.

Data and maps: CSIRO, Alice Springs.

Figure 3.71 Change over time in the percentage of land remote from water in two sub-IBRAs, southern Alice Springs pastoral district



Data and graph: CSIRO, Alice Springs.

Key points

- At the sub-IBRA scale, the distance from water indicator is potentially unreliable because the distributions of both waterpoints and biota are unlikely to extend uniformly across an entire sub-IBRA.
- It would be more meaningful to report the proportion of water-remote land by ecosystem (eg regional ecosystem, land system, pasture type) within sub-IBRAs. This can currently be done for some regions, but national reporting is hindered by the lack of consistent ecosystem and waterpoint mapping across the rangelands.
- The distance from water indicator cannot be effectively applied in relatively mesic rangelands (notably the northern tropical savannas), where there are large numbers of natural waterpoints for at least part of each year.
- In the future, studies could be undertaken to validate the relationship between distance from water and biodiversity for a greater range of landscape types and for a broader range of biota. Ideally this would allow target thresholds to be defined for the retention of water-remote land, such as the 10% threshold suggested in Biograze (2000).

Fauna surveys and records in rangelands

Changes in the number of sites surveyed for fauna across the rangelands and in the number of fauna records from those sites provide a useful indicator of Australia's commitment to understanding and conserving its faunal biodiversity. Field surveys are needed (Figure 3.72), especially in areas of suspected high biodiversity value. Another useful indicator of commitment to conserving biodiversity is the number of repeated surveys used to track changes in fauna populations, especially for those taxa suspected to be in decline.

Very little monitoring of biodiversity values currently occurs. Most current monitoring activities do not monitor biodiversity directly but measure surrogates as an incidental part of monitoring for other natural resource values (Hunt et al 2006).

Efforts are being made to correct these deficiencies. Whitehead et al (2001) described a new framework and Woinarski et al (2000a) synthesised information on fauna present at various sites surveyed across rangeland bioregions, including birds, mammals, reptiles, amphibians and a few key invertebrate groups. Where changes occurred in each of the taxa, those authors noted where, and what factors might have contributed to the changes. Woinarski et al (2000b) also introduced a new procedural manual for monitoring biodiversity.

Figure 3.72 Installing pitfall traps for field surveys, Stony Plains bioregion, northern SA

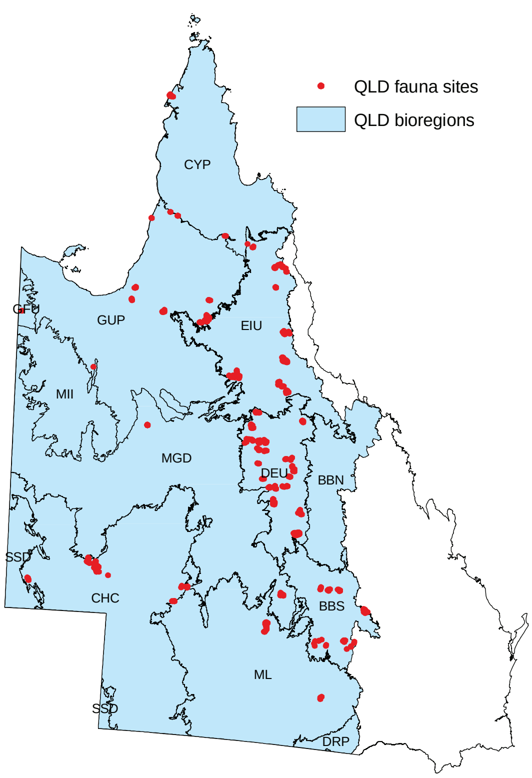
Photo: CSIRO, Alice Springs

Fauna surveys

Data on the numbers and spread of fauna surveys across all rangeland bioregions are incomplete, but an example of the usefulness of available data is provided by the distribution of fauna field survey sites across the rangeland bioregions of Queensland (Figure 3.73). There are few survey sites in western and far north Queensland, where pastoralism and Indigenous occupation are the primary land uses. More fauna surveys have been conducted in eastern bioregions, such as the Desert Uplands and Brigalow Belt, where multiple land uses include pastoralism, cropping and mining.

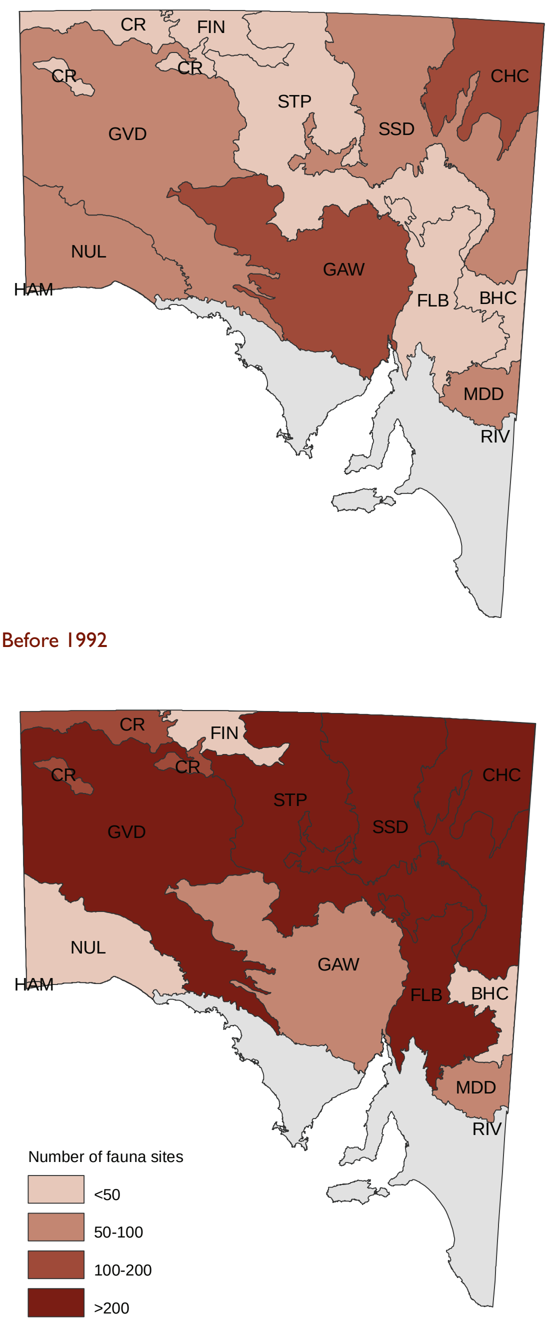
If the date of a fauna site survey is known, it can be used to track changes in the numbers of sites surveyed over time. For example, in South Australia, few sites had been surveyed for fauna before 1992 (Figure 3.74, top panel); by 2006, many more had been surveyed (Figure 3.74, bottom panel), although some sub-IBRAs still had no fauna survey sites.

Figure 3.73 Distribution of fauna survey sites across rangeland bioregions of Queensland



Source: Teresa Eyre, Biodiversity Sciences Unit, Queensland Environmental Protection Agency, and Alex Kutt, CSIRO Sustainable Ecosystems.

Figure 3.74 Number of fauna survey sites in the rangelands of SA, pre-1992 and 1992 to 2006



Before 1992

1992 to 2006

Source: Biological Survey and Monitoring, SA Department for Environment and Heritage. Map: ACRIS-MU.

Figure 3.75 Fat-tailed dunnart (*Smithopsis crassicaudata*), an example of faunal records accumulated through systematic survey of rangeland bioregions

Photo: Michael Mathieson, Queensland Environmental Protection Agency

To track changes it is essential to survey sites repeatedly, and efforts to do this are increasing. The number of fauna sites resurveyed across the rangelands of SA before 1992 was only 205 out of 661, whereas 831 sites out of 2000 have been resurveyed since then (J Foulkes, A Graham and D Thompson, Biological Survey and Monitoring, SA Department for Environment and Heritage, pers comm 2007).

Fauna records

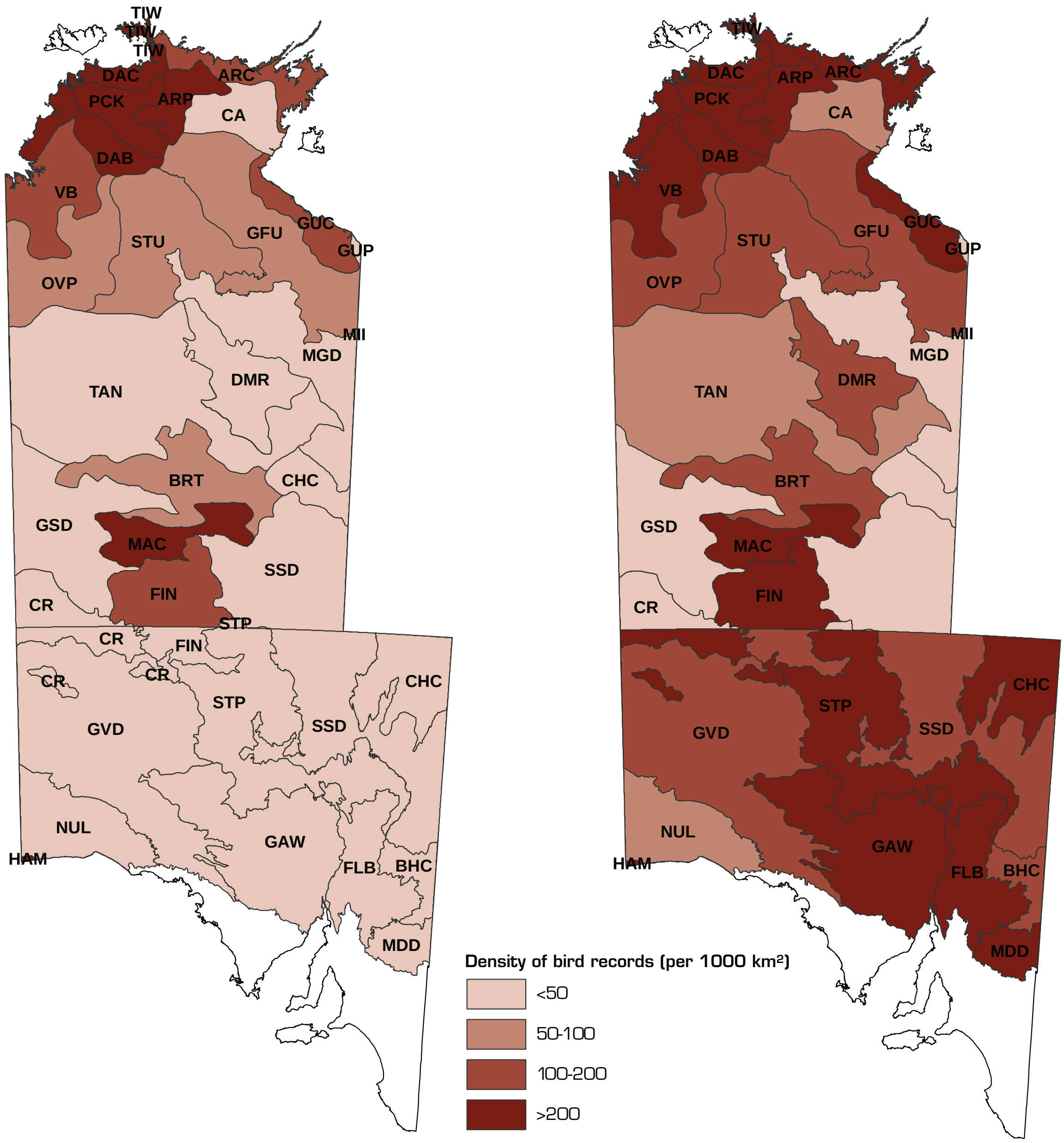
Another useful indicator of effort to conserve biodiversity is the number of records for different taxa across rangeland bioregions, such as the fat-tailed dunnart (*Sminthopsis crassicaudata*; Figure 3.75) and the Spencers goanna (*Varanus spenceri*; Figure 3.76). These records are currently incomplete, but the density of records for birds in the NT and SA, for example, markedly increased from the end of 1991 (Figure 3.77, left panel) to the end of 2005 (Figure 3.77, right panel). Similar changes are evident for the density of mammal records (Figure 3.78) and for reptile records (Figure 3.79). The density of records for fauna taxa differs across IBRA bioregions; as expected, there are fewer records from the more remote bioregions. At the sub-IBRA scale, fauna records can be very scarce.

Figure 3.76 Spencers goanna (*Varanus spenceri*)

This goanna is entirely restricted to the Mitchell Grass Downs bioregion in the NT.

Photo: Alaric Fisher, NT Department of Natural Resources, Environment and the Arts

Figure 3.77 Density of bird records, rangeland bioregions in the NT and SA

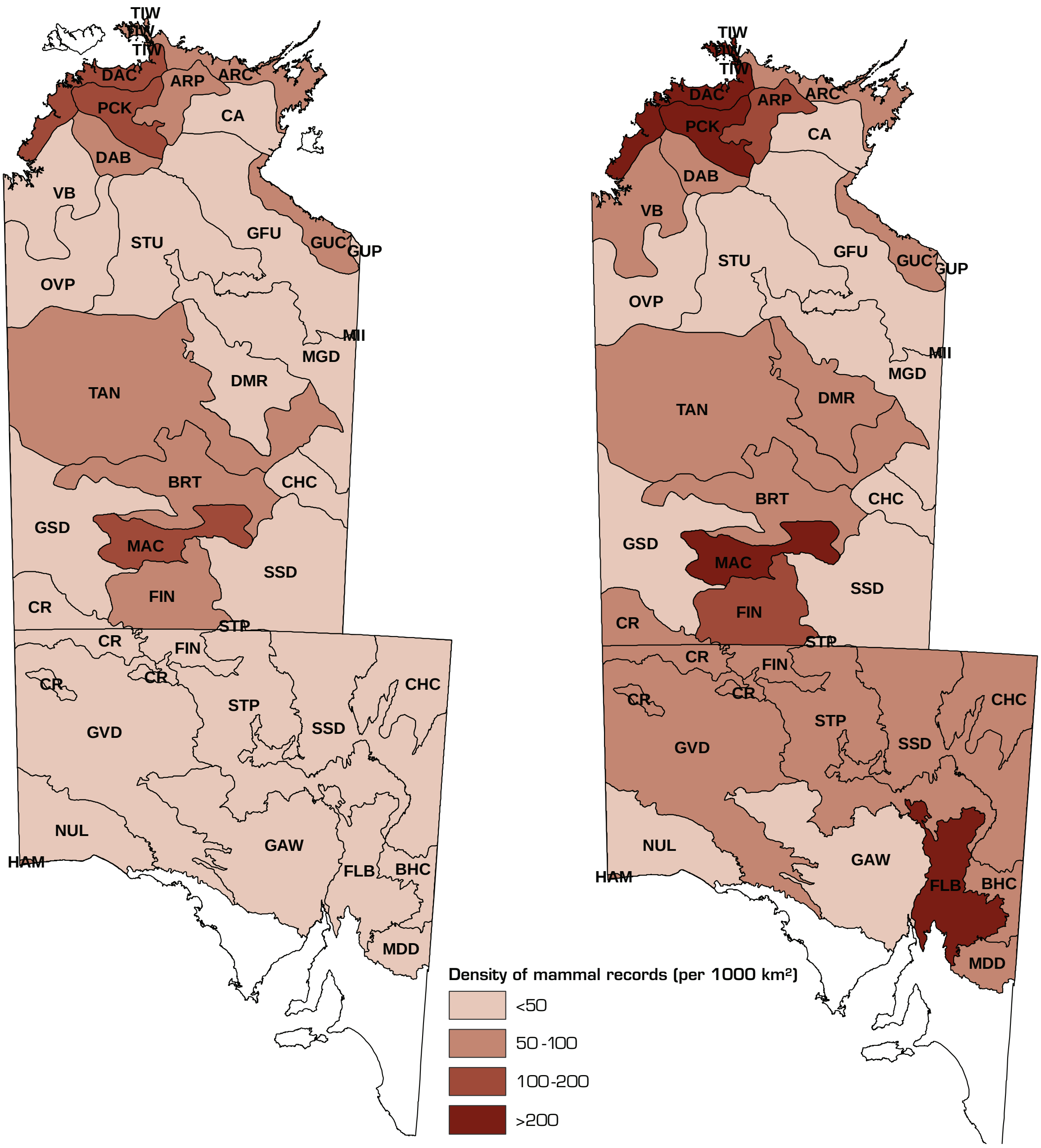


Before 1992

End of 2005

Source: J Foulkes, A Graham and D Thompson, Biological Survey and Monitoring, SA Department for Environment and Heritage, and Alaric Fisher, NT Department of Natural Resources, Environment and the Arts. Map: ACRIS-MU.

Figure 3.78 Density of mammal records, rangeland bioregions in the NT and SA

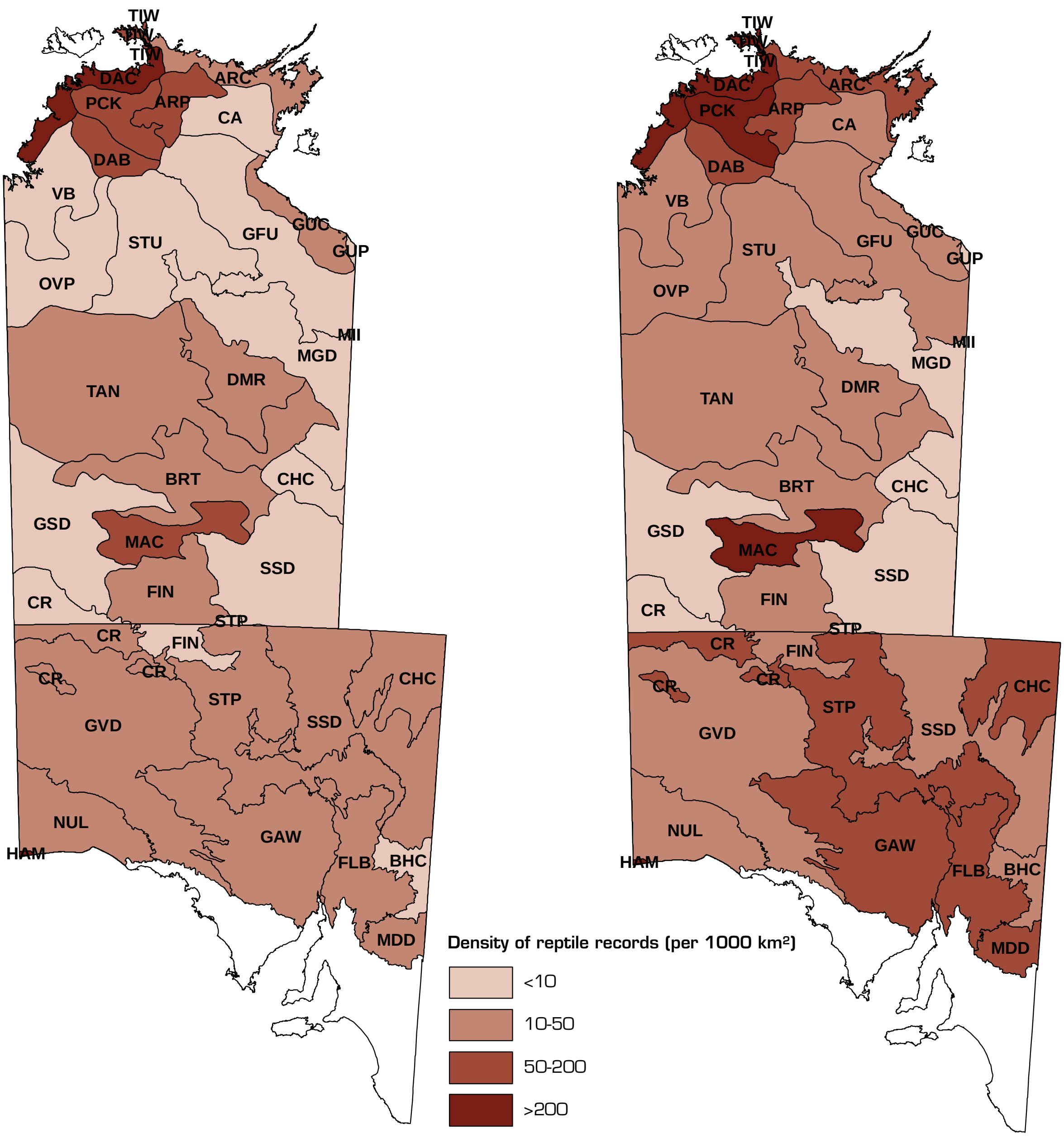


Before 1992

End of 2005

Source: J Foulkes, A Graham and D Thompson, Biological Survey and Monitoring, SA Department for Environment and Heritage, and Alaric Fisher, NT Department of Natural Resources, Environment and the Arts. Map: ACRIS-MU.

Figure 3.79 Density of reptile records, rangeland bioregions in the NT and SA



Before 1992

End of 2005

Source: J Foulkes, A Graham and D Thompson, Biological Survey and Monitoring, SA Department for Environment and Heritage, and Alaric Fisher, NT Department of Natural Resources, Environment and the Arts. Map: ACRIS-MU.

The tabulation of fauna records into a national database would produce a useful dataset. This huge task has been started by rangeland jurisdictions by combining museum records for WA, the NT and Queensland[25], in SA[26] and in NSW.[27]

Progress is confirmed by an analysis of fauna records in WA:

> Native frog, mammal and reptile specimen data in the Western Australian Museum were examined … and show that large areas of the State remain poorly sampled. The great majority of the collections have been made over the last 50 years … with several new species being described. (How and Cowan 2006)

Case study: changes in fauna populations within bioregions

Excellent examples of how data from repeated fauna surveys can be used to track changes in populations in different rangeland bioregions have been reviewed by Woinarski et al (2000a) and Day (2007). For example, Woinarski et al (2006) found that trends in vertebrate fauna populations in central Queensland from 1973 to 2002 were generally downward and that:

> [t]he escalating rate of clearing and other broad-scale environmental modification is likely to increase the rate of fauna change, as dependent woodland species continue to decline and be lost across the landscape, and be replaced by those more commensal species favoured by landscapes sculpted for human use.

Woodland fauna that specifically decreased included weebill, inland thornbill, spiny-cheeked honeyeater, striped honeyeater, jacky winter, rufous whistler, grey shrike-thrush, grey fantail, pale field-rat, delicate mouse, greater glider, rufous bettong and black wallaby (Woinarski et al 2006).

Clearing of forest and woodland vegetation resulted in some significant increases over this 29-year period, for example, in grassland birds such as the red-backed fairy-wren and brown quail. Those results have been confirmed by Hannah et al (2007).

Although there is now a moratorium on broadscale vegetation clearing in Queensland, concerns over declines in woodland populations continue because:

> … changes were evident not only across the changing landscape as a whole but there were also significant (consequential) changes at uncleared sites. (Woinarski et al 2006)

These concerns emphasise the importance of maintaining efforts to repeat fauna surveys across the rangelands and to track those efforts in ACRIS.

Reliability of fauna surveys

The capacity to systematically repeat fauna surveys within a bioregion is required to reliably document changes in rangeland biodiversity and to explore threatening processes. To understand and mitigate threats, rangeland managers require science-based analysis of resurveys and advice of any declines for their regions. Because many of Australia's rangeland bioregions are large and extend across jurisdictions, it is important that well-documented and standard fauna survey procedures be used to repeatedly monitor biodiversity. Unfortunately,

> … much of the evidence for change in biodiversity in the Australian rangelands and elsewhere has come from work that was not explicitly designed to reveal temporal trends nor intended to be repeated in the future. (Woinarski et al 2000a)

Detecting significant changes in the numbers of key fauna taxa present at a site, or across a set of sites in a bioregion, is difficult because of the inherent variability in terrestrial fauna survey data. The data vary due to changes in *seasonal quality*, site differences and real (seasonally adjusted) changes in fauna populations.

Key points

- The number of fauna surveys that have been conducted, and repeated, has increased notably for those rangeland bioregions where survey records were available.
- Numbers of fauna records have also markedly increased in those bioregions.

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25 http://www.museum.wa.gov.au/faunabase/prod/index.htm (accessed 22 March 2007)

26 http://www.environment.sa.gov.au/biodiversity/species_lists.html (accessed 22 March 2007)

27 http://www.wildlifeatlas.nationalparks.nsw.gov.au/wildlifeatlas/watlas.jsp (accessed 22 March 2007)

- A number of bioregional case studies using fauna surveys and resurveys have been conducted and have clearly illustrated both statistically significant and ecologically significant changes in fauna populations (see discussion on 'Power and sampling adequacy' in Woinarski et al 2006).
- The large variance of available data may fail to detect statistical significance and yet indicate ecological significance. The use of robust and systematic fauna survey methodologies and analyses, and their promotion for widespread application across different bioregions, would improve knowledge on fauna in the rangelands.

Flora surveys and records in rangelands

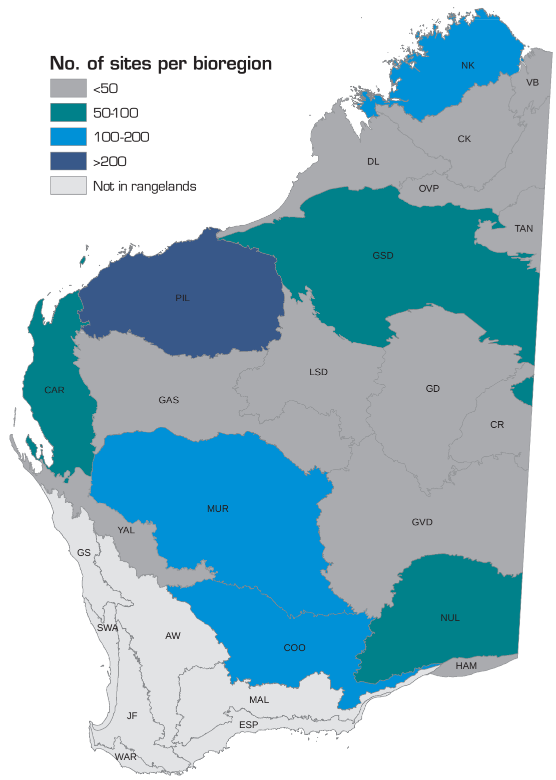
Changes in the number of sites surveyed for flora and in the number of plant species present on sites provide a useful indicator of how the diversity of the terrestrial flora elsewhere in the region is tracking. This information is particularly important at local scales if shifts are occurring in the composition of different plant groups — for example, shifts from palatable perennial grasses to unpalatable ephemeral grasses in a pasture.

Rangeland flora surveys and records

Survey sites in relatively undisturbed or 'reference' areas are very important for indicating and evaluating changes in areas with a history of disturbance, and flora survey sites have been specifically located in parks and reserves. For example, the State Herbarium of SA (Department for Environment and Heritage) has compiled a dataset of plant species collected from vegetation surveys primarily conducted in parks and reserves (SAPBIS; SA Plant Biodiversity Information System). Similar datasets have been collected by other state/territory herbariums.

Other valuable information on plant species comes from pasture monitoring sites located throughout most Australian rangelands. Many sites have been repeatedly surveyed so that changes in plant species composition can be tracked. Plant species richness from the WA and NSW pastoral monitoring programs is reported in the Sustainable management section of this report.

Figure 3.80 Density of flora/vegetation survey sites, WA rangelands



Source: WA Department of Environment and Conservation

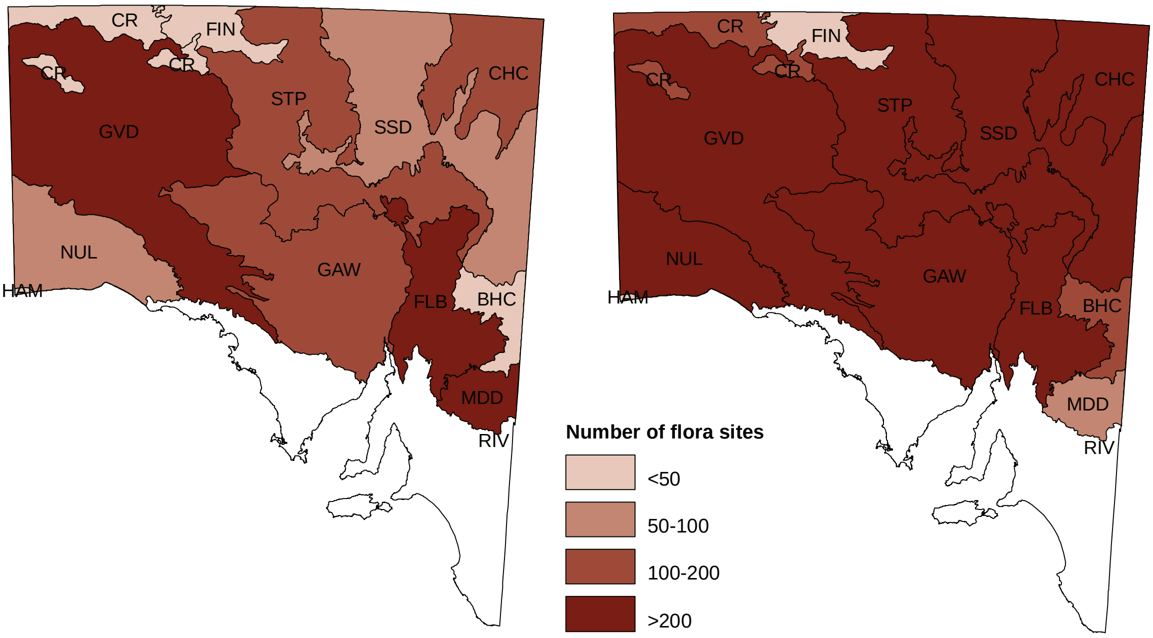
Indigenous organisations, for example the Dhimurru of the northeast Arnhem Land region[28], also have information on the flora of their lands. Much of that information is not included in rangeland analyses.

The distribution and numbers of flora/vegetation survey sites can potentially be mapped across all of Australia's rangelands, not just for the pasture monitoring sites. For example, flora/vegetation surveys have been conducted widely in WA (Figure 3.80). In general, sources of plant species information are highly varied, and flora survey data have not yet been compiled into a common set across the rangelands.

Dates of surveys provide a useful indicator of the increased emphasis being placed on recording and understanding Australia's rangeland flora, but have not yet been compiled for all jurisdictions. Such data can be used, for example, to compare the number of flora sites in SA surveyed before 1992 (Figure 3.81, left) with the number from 1992 onwards (Figure 3.81,

28 http://www.dhimurru.com.au/plantanimal.html (accessed 27 March 2007)

Figure 3.81 Number of flora/vegetation sites surveyed, rangeland bioregions of SA



Before 1992

Up to 2006

Source: Biological Survey and Monitoring, SA Department for Environment and Heritage. Map: ACRIS-MU.

right). The number of flora/vegetation sites surveyed in the past 25 years is much higher than the number surveyed before 1992, except in some remote arid northern regions, which have fewer survey sites.

Plant species records are also acquired as part of vegetation survey and mapping programs conducted by state and territory agencies (Figure 3.82).

Across the bioregions of the NT and SA, the density of flora records from surveys was extensive by 1991 (Figure 3.83, left); the density increased notably by the end of 2005 (Figure 3.83, right), in some regions more than in others.

Plant records from across Australia are now being made available online:

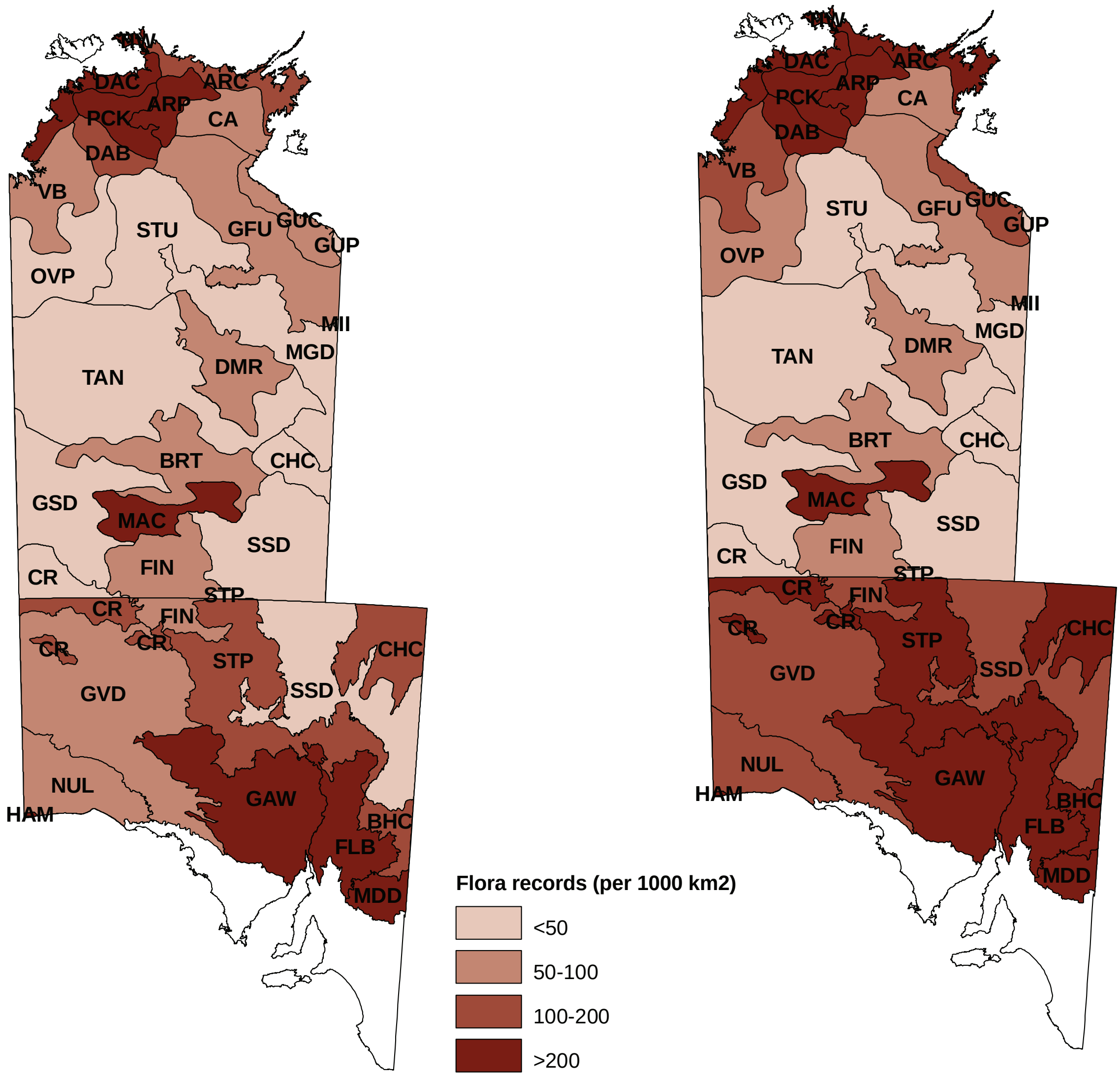
- Australia's Virtual Herbarium, a collaboration of all state, territory and national herbariums, aims to provide online public access to all of Australia's plant species records (currently about six million), along with descriptions, distributions and identification tools.[29]

Figure 3.82 Measuring plant attributes as part of vegetation survey

Photo: CSIRO, Alice Springs

[29] http://www.nt.gov.au/nreta/wildlife/plants (accessed 26 March 2007)

Figure 3.83 Density of plant records, rangeland bioregions across the NT and SA



Before 1992

End of 2005

Source: J Foulkes, A Graham and D Thompson, Biological Survey and Monitoring, SA Department for Environment and Heritage, and Alaric Fisher, NT Department of Natural Resources, Environment and the Arts. Map: ACRIS-MU.

- Flora of Australia Online provides national data on plant species, including distribution maps.[30]

Case study: changes in flora within a bioregion

A case study from Kakadu National Park in northern Australia demonstrates changes in species composition.

A baseline survey in 1995 to explore the impacts of different fire regimes on vegetation recorded more than 900 plant species at 134 sites (Edwards et al 2003). Those sites were resurveyed in 2000, when it was found that 5 tree species (of 47 recorded from sufficient samples to test), 9 shrub species (from 121) and 27 ground-layer species (from 111) showed significant change in abundance. When species were grouped into strata and life-form categories, there were increases in the cover of trees and shrubs and a reduction in cover and species richness of herbs. The changes in plant species composition and cover were attributed to a lower frequency of fires over the five years between surveys (Edwards et al 2003).

30 http://www.environment.gov.au/biodiversity/abrs/online-resources/flora/main/index.html (accessed 26 March 2007)

These findings have been used to guide the fire management strategies applied in the park.

Key points

- As for fauna surveys and records, the number of flora surveys and records increased notably for those rangeland bioregions where data were available.
- Long-term monitoring is needed to provide useful information on how the native flora of rangeland vegetation is changing.

Transformer weeds

'Transformer' weeds are invasive plants that can greatly alter the basic attributes of habitats and the biota that depend on those habitats. Transformers can change the character, condition, form or nature of an ecosystem over a substantial area relative to its extent (Richardson et al 2000).

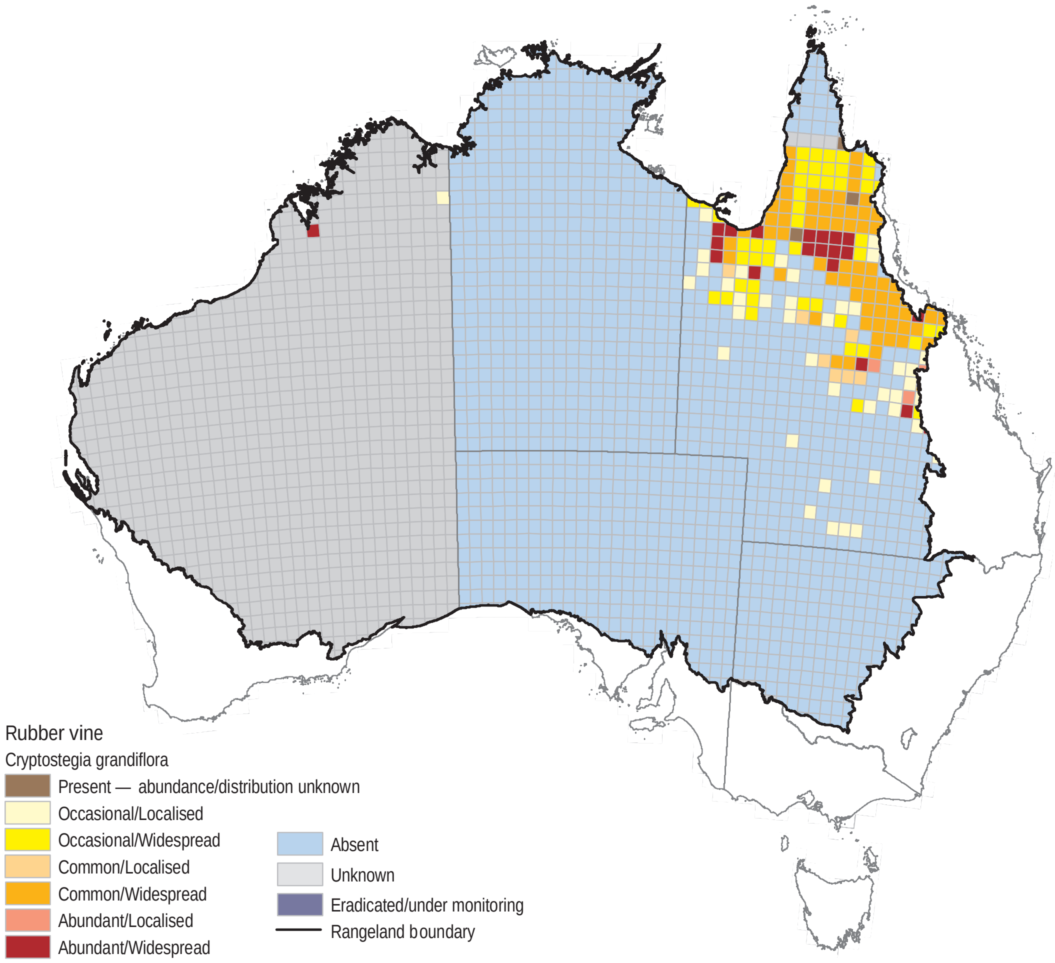
In Australia's rangelands, changes caused by transformer weeds are usually deemed undesirable. The weeds are typically introduced exotics that have the capacity to establish in relatively undisturbed landscapes. Because transformer weeds impact on biodiversity across Australia's rangelands, changes in their distribution and abundance are important indicators for assessing current and likely future impacts on biodiversity.

Although exotic weeds are briefly described in the Sustainable management section of this report as a factor reducing grazing values, the focus here is on transformer weeds that reduce biodiversity.

Indentification of transformer species

Because of their capacity to affect the economic potential of Australia's rangelands, as well as their impact on the environment, many of the transformer species identified here, such as rubber vine (*Cryptostegia grandiflora*), are also listed as WoNS. Although

Figure 3.84 Distribution of rubber vine (*Cryptostegia grandiflora*), Australia, 2006



Source: NLWRA, July 2007

rubber vine is currently mainly found in Queensland (Figure 3.84), it has the potential to invade extensive areas across Australia's rangelands, as shown by its high abundance in one area of WA.[31]

The National Weeds Strategy Executive Committee, in collaboration with the Bureau of Resource Sciences (now the Bureau of Rural Sciences [BRS]), evaluated 74 plant species nominated as WoNS and, using strict criteria, listed 20 WoNS (Thorp and Lynch 2000). That list has been reviewed by the ACRIS Biodiversity Working Group for those plants known to significantly 'transform' rangeland habitats and impact on biodiversity. The working group has selected seven transformer weeds from the WoNS list (Table 3.8) and has added four invasive exotic grasses known to be transformers because of their major impacts on biodiversity in the rangelands. The distribution and abundance of these transformer exotic grasses is an important indicator of change.

[31] http://www.weeds.org.au/natsig.htm (accessed 15 May 2007)

Habitat changes due to transformer weeds

Invasive exotic weeds can transform ecosystems by directly altering the composition of the vegetation (Grice 2006) and hence the life-forms required as habitat by the native animals in the original ecosystem. For example, mimosa (*Mimosa pigra*), has replaced native vegetation in many ecologically valuable wetlands of the Top End of northern Australia, greatly altering the distribution and abundance of native fauna.

Weeds can also affect ecosystems indirectly by altering attributes such as fire regimes. Invasive exotic grasses such as gamba grass (*Andropogon gayanus*) and buffel

Table 3.8 Eleven transformer weeds considered by the Biodiversity Working Group to have major impacts on biodiversity in Australia's rangelands, with a comparison to weeds listed as Weeds of National Significance (WoNS), by Grice (2004) and by Humphries et al (1991)

Species	Common name	WoNS[a]	Grice[b]	Humphries[c]	Ecosystems
Acacia nilotica	prickly acacia	✔	✔	✔	Grasslands/woodlands
Andropogon gayanus	gamba grass		✔		Floodplains and riparian communities
Pennisetum ciliare (syn. *Cenchrus ciliarus*)	buffel grass		✔	✔	Arid zone key habitats
Cryptostegia grandiflora	rubber vine	✔	✔	✔	Dry rainforest, monsoonal riparian communities
Hymenachne amplexicaulis	olive hymenachne	✔		✔	Floodplains and riparian communities
Mimosa pigra	mimosa	✔	✔	✔	Tropical wetlands and floodplains
Parkinsonia aculeata	parkinsonia	✔	✔	✔	Tropical rangelands, semiarid zone wetlands
Pennisetum polystachion	mission grass		✔	✔	Tropical forests, woodlands
Prosopis spp.	mesquite	✔	✔	✔	Semiarid zone grasslands and woodlands
Tamarix aphylla	Athel pine	✔	✔	✔	Arid/semiarid water-courses and riparian zone
Urochloa mutica	para grass			✔	Floodplains and riparian communities

Data sources:
[a] http://www.weeds.org.au/natsig.htm
[b] Grice (2004), Tables 1 and 2
[c] Humphries et al (1991)

grass (*Pennisetum ciliare*) have greatly altered the frequency and intensity of fires in the rangelands of northern and central Australia. Such changes in fire regimes have impacts on many plant and animal populations.

Other effects of transformer weeds act in synergy with processes such as livestock grazing that transform habitats and change the competitive relationship of native plants and animals. A comprehensive study of how disturbances affect birds in savannas, which included areas with the exotic buffel grass, found that bird species richness declined significantly with increasing levels of disturbance (Hannah et al 2007). In particular, there was an increased abundance of miners (interspecifically aggressive colonial honeyeaters).

Case studies: biodiversity changes due to transformer weeds

Rubber vine

Rubber vine (*Cryptostegia grandiflora*), is a transformer weed that has invaded many riparian habitats in the savannas of northeastern Australia (Figure 3.84), where it can smother native vegetation and form dense thickets (Figure 3.85). It has major impacts on biodiversity. Of 132 lizards in riparian habitats, not one was observed in rubber vine vegetation, and only one was observed in rubber vine vegetation in the surrounding woodland habitat (Valentine 2006). Laboratory experiments found that lizards chose native vegetation litter over rubber vine litter 80%–85% of the time (Valentine et al 2007).

Buffel grass

One introduced plant not included on the WoNS list is buffel grass, *Pennisetum ciliare* (syn. *Cenchrus ciliaris*). The current distribution and rate of buffel grass spread in the rangelands is unknown but is being investigated. The capacity of buffel grass to spread across rangelands in Australia and elsewhere is well established (Humphries et al 1991). For example, it was first recorded in SA in 1981 and has spread along the major roads the length of the rangelands. It appears to be spreading away from the highways along minor roads and drainage systems into other pastoral and Aboriginal rangelands. Buffel grass is considered the weed with the greatest environmental impact in the Anangu Pitjantjatjara Lands (Lang et al 2003).

Buffel grass is known to transform Australia's rangelands in ways that can be viewed as both positive and negative. In the positive view, it has improved livestock production in many regions of inland Australia and provided economic benefits to pastoral communities, particularly in Queensland savannas where tree clearing to enhance pasture production has been widespread (Figure 3.86). However, it is now a significant environmental weed of the arid conservation estate, and modelling suggests that it has the capacity to expand across a large proportion of northern Australia (Friedel et al 2006).

Figure 3.85 Rubber vine smothering trees in a riparian area, northeastern Queensland

Photo: Tony Grice, CSIRO

Figure 3.86 Grazing lands cleared and sown to buffel grass (*Pennisetum ciliare*), central Queensland

Remnant woody vegetation remains in the background. The pasture is dominated by buffel grass.

Photo: CSIRO, Townsville

The establishment of buffel grass following tree clearing in central Queensland has reduced floral diversity in brigalow and eucalypt woodlands to a far greater extent than has land clearing on its own (McIvor 1998, Fairfax and Fensham 2000). Ludwig et al (2000) reported a decrease in the abundance of Carnaby's skink (*Cryptoblepharus carnabyi*) and the delicate mouse (*Pseudomys delicatulus*) with increasing cover of buffel grass in cleared eucalypt woodlands of central Queensland.

Studies on buffel grass in remnant woodlands suggest that increasing vegetative cover in the landscape may be effective in reducing buffel grass spread because the species is less likely to occur in remnants located in landscapes where more than 30% of the original vegetation is retained (Teresa Eyre, Queensland Environmental Protection Agency, pers comm, 2007). As a restorative measure, regrowth may be important for the maintenance of biodiversity values in those landscapes, given the demonstrated impact of buffel grass on floral diversity (Fairfax and Fensham 2000, Franks 2002, Jackson 2005) and of burning regimes that alter faunal habitat suitability (Butler and Fairfax 2003, Hannah et al 2007).

Key points

- Case studies have shown that invasive exotic weeds can 'transform' habitats, which in turn can change species composition.
- Although the approximate distributions and abundance of transformer weeds are known across Australia's rangelands, better maps of current distribution and better models to predict potential spread are needed. This is especially true for exotic grasses such as buffel grass, where research is needed to investigate the potential for buffel grass status to change as a consequence of climate change (Friedel et al 2006).
- Knowledge of how and where transformer weeds directly and indirectly affect different fauna and flora species is improving. This growing knowledge contributes to increased understanding of changes in the biodiversity of Australia's rangelands.

Wetlands

Wetlands across Australia's rangelands provide critical habitats for numerous components of biological diversity, such as waterbirds, freshwater fish and amphibians, and aquatic invertebrates (Figure 3.87). Because many wetlands are temporary across arid and semiarid rangelands, any change in their distribution or extent due to climate change and/or extraction of water has the potential to adversely affect dependent biota (Roshier et al 2001).

Temporary wetlands pose severe challenges to many species. In a drying phase, highly mobile species, such as waterbirds, can move to other available wetlands, but less mobile species, such as frogs, must have survival adaptation mechanisms.

Figure 3.87 Swamp area on the Barkly Tableland (Mitchell Grass Downs bioregion, NT) listed in *A Directory of Important Wetlands in Australia*

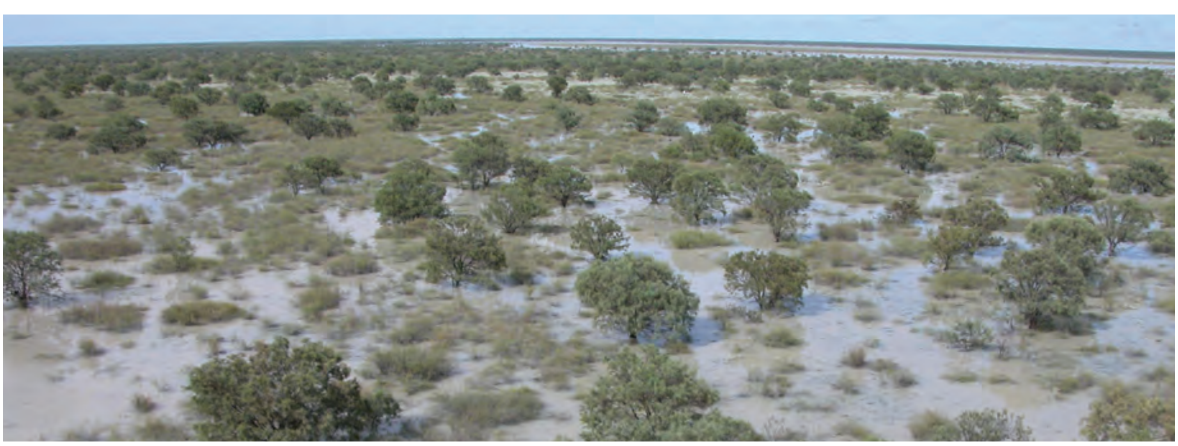
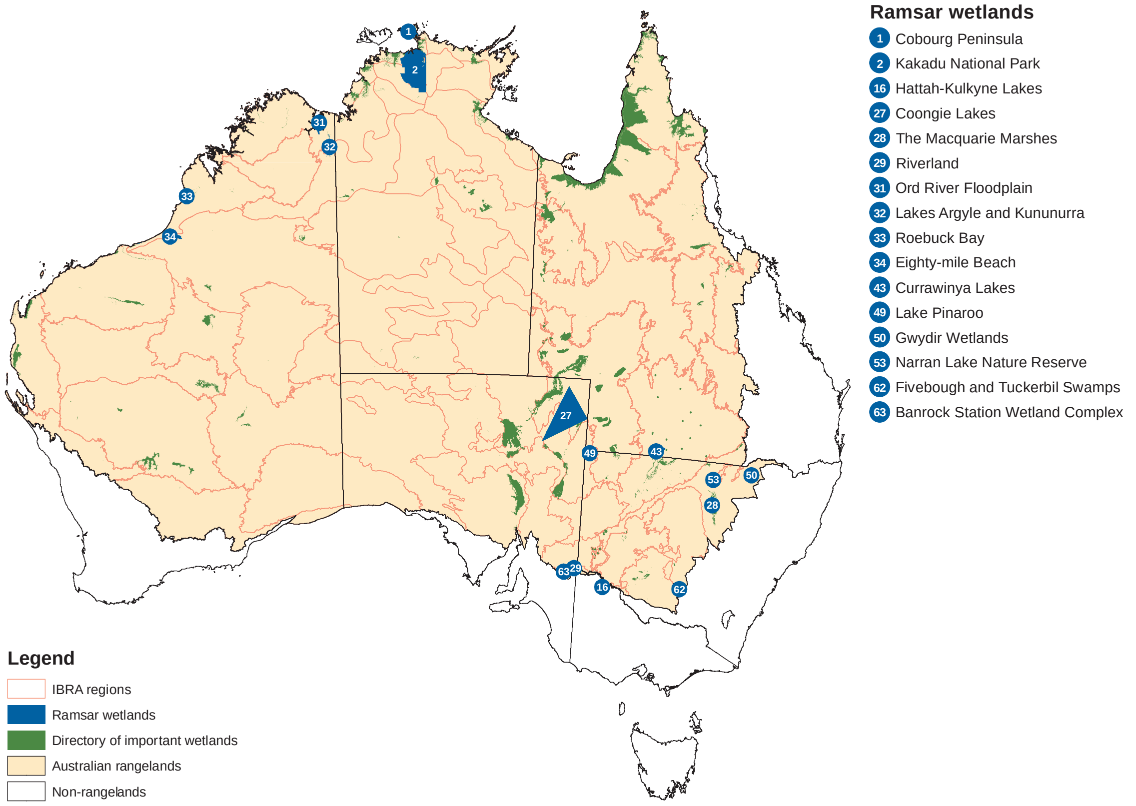


Photo: Roger Jaensch, Wetlands International

Figure 3.88 Internationally and nationally important wetlands within the rangelands, as listed under the Ramsar Convention on Wetlands and in *A Directory of Important Australian Wetlands*



Note: See http://www.environment.gov.au/water/publications/environmental/wetlands/directory.html for DIWA wetland names.

Source: Department of the Environment, Water, Heritage and the Arts, July 2007

Climate change may have significant effects on the condition and permanence of wetland habitats for biota across arid and semiarid rangelands, although there are currently limited data to demonstrate its potential to cause change. Emerging national wetland mapping and inventory work, if successful, may help to address this data deficit.

Listings of rangeland wetlands

'Ramsar wetlands' are designated as Wetlands of International Importance under the Ramsar Convention on Wetlands (Ramsar, Iran, 1971) because of their international significance in terms of ecology, botany, zoology, limnology or hydrology. Ramsar wetlands are also 'Matters of National Environmental Significance' and are protected under the EPBC Act.

In 2001, Australia had 57 sites designated as Ramsar wetlands. By 2006, that number had increased to 64, 16 of which are in the rangelands (Figure 3.88). A few of the 16 sites are coastal and might not be considered as 'rangeland' wetlands.

The Australian Government, in a cooperative project with state and territory governments, has developed the *Directory of Important Wetlands in Australia* (DIWA 2001). The directory aims to:

- identify sites and the wetland values in their local areas, particularly in relation to regional NRM planning and investment
- identify sites of importance for particular taxa, including threatened and migratory species
- provide the primary data source for identifying potential Ramsar sites.

The directory and its associated database provide information on the ecological and hydrological attributes of each nationally important wetland, and also contain information about wetlands' social and cultural values and some of the ecosystem services and benefits they provide. These data are accessible online at the website of the Department of the Environment, Water, Heritage and the Arts.[32]

Sixteen Ramsar wetlands were designated from 1974 to 2002, six of them after 1990. The DIWA database lists 291 wetlands within the rangelands as of 2006. Many of these are very small (eg 0.1-ha mound springs), but others, such as the tidal wetlands along the Gulf of Carpentaria on Cape York Peninsula, are very large (>1 million ha, Figure 3.88).

Monitoring and mapping Australia's wetlands

Satellite imagery of varying resolution (Landsat, SPOT[33], AVHRR) provides one data source for monitoring changes in the condition and distribution of temporary wetlands. Spectral matching using AVHRR data has been found to be a robust method for multitemporal studies of the presence/absence of water bodies in arid regions, provided salt-affected surfaces are excluded from the analysis. The accuracy of area estimates improves with size and regularity of shape of the wetlands being analysed. The low spatial resolution (1.1 km × 1.1 km pixels) precludes use of this methodology for area estimation in regions with complex, irregularly shaped drainage patterns (Roshier and Rumbachs 2004). The frequency of acquisition and the spatial resolution of satellite imagery are important considerations for monitoring wetlands because, as expected, temporary wetlands are strongly climate driven.

A study using analyses of satellite imagery to determine the distribution of different wetland types over 39 catchments within NSW found that approximately 5.6% of NSW is wetland (4.5 million ha), mostly (96%) in inland river catchments. Broad classification allowed identification of the extent of wetland types: floodplains (89%); freshwater lakes (6.6%); saline lakes (<1%); estuarine wetlands (2.5%); and coastal lagoons and lakes (1.5%). Conservation reserves protect only 3% of wetland areas (Kingsford et al 2004).

32 http://www.environment.gov.au/water/publications/environmental/wetlands/database/ (accessed 4 April 2008)

33 Le Système pour l'Observation de la Terre (French earth-observing satellites)

Figure 3.89 Wetland birds: little black cormorants (*Phalacrocorax sulcirostris*) and darters (*Anhinga novaehollandiae*) at nests

Many waterbird species are in decline in eastern Australia, Kingsford and Porter (in press).

Photo: Roger Jaensch, Wetlands International

Monitoring waterbirds

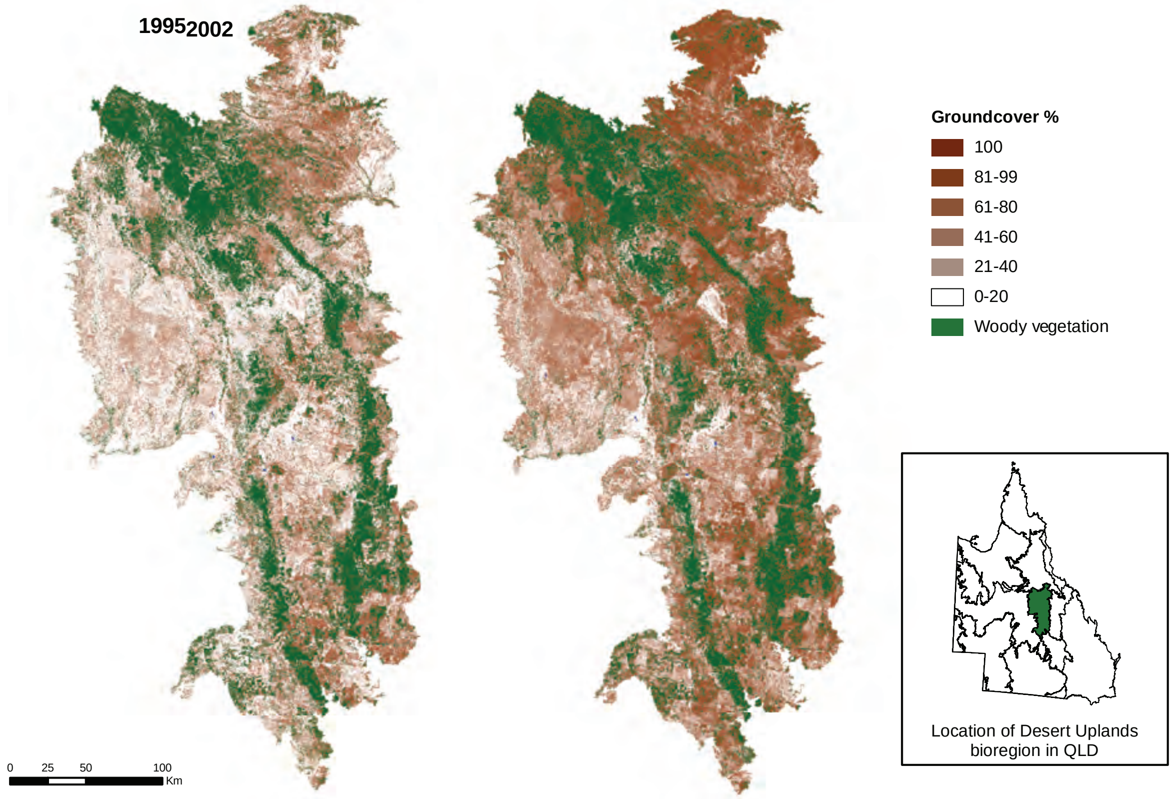
Repeat aerial surveys also demonstrate the importance of wetlands as critical habitats for waterbirds (Figure 3.89). A large area of eastern Australia, including extensive areas of rangeland, was monitored in 10 aerial surveys conducted in October between 1983 and 2004. Waterbird numbers were found to have declined across eastern Australia since 1983. The most significant decline occurred between 1984 and 1986, with further declines after 1991. The annual average number of birds during the first three years of the survey was about 1 100 000; from 1986 to 1995 about 405 000, and from 1996 to 2004 about 238 000 (Kingsford and Porter 2006).

Whether wetlands are regulated water bodies used as storages to manage river flows or unregulated natural lakes, it is important to define their condition and permanence as habitat for biota.

Key points

- The number of listed Ramsar and DIWA wetlands has increased notably since the early 1990s. This increase is an indicator of Australia's commitment to conserve habitats vital to the biota dependent on wetlands.

Figure 3.90 Groundcover over the Desert Uplands bioregion, 1995 and 2002 (%)



Source: Natural Resource Sciences, Queensland Department of Natural Resources and Water

- There is a continuing need for studies on the condition and persistence of wetlands as critical habitats for dependent taxa and for studies to improve our understanding of linkages between wetland habitat conditions (eg permanence, salinity, climate change effects) and specific components of biodiversity (eg waterbirds, frogs, invertebrates).

Habitat condition derived from remotely sensed groundcover

Remote sensing techniques have the potential to measure the amount and type of cover on the ground surface, such as the amount of perennial grass cover. The type and amount of ground surface cover (eg vegetation versus bare soil) indicates habitat condition for biota dependent on that cover. The amount of vegetation cover has also been used to indicate landscape function (see earlier in this chapter).

The capacity to use remote sensing to monitor land surface cover as habitat condition is improving. Landsat imagery has the spatial resolution and a historical archive that makes it valuable for understanding climate and management effects on native vegetation at a range of scales from small remnant to region. Regional and national vegetation monitoring programs based on time-series Landsat imagery are now operational in Australia (Wallace et al 2006).

However, remotely sensed groundcover only indirectly indicates biodiversity.

Monitoring groundcover as habitat condition

Remote sensing has mostly been applied to assess changes in the amount and type of groundcover for local landscapes within regions. Few groundcover assessments have been applied at regional scales, but the potential to do so can be shown by an example from Queensland's SLATS.

Imagery was acquired from the Landsat archive to cover the Desert Uplands IBRA bioregion in central Queensland, an area of about 69 000 km^2. The imagery was for every two years from 1989 to 2001 and then every year to 2004.

As an example of changes in a groundcover index[34], data for 1995 and 2002 were mapped (Figure 3.90). Changes are evident from the spatial differences in the intensity of white to light to dark brown colours. Much of the open rangeland in the northeast area of the Desert Uplands bioregion had a higher cover in 2002 (darker brown) than in 1995 (lighter brown). Note that areas covered by dense woody vegetation (green, areas of >20% foliage cover) and water (blue) are not considered in this comparison.

When interpreting maps of broad spatial changes in groundcover, it is important to keep in mind that the accuracy of detecting and monitoring changes in groundcover with satellite imagery depends on the openness of the vegetation. As woody cover increases, the accuracy of estimates of the groundcover index decreases. The index was not calculated where the projected foliar cover of woody vegetation exceeded 20%.

Case studies: habitat condition affects biodiversity

A number of significant relationships were found between plant, ant and vertebrate diversity measures (species abundance, composition, richness) and land condition based on regressions using 216 rangeland sites positioned across five land types in the Einasleigh Uplands of northern Queensland and the Ord Victoria Plains in the NT. These studies found that land condition appears to be the most strongly predictive for components of the biota whose ecology is closely linked to characteristics of the ground surface and density of ground layer vegetation, most notably ants.

However, there was only a weak relationship between land condition and many aspects of biodiversity, and the response of biota to land condition was complex and highly variable between taxa, land types and locations (Fisher and Kutt 2006).

The authors of the studies recommended that comprehensive biodiversity monitoring programs, at local or regional scales, include the direct assessment of selected biota.

Other studies in northern Australia's rangelands have found that decreases in habitat condition (low groundcover and poor soil surfaces) near cattle waterpoints contributed to declines in plant, small mammal, granivorous bird and invertebrate diversity (Woinarski 1999, Karfs and Fisher 2002, Churchill and Ludwig 2004).

Interpreting habitat condition for biodiversity

Although groundcover can provide a useful indicator of habitat condition, there are a number of constraints and limitations when using this information to interpret effects on biodiversity (Fisher and Kutt 2006):

- Components of biodiversity are likely to respond in a complex fashion to the spatial configuration of land condition across the landscape. Biodiversity status will be poorly predicted by limited point assessment of land condition.
- The history of land condition, other management influences such as fire frequency, and fine-scale climate variability are not necessarily reflected by the current condition.
- Rangeland condition assessment generally fails to capture the condition (ie health) of rare and restricted ecosystems, although these are generally areas of high biodiversity significance.
- Simplistic categorisations of land condition cannot adequately encompass the range of responses found in many biotic groups across different habitats.
- Perceptions of condition (and changes in condition) may diverge between ecological and production viewpoints (for example, in relation to introduced pasture and woody thickening).

According to Bastin and Ludwig (2006), challenges to using satellite-based data to map changes in vegetation condition are robustness, efficiency and generality. They conclude that mapping condition will always be difficult because of the large area, spatial complexity and temporal variability of arid-zone vegetation.

34 See Byrne et al (2004) and Scarth et al (2006) for details of this index.

Key points

- Changes in the amount of vegetation versus bare soil covering the ground surface can be a useful indicator of habitat condition, especially if considered relative to what might be expected for a given rangeland climate and soil type. Conceptually, the intactness of vegetation cover in a landscape indicates the structural and functional integrity of habitats, which is critical for maintaining plants and animal populations.
- More studies are critically needed to establish linkages between habitat condition indicators and the species dependent on critical amounts and types of groundcover.
- Studies linking groundcover with biological diversity have been largely based on local sites, but broader landscape and regional analyses are needed for the purposes of rangelands reporting.

Rangeland birds

Birds are a useful indicator of biodiversity (Mac Nally et al 2004) because changes in their population composition, abundance and distribution can signal that habitats have been significantly altered. Many such habitat changes affect not only birds but other biota.

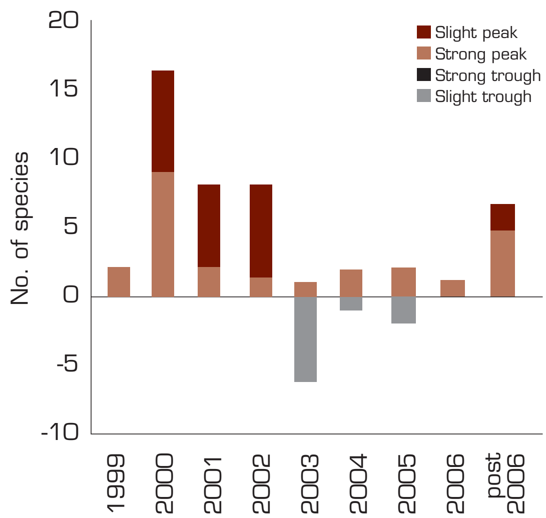
Birds are relatively easy to monitor: they are active during the day, are typically colourful, and have distinctive calls even if they cannot be seen. Many people enjoy observing, recording and contributing bird species information to formal databases, such as those maintained by Birds Australia.

Historical changes

Contrary to the expectation that there would be few bird conservation problems in Australia's rangelands, Reid and Fleming (1992) found that by the early 1990s a number of bird species had declined in abundance and extent since European settlement.

A recent analysis of changes in rangeland birds by Cunningham et al (2007) indicates that declines continue to occur for some species. Their analyses were based on 1999–2006 records in the Atlas of Australian Birds (Box 3.11). The reliability of trends in bird species composition depends on repeated surveys over long periods, so only those survey sites that had been repeatedly visited over a nine-year period (from 1998 to 2007) were included in their analyses.

Figure 3.91 Peaks and troughs in relative abundances of 60 rangeland bird species, 1999 to post-2006



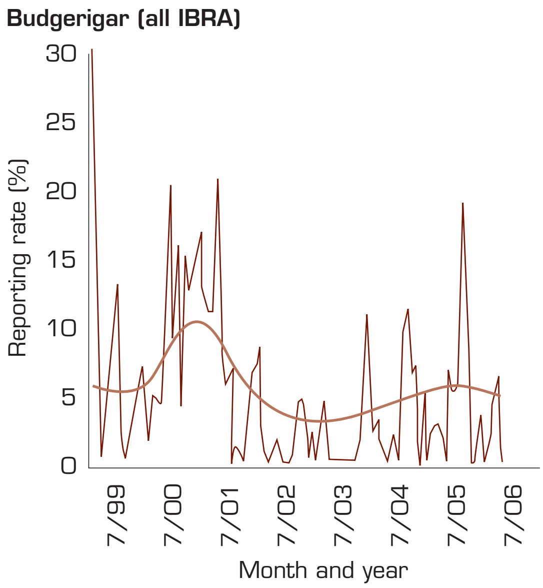
Source: Cunningham et al (2007)

Instead of using maps to represent the data, which would oversimplify complex patterns, this section uses graphs to illustrate four types of change: peaks and troughs in the overall relative abundance of 60 rangeland birds between 1999 and 2006, including an example of a species that peaked in the 2000–2001 wet period, and the trends for a 'decreaser' species, an 'increaser' species and a stable species.

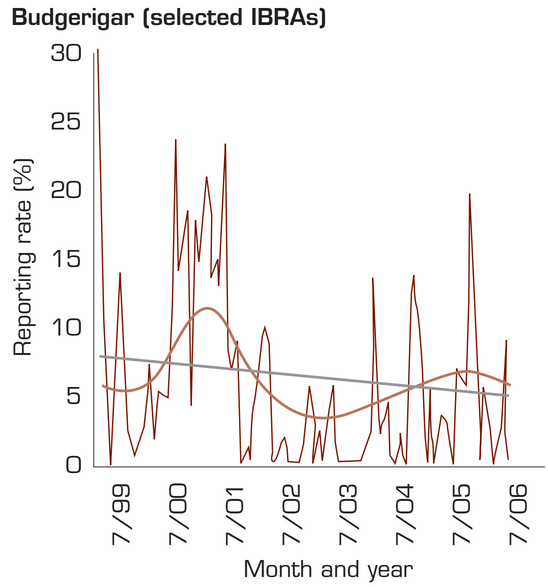
Abundance of rangeland birds

Based on a high concordance among three experts evaluating peaks and troughs in the abundances of 60 rangeland birds over seven years (1999–2006), Cunningham et al (2007) found that many species showed peaks in occurrence in 2000 and 2001, followed by a less distinct period of troughs in 2003–2005 (Figure 3.91). They interpreted this pattern as corresponding to higher-than-average rainfalls before 2002 and the drought that occurred from then onwards. One species that clearly peaked in the number of times it was observed during the 2000–2001 wetter period was the budgerigar (*Melopsittacus undulatus*) (Figures 3.92 and 3.93).

Figure 3.92 Observed and smoothed reporting rates for the budgerigar (*Melopsittacus undulatus*)



Aggregated over year by month for all rangeland Interim Biogeographic Regionalisation for Australia (IBRAs)



Aggregated over year by month for only those rangeland IBRAs where the budgerigar was observed at least once. A linear trend is also shown.

Source: Cunningham et al (2007)

Changes in bird species

Of the 60 rangeland bird species evaluated, the three experts agreed that there were adequate data on 49 species to test for statistically significant trends (Cunningham et al 2007). They concluded that 11 species (22%) had decreased over the 1999–2006 period, 20 (41%) had increased, and 18 (37%) had remained stable. A species was also assigned a stable status when the three experts could not confidently assign a significant trend for the seven-year period. The grey crowned babbler (*Pomatostamos temporalis*; Figure 3.94) declined, while the crested pigeon (*Ocyphaps lophotes*) increased and the magpie-lark (*Grallina cyanoleuca*) remained stable (Figure 3.95).

Cunningham et al (2007) were constrained to using only the 1999–2006 period because of the available data. It was not possible to infer longer-term trends, given the highly variable climate of the rangelands and the fact that the ecologies of many species are responsive to irregular and unpredictable drought and rains, fire and many other factors. Detailed statistical analyses to Atlas of Australian Birds data for 10 rangeland IBRA bioregions could only be applied confidently because of the low numbers of bird surveys in most bioregions. Despite these

Figure 3.93 Budgerigars — observations peaked during the 2000–2001 wetter period

Photo: Robert Ashdown

Figure 3.94 Grey crowned babbler (*Pomatostamos temporalis*) — a species that has declined in the rangelands

Photo: Geoffrey Dabb

Box 3.11 Rangeland bird data

Based on bird surveys conducted in the rangelands soon after European settlement, Reid and Fleming (1992) analysed changes in bird species composition and found significant declines for some species. Their analyses built on information compiled by Garnett (1992). These data and analyses provide an assessment of the status of rangeland birds up to the early 1990s.

Changes in bird population composition and distribution across Australia and its territorial islands have been documented in The State of Australia's Birds reports (eg Olsen et al 2003). Changes noted in the reports are based on comparisons of findings from the first Bird Atlas, based on bird surveys conducted from 1977 to 1981, with those in the second Bird Atlas, based on surveys from 1998 to 2002. Those changes are not reported here, but readers interested in general changes in bird species across Australia are referred to Barrett et al (2003) and Olsen et al (2003).

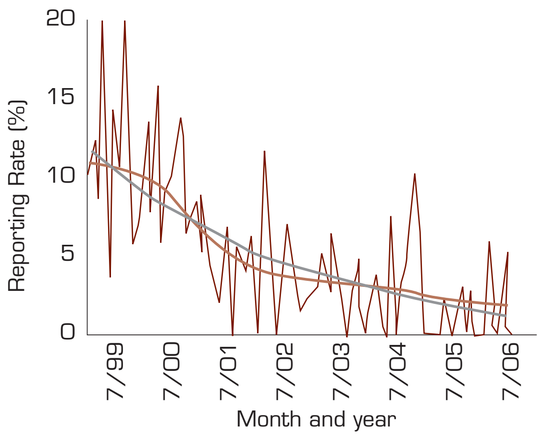
Bird Atlas data are collected by Birds Australia, the name used by the Royal Australasian Ornithologists Union, the goal of which is to conserve native birds and biodiversity. Its members have regularly observed birds and have provided their records to a database, known as the Atlas of Australian Birds, that now includes over 6 million records from across Australasia and Antarctica. Details of this volunteer system and the survey methods used by the Atlas can be found in Barrett et al (2003) and Weston et al (2006).

The most recent Bird Atlas records (up to 2007) have been analysed to detect significant changes or trends in Australia's rangelands (Cunningham et al 2007).

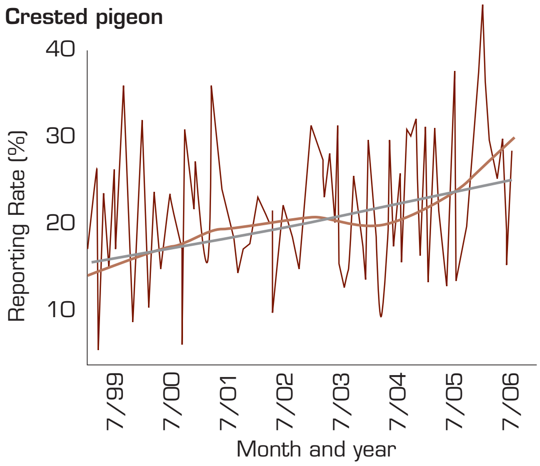
Bird species and numbers can fluctuate greatly between surveys: Maron et al (2005) found that 'site-level bird assemblage composition was markedly different between the two [yearly] survey periods'.

Figure 3.95 Observed and smoothed reporting rates for decreaser, increaser and stable species

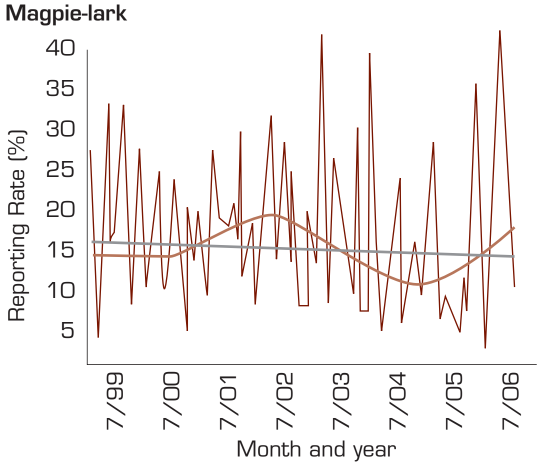
Grey crowned babbler



Crested pigeon



Magpie-lark



Top: A decreaser species
Centre: An increaser species
Bottom: A stable species

Note: Changes are based on data aggregated over year by month for only those rangeland IBRAs where the species was observed at least once. Linear trends are also shown.

Source: Cunningham et al (2007)

constraints, the authors stated that 'the results of this study flag changes in the relative occurrence of bird species that provide information on the current trends in bird populations in the rangelands. Placing these in the context of longer-term climatic or other variation will require more years of data collection.' Additional bird surveys would, they concluded, improve confidence in longer-term trends for those rangeland bioregions currently undersampled.

Key points

- The study by Cunningham et al (2007) demonstrated that records in the Atlas of Australian Birds could be used to explore significant trends over the seven-year period from 1999 to 2006.
- Substantial changes occurred among the 60 rangeland bird species analysed (some increased, some decreased and some remained stable).
- Causes of significant trends, and whether such trends would persist, were unknown, although records for many bird species peaked during the wetter 2000–2001 period and some showed troughs during the drought of 2002–2004.
- The adequacy of bird survey data has been summarised by Cunningham et al (2007) and is influenced, among other factors, by the variable climate in the rangelands and the low numbers of bird surveys in particular regions.

Conclusions

- Historically, there have been substantial declines in rangeland biodiversity. There is no reason to believe that the declines have ceased, given current land uses and time lags between impacts and their biological consequences.
- Realistically, there is only limited capability to report trends in biodiversity in rangelands at the national scale because of inconsistencies between jurisdictions in data collection, data gaps and limited specific biodiversity monitoring being undertaken to report at a bioregional or national scale.
- There are currently no coordinated broadscale biodiversity monitoring programs analogous to rangeland pasture condition monitoring (except for Birds Australia Atlas surveys).

- Although a set of useful indicators for reporting change in biodiversity has been developed, data for most of them are at best incomplete across the rangelands, and only some can currently report change over time.
- Improved 'habitat-condition' assessment tools at site scale relevant to rangeland users are needed (ie substantial research and development is required).
- There is a need to ensure consistency of indicator assessments at regional levels. The indicators used and their application should be meaningful for biodiversity conservation and management decision making.
- Substantial efforts and resources are needed to sample biota and measure ecosystem condition trends directly in order to track biodiversity. This may require the measuring and analysis of new biological indicators.

Box 3.12 Biodiversity monitoring activities

An ACRIS project was initiated in 2006 to find out:

- what biodiversity monitoring activities were occurring in the rangelands of each state and territory
- where monitoring was occurring
- whether respondents felt that this monitoring provided sufficient information to detect changes in biodiversity.

Project findings are reported in detail by Day (2007), with Table 4 in her report listing 15 'Current activities with potential for use in monitoring change in biodiversity', such as current pasture-monitoring programs. Information on current activities was obtained by interviews and a questionnaire, and the author notes that 'the low rate of [questionnaire] response means any conclusions are based only on the information available, and hence need to be interpreted with care'.

The following were among the key conclusions:

- There is a considerable amount of good baseline biodiversity information recorded in the relevant state/territory flora and fauna databases (eg Atlas of NSW Wildlife); however, there are gaps in coverage for the rangelands.
- Biodiversity programs that have a resampling component are usually short-term and local or regional in scale.
- Programs that are widespread usually provide only indirect information about biodiversity and/or sample the environment selectively.

Other findings suggest a considerable capacity for state/territory and Australian Government agencies to monitor biodiversity in the rangelands. For example, Day noted that 'Programs of relevance to the ACRIS report … included flora and fauna surveys by state and Commonwealth government departments and other organisations, large scale programs related to riparian systems (including waterbird surveys), individual species monitoring, specific research programs, local detailed fire mapping and the status of the national reserves system.'

Day's other, more general, conclusions about biodiversity monitoring in the rangelands included the following:

- The actual use of an indicator often depends more on the practicalities of application than on whether it is a good measure of biodiversity.
- For many indicators, much work still needs to be done to validate the proposed correlation between the indicator and biodiversity.
- To identify the best indicators for monitoring biodiversity in the rangelands, and make best use of the resources required to apply them, careful consideration needs to be given to their validation.

- Further investments (in an ACRIS-style model) and sustained efforts in coordinating and collating biodiversity data are required as part of a comprehensive biodiversity monitoring program involving state/territory agencies, and across regional NRM groups.

An analysis of the capacity to monitor biodiversity in Australia's rangelands by using a few key indicators has been provided by Day (2007), who assessed recent biodiversity monitoring activities (see Box 3.12).

Socioeconomic change

This section provides a socioeconomic update on the rangelands and reports on the value of non-pastoral products and on changes in land uses and land values. This information is critical because in Australia's rangelands non-pastoral activities and land uses are increasing and significantly contributing to overall economic value. Those activities have changed social structures (ie employment) and land market values.

Background

Natural resources are managed by people (Figure 3.96). Understanding the needs, capacities and motivations of Australia's land managers is critical to designing sound policy and program interventions and evaluating their impact at both the national and the regional scales. It is widely acknowledged that the condition of the natural resource base, a land manager's socio-demographic characteristics and management practices, enterprise financial status and the level of social capital in a community or industry are all interdependent.

Social and economic considerations in the rangelands are varied and complex. Since land management practices are crucial for positive 'triple bottom line' outcomes, a priority for those working with land managers has been to better understand their capacity to undertake a variety of land management practices. Measuring land manager capacity directly is problematic, so *Rangelands — Tracking Changes* (NLWRA 2001a) identified proxy indicators of capacity to undertake land management practices. These included median age of farmers, net emigration of young people and age-dependency ratio. However, preliminary work by the BRS indicates that proxy indicators are not a strong predictor of ability to adopt sustainable land management practices. Further studies are needed to understand land managers' behaviours in the rangelands.

The proxy indicators were tested in five pilot regions (ABS 2004). They showed that, in all regions except the Victoria River District in the NT, the median age of pastoralists was increasing, there was a net emigration of young people, and the age-dependency ratio was increasing.

Regional profiles

The sources of the data presented in this section are the ABS 2001 Census and the Australian Bureau of Agriculture and Resource Economics (ABARE) farm surveys from 1999 to 2006. In the absence of indicators of the ability of land managers to adopt sustainable land management practices, the information provided here gives context to the biophysical data provided in the other parts of this chapter, as well as outlining some socioeconomic trends.

Figure 3.96 People on the land — integral to managing the rangeland's natural resources

Coral Beebe on her family's property, Ucharonidge, NT.

Photo: Newspix / James Croucher

The pastoral zone used by ABARE to define the rangelands differs from the rangelands boundary adopted by ACRIS. Boundary differences are most marked in the east, where some of the most significant non-pastoral agricultural production occurs. Reporting is by statistical local areas (SLAs) rather than by IBRA bioregion, making it difficult to spatially compare commodity values by SLA with the IBRA regionalisation used by ACRIS.

Socioeconomic profiles based on ABS data

Characteristics of rangeland communities are listed below. The following 'headline' statements cover the whole of each rangeland SLA and therefore include people living in urban centres, as well as those actually managing the rangelands.

- *Age structure*: Overall, the changes in age structure in the rangelands reflect two trends: the aging of the national population (Figure 3.97) and the migration of young people away from rural areas.
- *People migration*: No region had in-migration of young people (Figure 3.98). Out-migration was still occurring even in the places where it had previously been low.
- *Education*: The level of educational attainment suggests that the traditional farming education of learning on the job is more common than in the non-rangelands areas.
- *Employment*: There was a dramatic drop in unemployment in the rangelands over the 10-year period to 2001. This rangelands trend mirrors the decrease in unemployment across Australia as a whole through that decade.
- *Dependency*: There was an overall slight decrease in the dependency ratio across the rangelands; that is, there were fewer people aged either under 15 or over 65 per 100 people in the rangelands.
- The SEIFA[35] *Index for Relative Socioeconomic Disadvantage* shows that the most disadvantaged areas in the rangelands are well below the Australian average score. Much of the NT and WA and the western half of SA comprised the two most disadvantaged categories.
- *Employment diversity*: Regional employment diversity tracks the number of people employed by the three main employment sectors in the region. Low-diversity areas have more than 60% of their employment in the three main sectors, and high-diversity areas have less than 50%. Diversity is desirable because it adds resilience to a community during poor times in one employment sector. Roughly equal numbers of IBRA regions are categorised as having low or moderate employment diversity. The Nullarbor, Cape York and the west coast are the sites of low diversity. The moderate-diversity regions are in a nearly continuous belt across the country. Most of the high-diversity IBRA regions are on the north coast of the NT (Hanslip and Kelson 2007).

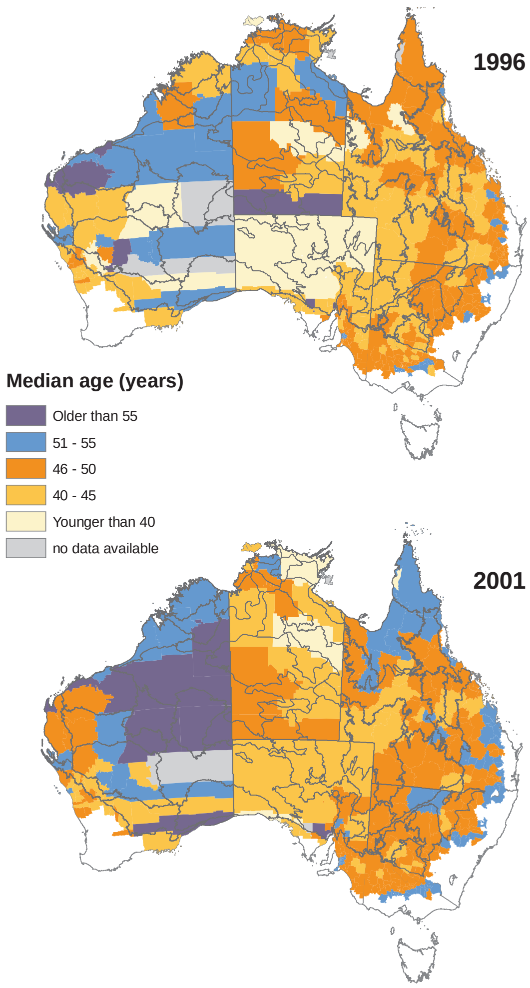
Profiles based on ABARE statistics

An ABARE farm survey is a sample rather than a census. In the rangelands, the number of farms included in a single rangeland region ranged from a low of five to a high of around 100. As a result, any conclusions based on these data must be considered indicative; however, they provide information in addition to that available from the ABS statistics.

- *Extent of training*: Training was a priority among most farmers in the majority of regions sampled in 1999. In almost all the regions for which there are data, a majority of farmers had recent training.
- *Off-farm income*: Based on the few regions for which there are data, off-property incomes in the rangelands are low (mostly less than $20 000), with the highest income category being just over $20 000. This compares unfavourably with the off-property incomes reported by non-rangelands farmers in BRS landholder surveys.
- *Level of income*: No area of the rangelands is clearly associated with particular income levels. The southwest and northeast seem to have higher levels of income than the southeast. If there were a financial barrier to adoption of any particular practice, it would more likely occur in the regions included in the lowest income category.

[35] Socio-Economic Indexes for Areas: http://www.abs.gov.au/websitedbs/D3310114.nsf/home/Seifa_entry_page (accessed 9 April 2008)

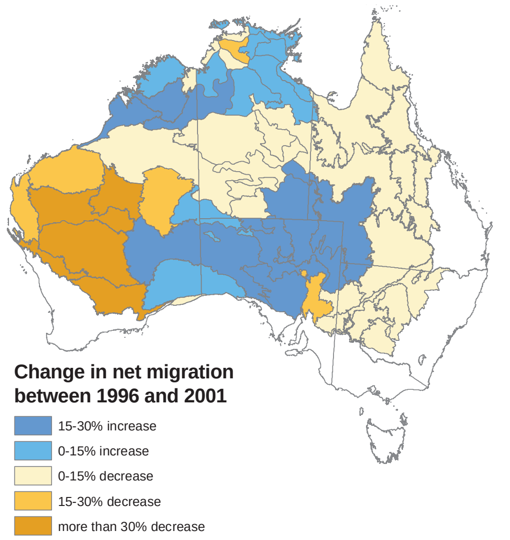
Figure 3.97 Change in median age in rangeland SLAs, 1996 to 2001



Data: ABS Population and Housing Census, 1996 and 2001. Map: BRS, 2007

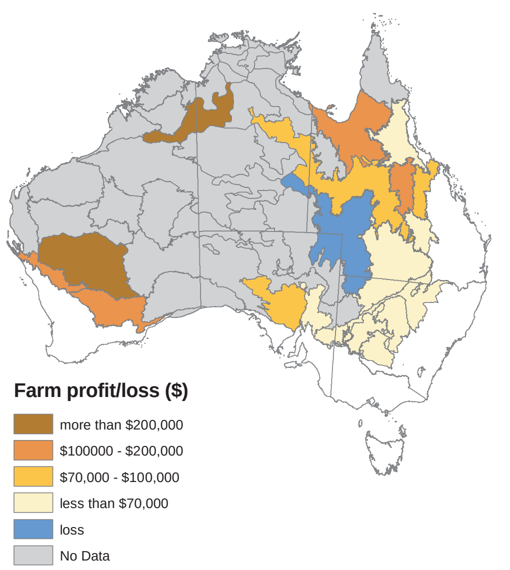
- *Profit at full equity*: Four regions in the western part of the rangelands are in the same category for farm cash income as they are for profit at full equity (Figure 3.99). This indicates low debt levels. In the east, many of the regions move down in category, indicating that they carry debt. One region is in an average loss position after debt is taken into account. Virtually all the regions for which there are data are in a healthy equity-ratio situation.

Figure 3.98 Change in net youth migration, 1996 to 2001



Data: ABS Population and Housing Census, 1996 and 2001. Map: BRS, 2007

Figure 3.99 Profit at full equity (2004–06 average)



Data: ABARE Farm Surveys. Map: BRS, 2007.

Figure 3.100 Cotton — a significant contributor to non-pastoral agricultural production in the rangelands

In 2001, cotton production was worth $56.6 million, or 23% of the total value of all rangeland crops.

Photo: CSIRO

Key points

- The rangelands share two main traits with the rest of Australia: low unemployment and an aging population.
- Factors that separate the rangelands from non-rangeland areas include the rangelands' inaccessibility, relatively low educational levels and socioeconomic disadvantage.

Contributing elements to socioeconomic change

Many elements contribute to the complete socioeconomic picture for the rangelands. In the following sections, three elements that are particularly relevant to agriculture in the rangelands are presented:

- non-pastoral agricultural activity
- land use
- pastoral land values.

Agriculture in the rangelands is changing in response to pressures and opportunities.

Non-pastoral agricultural activity

This section describes the importance of non-pastoral agricultural activity, primarily cropping and horticulture, across Australia's vast rangelands. Data are based on SLAs within a pastoral zone defined by ABARE (Figure 3.102). The ABARE pastoral boundary differs in places from the rangelands boundary used in other themes in this report, which are based on IBRA bioregions.

National overview

In 2001, non-pastoral enterprises in rangeland regions (Figures 3.100 and 3.101) contributed $627 million or 26% of the total value of Australia's agricultural products from the rangelands ($2427 million) (Table 3.9). Traditional pastoral production (grazing of sheep and cattle) contributed the other $1800 million (74%) to the total.

Of the 23 716 people employed within the rural sector of the rangelands in 2001, 27% held jobs in the non-pastoral sector. These data were collected by SLA (Figure 3.102), primarily in the 2001 Census conducted by the ABS and in farm surveys conducted by ABARE. Enterprises and industries were defined using Australian and New Zealand Standard Industrial Classifications.

Products from horticulture and field crops contributed the greatest values from non-pastoral rangeland agriculture in 2001 (Table 3.10.1). The principal horticultural products included grapes, mangoes,

Figure 3.101 Grapes — an important component of horticulture in the rangelands

In 2001, there were 464 grape-growing enterprises that collectively generated $104.9 million, 30.3% of the total value of rangelands horticulture ($345.7 million).

Photo: NT Department of Primary Industries, Fisheries and Mines

Table 3.9 Estimated value of agricultural products, number of holdings and people employed, pastoral and non-pastoral enterprises within Australia's rangelands, 2001

2001	Pastoral	Non pastoral	Total
Value of products[a] ($m)	1 800	627	2 427
Number of holdings[b]	3 997	1 888	5 885
People employed in agriculture	17 197	6 519	23 716

Note: 'Agriculture' is defined broadly and includes pastoral, field cropping and horticultural activities. Pastoral enterprises include sale of cattle for meat and sheep for meat and wool. Any other agricultural activity was considered 'non-pastoral', including production from livestock other than sheep and cattle.

[a] ABS estimates the gross value of a product for an SLA by taking production data and multiplying by an average price for that product for the state where the SLA is located. The production data provided by the ABS refer to those SLAs in the Australian rangelands where some agricultural production was reported in the 2001 Census.

[b] With an estimated value of agricultural production greater than $22 500 per year.

Source: ABS

citrus and vegetables (Table 3.10.2). The total value of field crops was dominated by wheat and cotton. Livestock, other than sheep and cattle, produced in the rangelands include goats, pigs and poultry. In 2001, more than 6500 people were employed in these non-pastoral enterprises (Table 3.10.3).

Figure 3.102 Statistical local areas within the rangelands, as defined by ABARE

Note: SLAs within the pastoral zone defined by ABARE as those areas experiencing very low rainfall. Non-rangeland areas are those with medium to high rainfall. These rangeland SLAs are used in reporting survey statistics.

Map: Chudleigh and Simpson (2004).

Table 3.10.1 Principal land uses contributing to non-pastoral agriculture in the rangelands, 2001

Land use	Gross value ($)	% total non-pastoral production value
Horticulture	345 724 536	55
Field crops	238 638 536	38
Other livestock	38 080 561	6
Not defined [a]	4 646 699	1
Total	627 090 332	100

[a] Data are not suitable for publication by ABS because of small sample size.

Table 3.10.2 Number of enterprises, by non-pastoral product, 2001

Crop	Number of enterprises
Mangoes	566
Grapes	464
Cereals for grain	413
Citrus	369
Vegetables	312

Note: More than one product may be produced on the same holding, so the number of enterprises cannot be added with any confidence.

Table 3.10.3 Employment, by industry sector, 2001

Industry sector	People employed	% total non-pastoral employment
Horticulture	3003	46
Field crops	2682	41
Other livestock	477	7
Undefined	357	6
Total	6519	100

Source: Data based on Chudleigh and Simpson (2004).

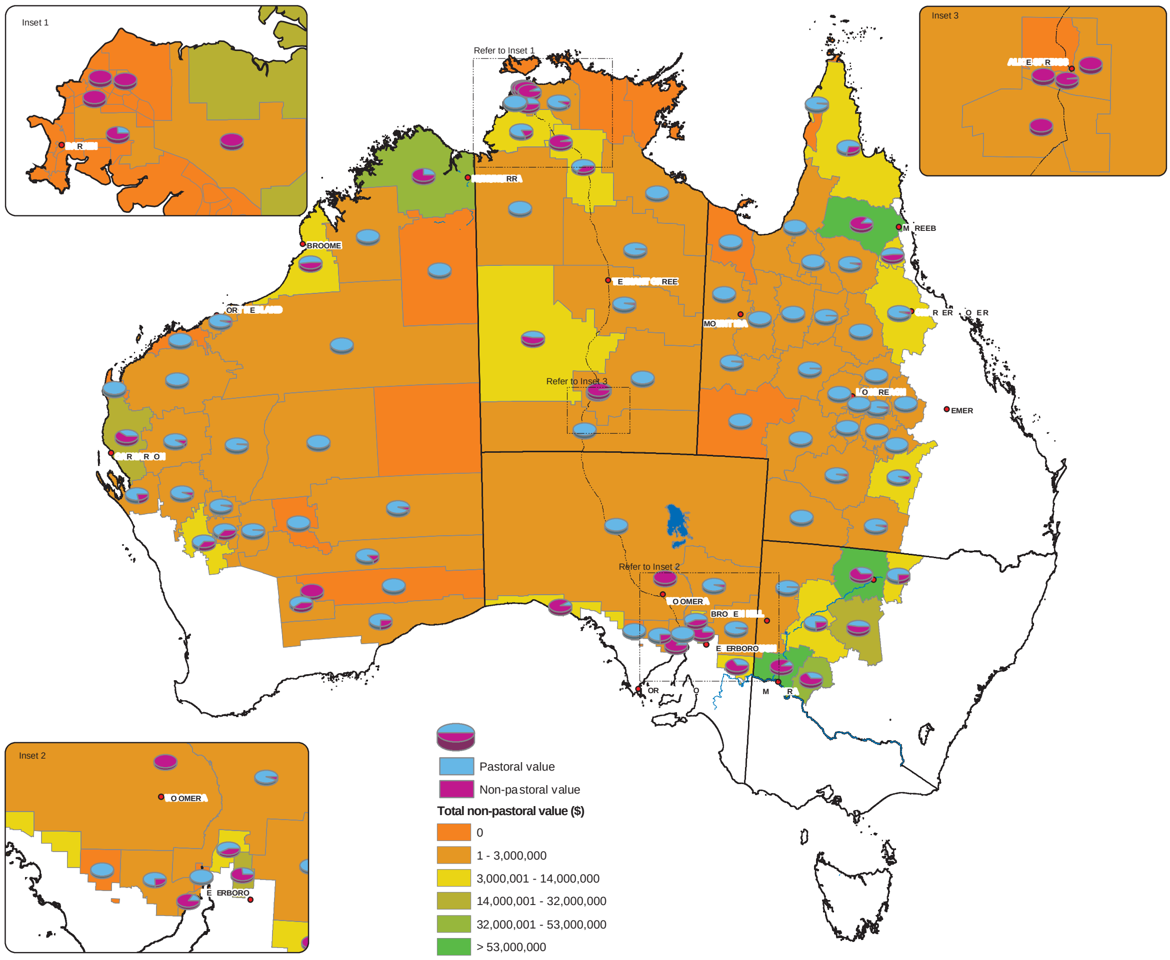
Land areas contributing to non-pastoral activities remain small, with only 0.2% (11 909 km^2), being used for dryland agriculture in 2001 (Table 3.11) and an even smaller area (510 km^2) for irrigated agriculture.

Table 3.11 Land areas used for conservation, pastoral and agricultural production, and urban settlements in Australia's rangelands, 2001

Land use	Area (sq km)	Area (%)
Conservation and natural environments	2 292 270	38.65
Production from relatively natural environments	3 513 376	59.24
Production from dryland agriculture and plantations	11 909	0.20
Production from irrigated agriculture and plantations	510	0.01
Intensive uses (eg urban)	2 422	0.04
Water	110 417	1.86
Total	**5 930 904**	**100.00**

Source: Stewart et al (2001), reproduced in Donohue (2003).

Figure 3.103 Gross value of non-pastoral agricultural production in the rangelands, 2001



Data based on Chudleigh and Simpson (2004). Map: NLWRA.

State and territory non-pastoral products and values

In 2001, the value of non-pastoral products from rangelands varied considerably among states and territories (Figure 3.103; Table 3.12). Value was highest for NSW, where non-pastoral production (largely of cereals, grapes and cotton) contributed 60% of total agricultural production. The second highest value was for Queensland, which produced fruit (excluding grapes), sugar and peanuts, mostly on the Atherton Tableland. WA was the leader in vegetable production. As expected, the lowest contributions were typically from SLAs in the more arid rangelands.

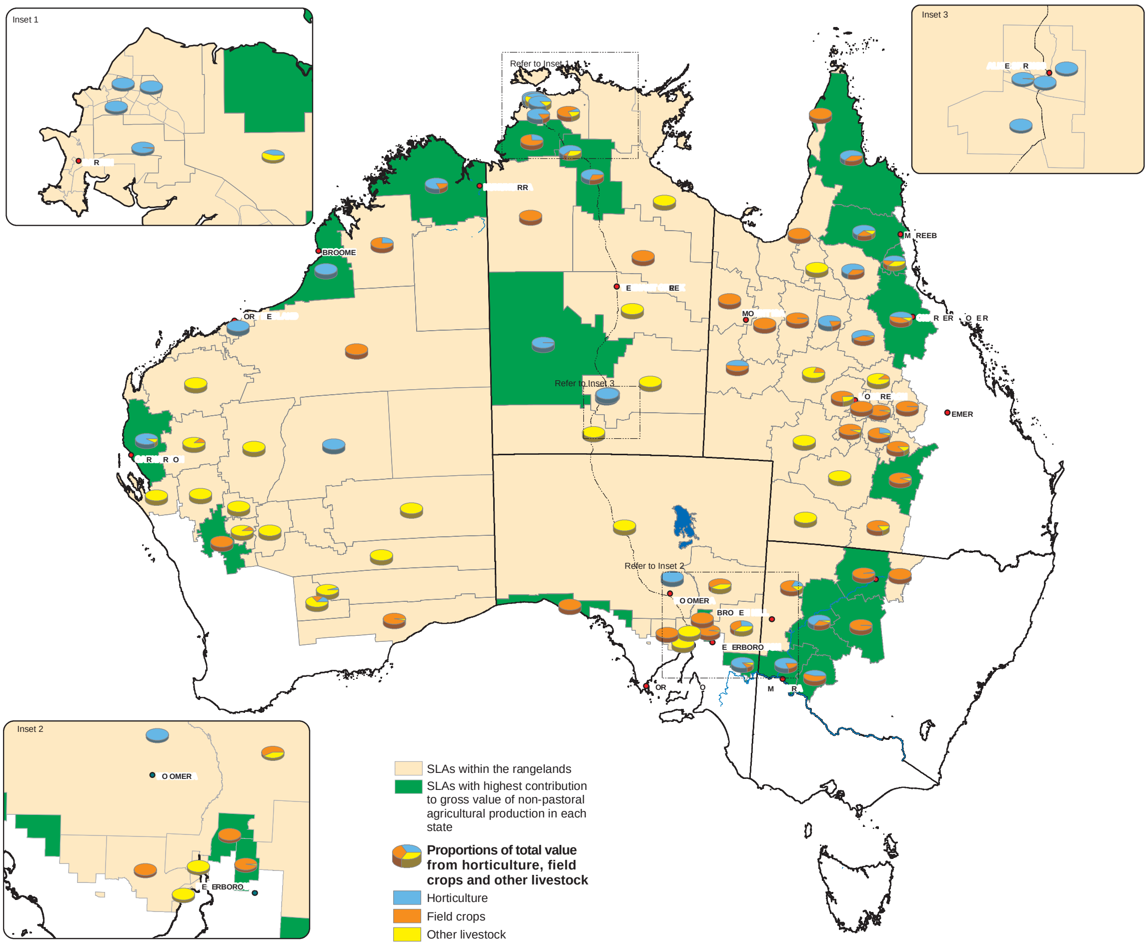
The proportional value of rangeland non-pastoral products varies considerably between jurisdictions (Figure 3.104), but overall is only a very small proportion of their total non-pastoral production. An exception is the NT, which is entirely defined as rangeland SLAs.

Table 3.12 Value of non-pastoral products from each state or territory in the rangelands, 2001

State	Value of pastoral industries ($m)	Value of non-pastoral industries ($m)	Total value of agriculture ($m)	Non-pastoral agriculture as a percentage of total agriculture
New South Wales	196.6	270.7	467.2	58%
Queensland	1167.9	157.0	1324.9	12%
Northern Territory	198.4	71.2	269.6	26%
Western Australia	189.1	90.6	279.7	32%
South Australia	83.2	37.7	120.9	31%
All Australian rangelands	1835.2	627.2	2462.3	26%

Source: Data based on research by Chudleigh and Simpson (2004).

Figure 3.104 Proportional gross value of horticulture, field crops and livestock for each SLA across the rangelands



Data based on research by Chudleigh and Simpson (2004). Map: NLWRA.

As might be expected, the value of production of non-pastoral agriculture is concentrated in specific areas of the rangelands (Figure 3.104) — those with higher rainfall, irrigation schemes, aquifers with suitable groundwater for irrigation and better soils. A small number of rangeland regions contribute a high proportion of non-pastoral value.

Rangeland horticulture

In 2001, horticulture contributed $345.7 million (56%) of the total value of non-pastoral agricultural production across Australia's rangelands (Table 3.13). Relative to the gross value of Australia's total horticultural production of $6604.6 million, the contribution from rangelands was 5.2%. The rangelands contributed 7.6% of Australia's fruit production (excluding grapes) and 3.4% of Australia's vegetable production.

Table 3.13 Contribution of rangeland horticulture to Australian horticulture, 2001

Product group	Rangelands ($m)	Australia ($m)[a]
Fruit (excluding grapes)	155.7 (7.6%)	2041.5
Grapes	104.9 (6.9%)	1517.5
Vegetables	74.7 (3.4%)	2182.6
Nurseries, flowers and turf	10.4 (1.3%)	794.7
Total value of horticultural production	345.7 (5.2%)	6604.6

[a] Includes rangelands states as well as Victoria, Tasmania and ACT

Source: Chudleigh and Simpson (2004).

Based on ABS Census data for 1997 and 2001, the value of horticultural products in the rangelands increased by 54% (Table 3.14), although caution is advised when interpreting these results, as climate and prices may have contributed to the increase.

Table 3.14 Changes in value of rangeland horticultural production, 1997 to 2001

Product group	1997 ($m)	2001 ($m)
Fruit (excluding grapes)	107.1	155.7
Grapes	56.9	104.9
Vegetables	50.9	74.7
Nurseries, flowers and turf	10.2	10.4
Total value of horticultural production	225.1	345.7

Source: Data based on research by Chudleigh and Simpson (2004).

In 2001, 3003 people were employed in horticultural industries in the rangelands, compared to 69 481 people employed in horticultural activities nationally.

Notable differences between states and territories exist in horticultural production across the rangelands (Table 3.15).

- Queensland produces 44% of the value of fruit (excluding grapes), or $68 million of the total value of $155.7 million.
- NSW and the NT each make up about 22% of the total value of fruit production (excluding grapes).
- Fruit production (excluding grapes) was mostly citrus in NSW and mangoes and bananas in WA and the NT.
- Queensland also produced mangoes and bananas but to a lesser extent, and produced a greater variety of fruits.
- The value of grape production in the rangelands was dominated by NSW, followed by the NT.
- WA dominated vegetable production.

Table 3.15 Values of different horticultural products from the rangelands, by state or territory, 2001 ($ million)

State	Fruit excluding grapes	Grapes	Vegetables	Nurseries, flowers and turf	Total
New South Wales	35.1 (22%)	89.7 (86%)	5.3 (7%)	2.0 (19%)	132.1 (38%)
Queensland	68.0 (44%)	0.2 (0.2%)	14.0 (19%)	4.1 (39%)	86.3 (25%)
Northern Territory	34.3 (22%)	14.3 (14%)	3.9 (5%)	3.6 (35%)	56.1 (16%)
Western Australia	14.7 (9%)	0.3 (0.3%)	51.5 (69%)	0.7 (7%)	67.2 (19%)
South Australia	3.6 (2%)	0.4 (0.4%)	0.03 (0.4%)	0.0 (0%)	4.0 (1%)
Australian rangelands	155.7	104.9	74.7	10.4	345.7

Source: Data based on research by Chudleigh and Simpson (2004).

Horticultural production was concentrated in those rangeland regions where irrigation is usually feasible and where soils are suitable for irrigated agriculture (Figure 3.105). Although there were general similarities in regions with different horticultural products, there were specific differences for grapes (Figure 3.106), vegetables (Figure 3.107) and mangoes (not shown).

Rangeland cropping

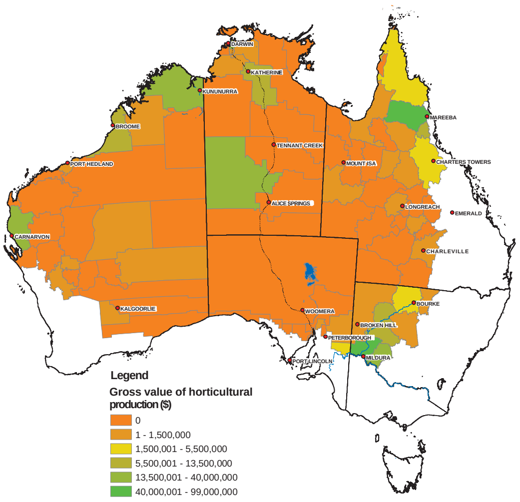
Crop production is a significant industry in Australia's rangelands. In 2001, cropping contributed $239.2 million or 38% to the total value of non-pastoral agricultural production (Table 3.16). This crop production was mostly wheat and cotton, but other cereal crops, sugarcane and hay contributed significantly to the total.

Table 3.16 Values of different crops produced across the rangelands, 2001

Crop	$m	%
Wheat	100.1	42
Cotton	56.6	23
Other cereals, oilseeds, legumes and peanuts	23.4	10
Pastures and grasses and crops for hay	16.2	7
Other crops	42.9	18
Total	239.2	100

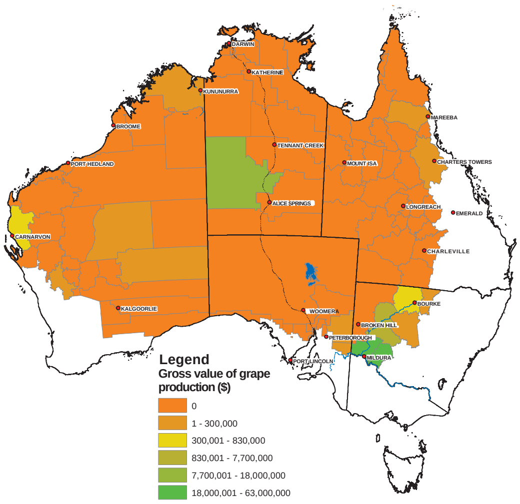
Source: Data based on research by Chudleigh and Simpson (2004).

Figure 3.105 Gross value of all horticultural products, by rangeland statistical local area, 2001



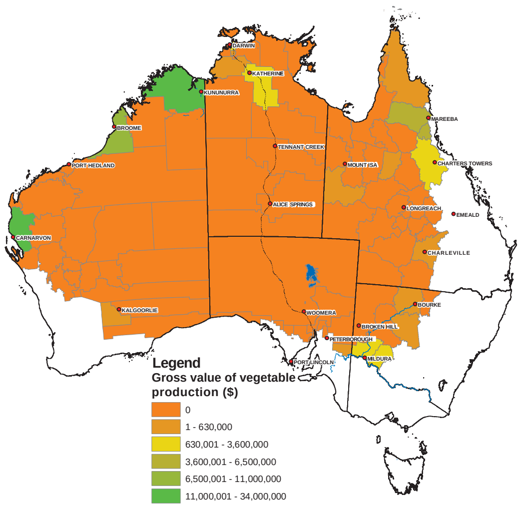
Source: Chudleigh and Simpson (2004). Map: NLWRA.

Figure 3.106 Gross value of grapes produced, by rangeland statistical local area, 2001



Source: Chudleigh and Simpson (2004). Map: NLWRA.

Figure 3.107 Gross value of vegetables produced, by rangeland statistical local area, 2001



Source: Chudleigh and Simpson (2004). Map: NLWRA.

The contribution from rangelands cropping was 2% of the total value of Australia's field crop production in 2001. Cotton growers in the rangelands produced 4.3% of Australia's total value of cotton production.

Based on ABS Census data in 1997 and 2001, the value of cotton and some grain crops decreased, but the overall value of all field crops increased, largely due to wheat (Table 3.17). Caution is advised when looking for trends because climate and prices may have contributed to the changes reported.

ABARE data from broadacre holdings in the rangelands show that, in the 14 years to 2001, there

Table 3.17 Rangeland crop production, 1997 and 2001 ($ million)

Crop	1997	2001
Wheat	63.3	100.1
Cotton	80.8	56.6
Other cereals, oilseeds, legumes and peanuts	29.5	23.4
Pastures and grasses and crops for hay	5.1	16.2
Other crops	42.1	42.9
Value of all field crop production	220.8	239.2

Source: Data based on research by Chudleigh and Simpson (2004).

was a significant increase in non-pastoral product receipts in SA and NSW while the NT showed a significant decrease. Queensland and WA showed no significant trend over those years.

At a regional level, several of the ABARE regions showed significant trends in the value of non-pastoral products. Cape York (Queensland) and the Pilbara (WA) regions had positive trends, while Alice Springs (NT) and Victoria River (NT) both showed negative trends. Increasing diversification in the rangelands of the NT has arisen mainly from horticultural production, but the impact of this would not have been captured in the ABARE broadacre survey.

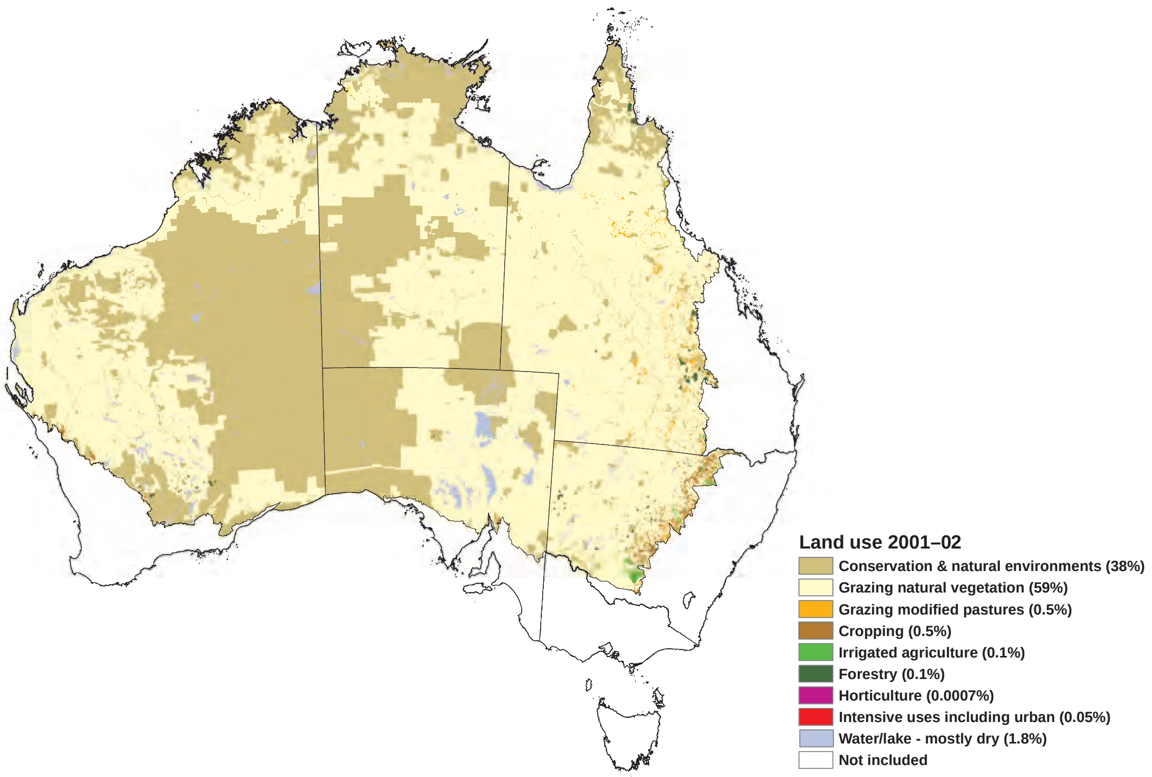
Cropping in the rangelands employed 2682 people, or 7.5% of the 35 745 employed in the whole of Australia's cropping industry. Each state and territory within the rangelands contributed differently to this

Table 3.18 Values of different crops produced in each state and territory across the rangelands, 2001 ($ million)

State	Wheat	Cotton	Other cereals, oilseeds, legumes and peanuts	Pasture and grasses and crops for hay	Other crops	Total
New South Wales	69.6	51.5	11.6	3.9	0.1	136.7
Queensland	0.9	4.5	3.9	3.5	35.2	48.0
Northern Territory	0.0	0.0	0.7	7.2	0.3	8.2
Western Australia	3.5	0.6	2.2	0.8	7.2	14.3
South Australia	26.1	0.0	5.1	0.8	0.1	32.0
Australian rangelands	100.1	56.6	23.5	16.2	42.9	239.2

Source: Data based on research by Chudleigh and Simpson (2004).

Figure 3.108 Land uses across Australia's rangelands, July 2001 to June 2002



Note: The 'Conservation and natural environments' class is characterised by a relatively low level of human intervention. It includes nature conservation, areas managed primarily for the sustainable use of natural ecosystems (including traditional Indigenous uses), unallocated Crown land, and other minimal uses (such as defence and stock routes).

Data: BRS. Map: NLWRA.

total value (Table 3.18). Of the $100 million worth of wheat produced in all the rangelands in 2001, NSW contributed $70 million (70%) and SA $26 million (26%). The NSW rangelands also dominated production of other cereals and cotton. Queensland rangelands dominated sugar and tobacco, largely from the Atherton Tableland.

Key points

- Non-pastoral products (particularly cropping and horticulture) contribute significantly to regional economies in different parts of the rangelands. Cropping is concentrated on the rangelands' eastern, southern and southwestern margins, which have better soils and relatively more reliable rainfall. Horticulture is more widespread, as it is supported by groundwater that allows irrigation.
- The value of the main horticultural products (grapes, other fruit and vegetables) increased substantially between 1997 and 2001. The overall value of all field crops (and mainly wheat) increased during the same period, although the value of cotton and some grain crops decreased. These changes should be interpreted cautiously, as climate and prices may have contributed to reported changes. A longer period of reporting is required to quantify the rate of change in the value of non-pastoral products.
- The pastoral zone used by ABARE to define the rangelands differs from the rangelands boundary adopted by ACRIS. Boundary differences are most marked in the east, where some of the most significant non-pastoral agricultural production occurs. Reporting is by SLA rather than IBRA bioregion, making it difficult to spatially compare commodity values by SLA with the IBRA regionalisation used by ACRIS.

Box 3.13 Land use mapping

Data and maps on land uses across Australia's rangelands have been generated using the SPREADII (Spatial Reallocation of Aggregated Data) model (Knapp et al 2006). The model was developed by the Bureau of Rural Sciences (BRS 2006). SPREADII links agricultural statistics for various crops and pastures with time-series satellite data and with available spatial data on non-agricultural land uses. Linking those different data requires caution because:

- the land use maps are a snapshot of land use at a particular time
- the resolution (pixel size) of the AVHRR satellite data used is 1.1 km, which is too coarse to map land uses covering small areas
- some agricultural land uses and crop types are impossible to distinguish with satellite data alone, and other spatial data must be used.

Model outputs are mapped to the nationally agreed Australian Land Use Mapping (ALUM) system. That mapping method is statistically robust and cost effective, making it useful for detecting gross land use changes over large areas such as the rangelands. ALUM maps have been generated by BRS for ACRIS to cover the 1992 to 2002 period.

Catchment-scale land use data have also been collected by states and territories. Those data are available for most of the rangelands, but have been collected only for about 10 years and are still incomplete for many areas. Therefore, catchment-scale land use data were not used in this report.

Land use

Australia's rangelands encompass a rich variety of different land uses, as illustrated by a map for 2001–02 (Figure 3.108). In addition to the typical grazing of natural vegetation by livestock, other land uses include conservation in large areas and cropping and horticulture in smaller areas.

Land use changes: 1992 to 2002

Changes in land use across the rangelands are associated with expansion of the conservation estate, Indigenous land ownership, mining activity and the development of non-pastoral enterprises. Land use maps covering rangeland regions from 1992 to 2002 have been generated (Box 3.13), and the information assessed.

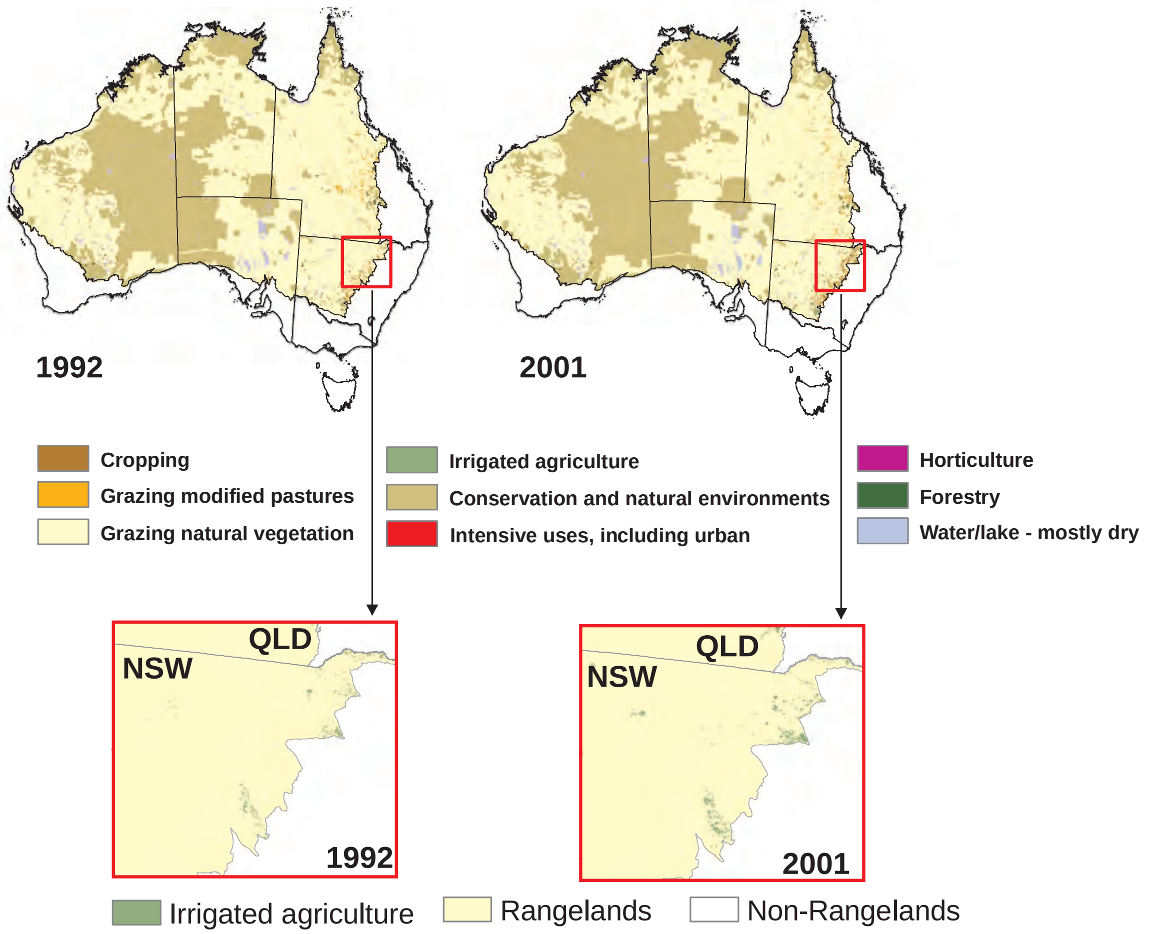
Comparing land uses in 1992 and 2001 across all rangeland regions (Figure 3.109) indicates that very little has changed — pastoral and conservation land use remained extensive while other land uses varied somewhat but remained relatively small in area (Table 3.19). However, by 'zooming in' on an area

Table 3.19 Land uses, selected financial years between 1992–93 and 2001–02 (km^2)

Land use	1992–93	1993–94	1996–97	1998–99	2000–01	2001–02
Conservation and natural environments	2 318 507	2 320 796	2 325 253	2 339 217	2 365 104	2 368 415
Grazing natural vegetation	3 731 800	3 725 300	3 729 100	3 697 900	3 663 100	3 666 400
Forestry	12 008	12 008	12 024	12 007	11 730	11 697
Grazing modified pastures	31 161	30 627	17 114	27 301	33 403	30 478
Cropping	47 624	20 024	25 345	31 282	33 301	28 903
Horticulture	66	53	84	5 427	71	45
Irrigated agriculture	4 752	6 076	5 898	6 961	7 801	8 617

Source: see Box 3.13.

Figure 3.109 Land uses, 1992 and 2001



Top: All rangelands

Bottom: Smaller area in northeastern NSW and southeastern Queensland

Source: see Box 3.13. Map: NLWRA.

along the eastern margin of the rangelands (northeastern NSW and southeastern Queensland), it is evident (Figure 3.109, lower panels) that irrigated agriculture has increased in that area. Survey data confirm that irrigated agriculture more than doubled in area over the 10 years across all the rangelands (Table 3.19).

Key points

Between 1992–93 and 2001–02:

- land use type was relatively static across the rangelands
- the predominant land use in the rangelands remained domestic livestock grazing of natural vegetation, which decreased by 65 400 km^2
- conservation and natural environment land uses increased by ~50 000 km^2
- irrigated agriculture, including sugar, cotton and other irrigated enterprises, increased steadily.

Land values

Changes in land values over various periods from 1991 to 2006 are reported for each state or territory either by IBRA bioregion or by pastoral district, although only the average for 2002–06 for each rangeland bioregion is reported for Queensland.

Pastoral land values are a useful socioeconomic indicator for rangeland enterprises:

Box 3.14 Pastoral land value data

Queensland land values were compiled regionally, with valuations made progressively during the period from June 2002 to June 2006 (but only reported in 2006). The valuations were averaged for rural land parcels after applying a number of filters for minimal size and primary land use. Queensland was not able to report changes in land values. Valuations were based on 'unimproved' property values sourced from the Queensland Valuations and Sales System.

SA reported changes in land values for the area of pastoral lease tenure within IBRA bioregions for 1998 and 2004. The SA Valuer-General provided an 'unimproved' value for each pastoral lease, based on recent sales. The SA Pastoral Board uses these unimproved values as a component in setting annual rental charges for pastoral leases. Rangeland bioregions with less than 50% pastoral tenure and/or fewer than five leases were excluded from this report.

The NT reported land values for pastorally significant IBRA bioregions for 1991 and 2003. Bioregions were excluded if they had limited pastoral tenure and/or a small number of pastoral leases.

WA reported changes in 'lease and improvement value', also known as 'bare' lease value (ie lease and all fixed improvements), by pastoral area on an annual basis between 1992 and 2006. Valuations were estimated as average levels of value on either a dry sheep equivalent (DSE) or large stock unit basis (1 large stock unit = 7 DSEs). Land values by pastoral area have been approximately aligned with rangeland IBRA bioregions. 'Lease and improvement' values for WA are not directly comparable to the 'unimproved' values for Queensland, SA and the NT.

NSW pastoral lease values were selected from data available online*. This provided the area, carrying capacity (DSE basis) and property market values (1996, then 2002 to 2006 on an annual basis) for a typical property from eight localities in the Western Division. A 'typical' property is one that is considered representative of the locality and will indicate the market trend. Values were converted to $/km^2 and are reported for the corresponding IBRA bioregion of each locality. These are typical values, not the average (or some other statistical) value for the whole of each bioregion. NSW values reflect changed market values, which are different from the 'unimproved' lease values for Queensland, SA and the NT.

All values were adjusted to 2005 dollars using the Consumer Price Index.

* 'Western grazing', Table 16, http://www.lands.nsw.gov.au/valuation/nsw_land_values (accessed 3 April 2007)

- Land values underpin inherent resource potentials and indicate relative profitability for different rangeland regions. They help identify declining regions, where various forms of economic and social adjustment may be required.
- Land values help identify areas where pastoralists may be cash poor (based on gross margins) but asset rich. If the ratio of profitability to asset value declines below a critical threshold, it can be very difficult for those buying into (or expanding in) a region to repay loans, which may result in land resources being stocked beyond sustainable limits to service loan debts (particularly during periods of lower *seasonal quality*).
- Rangeland values indicate the extent to which land values are being forced up by recent large increases in property prices elsewhere (eg prices for residential real estate).

Changes in pastoral land values are reported separately for each state and territory, as the data were provided in different forms (Box 3.14). The separate state and territory analyses are also assessed for general changes in land values across the rangelands.

Table 3.20 Unimproved rangeland values for Queensland IBRA bioregions and sub-IBRA regions

Bioregion	Average unimproved value ($/km²)	Total valued area (km²)	Average unimproved value ($m)[a]	Sub-IBRA value range ($/km²)	Number of valued entities
Brigalow Belt North	34 873	58 636	1.058	3 772 – 64 328	587
Brigalow Belt South	17 780	50 149	0.559	3 293 – 21 182	567
Channel Country	598	196 820	0.535	104 – 1 234	105
Cape York Peninsula	11 731	49 737	0.457	420 – 34 234	73
Desert Uplands	4 953	62 690	0.441	1 183 – 14 031	372
Darling Riverine Plains	10 950	7 283	0.373	5 272 – 13 571	125
Einasleigh Uplands	26 712	105 915	0.637	6 282 – 52 058	601
Gulf Fall and Uplands	n.d.	2 415	n.d.	n.d.	1
Gulf Plains	2 876	203 029	0.736	38 – 12 610	259
Mitchell Grass Downs	4 792	242 952	0.504	333 – 6 668	1 166
Mount Isa Inlier	16 246	53 852	0.203	302 – 19 074	73
Mulga Lands	2 262	168 576	0.187	220 – 4 582	909
Simpson–Strzelecki Dunefields	43	12 858	0.113	39–49	5

n.d. = not disclosed

[a] 2005 dollars

Source: Queensland Valuations and Sales System; see Box 3.14.

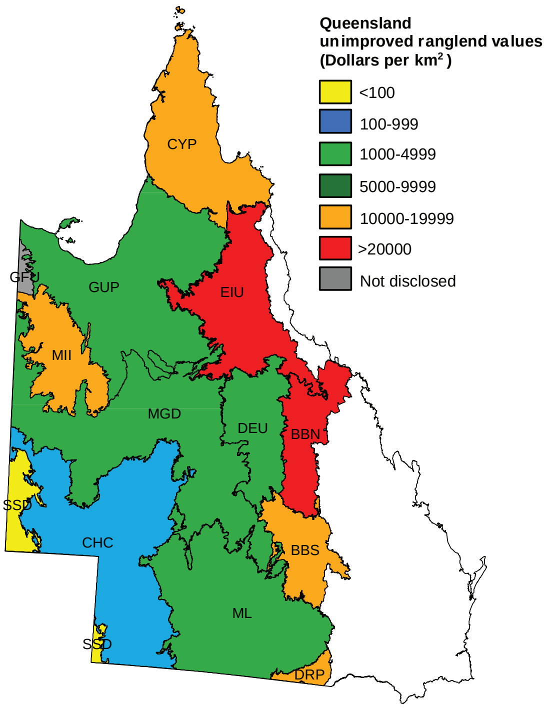
Queensland

There was a very large range in average land value between rangeland bioregions (Table 3.20), with the most valuable land being in north and northeast bioregions, such as the Brigalow Belt North and Einasleigh Uplands (Figure 3.110). As expected, the least valuable lands were in the dry southwest (the Channel Country and Simpson–Strzelecki Dunefields). The Mount Isa Inlier is an exception: the high mean value and large range in land values may be associated with mining interest in the region. However, reporting averaged values masks high variability within IBRA bioregions.

Within some bioregions, there were large differences in land values between component sub-IBRAs (Table 3.20). The differences reflect differing soils and the resulting vegetation growth under similar climatic conditions. The Mulga Lands, for example, had sub-IBRA mean values ranging from \$220/km^2 to \$4582/km^2; an even larger range was found in the Gulf Plains (\$38/km^2 to \$12 610/km^2).

The average areas of entities (akin to properties) in the Mulga Lands, Desert Uplands, Mitchell Grass

Figure 3.110 Classes of averaged unimproved values for Queensland bioregions



Source: Queensland Valuations and Sales System, see Box 3.14.

Table 3.21 Changes in unimproved values for SA pastoral leases, 1998 to 2005, averaged by IBRA bioregion

Bioregion	Unimproved lease value ($/km^2, 2005 $)		Ratio of change (1998 to 2005)
	1998	2005	
Finke	15	28	1.9
Channel Country	25	42	1.7
Stony Plains	27	46	1.7
Gawler	63	105	1.7
Broken Hill Complex	126	206	1.6
Flinders Lofty Block	115	184	1.6
Murray-Darling Depression	127	204	1.6
Simpson–Strzelecki Dunefields	23	37	1.6

Source: SA Valuer-General; see Box 3.14.

Table 3.22 Changes in unimproved average pastoral lease values, NT bioregions, 1991 to 2003

Bioregion	Unimproved lease value ($/km^2)[a]		Ratio of change (1991 to 2003)
	1991	2003	
Daly Basin	410	623	1.5
Sturt Plateau	220	319	1.5
Gulf Fall and Uplands	155	203	1.3
Ord Victoria Plain	537	569	1.2
Burt Plain	142	162	1.1
Finke	82	89	1.1
Mitchell Grass Downs	522	544	1.0
Channel Country	107	112	1.0

[a] 2005 dollars

Source: see Box 3.14.

Downs and Einasleigh Uplands bioregions were similar (Table 3.20), but their average value was much less in the Mulga Lands and comparatively high in the Einasleigh Uplands. Unimproved values were not well correlated with mean property size.

Changes in land values could not be assessed from the available data for Queensland. Future data acquisition and analysis will provide the basis for reporting changes in land values for Queensland bioregions.

South Australia

Unimproved values of pastoral leases increased between 1998 and 2004 in all SA rangeland IBRA bioregions (Table 3.21), with the largest relative increase (factor of 1.9) in the Finke bioregion. Relative increases were similar (1.6–1.9) across bioregions, which may indicate continued confidence in pastoralism (both sheep and cattle) by the majority of rangeland business enterprises in SA. There was a general south to north decline in averaged values of pastoral leases in line with increasing aridity.

Northern Territory

Unimproved land values increased in all pastorally significant NT IBRA bioregions between 1991 and 2003 (Table 3.22), although data were not available to report changes for individual years. The more northern Daly Basin and Sturt Plateau bioregions had the greatest increase in values over the 12-year period. This is consistent with recent infrastructure

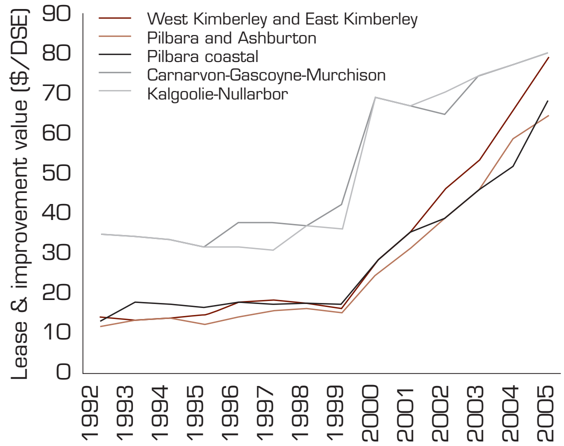
Table 3.23 Changes in average 'lease and improvement' values, WA pastoral areas, 1992 to 2005

Pastoral area	Component bioregions	$ per dry sheep equivalent[a]		Ratio of change (1992 to 2002)
		1992	2005	
West Kimberley and East Kimberley	Central Kimberley, Dampierland, North Kimberley, Ord Victoria Plain, Victoria Bonaparte	13.96	78.57	5.6
Pilbara and Ashburton	part Pilbara, part Gascoyne	11.96	64.29	5.4
Pilbara Coastal	part Pilbara	13.96	67.86	4.9
Carnarvon–Gascoyne–Murchison	Carnarvon, part Gascoyne, part Murchison, part Yalgoo	34.89	80.00	2.3
Kalgoorlie–Nullarbor	Coolgardie, part Murchison, Nullarbor	34.89	80.00	2.3

[a] 2005 dollars

Source: see Box 3.14.

Figure 3.111 Changes in average 'lease and improvement value' for pastoral areas, WA, 1992 to 2005



Note: Pastoral areas have been aligned to IBRA bioregions.

Source: see Box 3.14.

development and land use intensification in the Sturt Plateau region and the further subdivision of pastoral leases in the Daly Basin bioregion. These regions also have more reliable seasonal conditions and relatively stable livestock carrying capacities.

Unimproved land values remained relatively unchanged in southern bioregions of the NT (Table 3.22), such as the Channel Country and Mitchell Grass Downs. The arid Finke bioregion had the lowest valuation, which was consistent with its highly variable climate and low stock carrying capacity.

Western Australia

There were few or no changes in the estimated average 'lease and improvement' value of pastoral leases between 1992 and 1999 in WA bioregions (Figure 3.111). There was a large increase in the average value of southern (predominantly sheep-grazed) pastoral leases between 1999 and 2000 and a less steep, but continuous, increase between 2002 and 2006. Between 1992 and 2005, values of northern cattle-grazed pastoral leases increased more than fivefold, while values of southern leases roughly doubled (Table 3.23).

Factors that probably contributed to increased rangeland values in WA include:

- an increase in the live-cattle trade and prices, particularly in northern pastoral areas
- an increase in herd productivity, particularly through the sale of younger cattle
- a sustained run of good seasons in the northwest and the Kimberley, resulting in higher cattle birth and growth rates and allowing for increased build-up and turn-off of herds
- shorter runs of good seasons in the south, allowing for higher turn-off.

Table 3.24 Changes in property market values for pastoral leases in NSW rangeland bioregions

Locality	Associated IBRA bioregion	Property market value ($/km^2)[a]			Ratio of change (1996 to 2005)
		1996	2002	2005	
Hay	Riverina	8 519	10 653	20 605	2.4
Brewarrina	Darling Riverine Plains	4 328	5 164	7 753	1.8
Bourke	Cobar Peneplain	468	375	774	1.7
Wilcannia	Mulga Lands	368	310	642	1.7
Lightning Ridge	Brigalow Belt South	3 241	3 685	4 935	1.5
Balranald	Riverina	3 374	2 322	3 966	1.2
Wentworth	Murray-Darling Depression	2 080	1 428	2 537	1.2
Cobar	Cobar Peneplain	868	424	865	1.0
Average — Riverina		7 444	7 004	12 285	1.7
Average — Cobar Peneplain		836	431	820	1.0

[a] 2005 dollars

Note: Values are for a typical property in each bioregion, not the average of all properties within the region.

Source: see Box 3.14.

New South Wales

Between 1996 and 2002, values of NSW pastoral properties typical of various rangeland localities either declined or remained fairly constant (Table 3.24). Properties in the Cobar Peneplain bioregion (Cobar and Bourke) showed the biggest decreases. Property values also fell in the southern part of the NSW rangelands, including the Wentworth (Murray-Darling Depression IBRA) and Balranald (western Riverina IBRA) regions. Properties in the Hay area were an exception: their value typically increased.

Between 2002 and 2005, property values increased in all NSW localities (Table 3.24), with particularly strong growth in the Hay region and less in the Brewarrina, Bourke, Wilcannia and Lightning Ridge regions. These increased land values have mostly been contrary to the general level of profitability of NSW rangeland enterprises. One reason for this is that increasing prices for prime agricultural land further east have had a 'ripple' effect, as primary producers have progressively moved their operations towards more marginal areas where land values are perceived to be better aligned with returns.

Property values in the Cobar Peneplain bioregion recovered after a 1996 to 2002 decline, to a value in 2005 similar to that in 1996 (Table 3.24). In this and other eastern rangeland bioregions in NSW, relatively small properties have been rendered non-viable by woody thickening and have been purchased for recreational pursuits, mainly hunting. Purchasers generally seek lower-valued properties and are influenced by the perception of 'bargain' prices for relatively large areas. Rather than being 'lifestyle' blocks, these properties generally have absentee owners.

Probable reasons for regional differences in NSW rangeland values include:

- large gains in the eastern rangelands driven by opportunities for alternative enterprises, such as dryland and irrigated cropping in the Riverina and beef cattle and dryland cropping in the Darling Riverine Plains
- declines in some localities due to poorer *seasonal quality* through the 1990s and low wool prices, leading to marginal profitability for wool growers

- higher meat prices for sheep in recent years, providing opportunities to cross merinos with meat-sheep breeds
- higher demand for goat meat, providing an alternative income stream for woolgrowers who can harvest feral goats or run domesticated goats
- strong beef cattle prices, providing a higher income from raising cattle on pastoral leases that traditionally ran sheep.

Key points

- Land values have increased appreciably across most of the grazed rangelands. Despite the problems in comparing jurisdictional land value data, the increases can be estimated to be in the order of 150% to 300%. This is a very substantial barrier for those seeking to buy into rangeland pastoral enterprises and implies that landholders are under considerable pressure to maintain returns on equity.
- Information on change in pastoral land values provides underlying information about relative profitability, asset-to-income ratios and ability to service debt. These all contribute to an understanding of longer-term viability and may also provide insight into regional change in stocking density (ie sustainable management).
- Typical increases in rangeland values were far higher than could possibly be accounted for by increases in real productivity (ie turn-off of meat and/or fibre). Increasing cattle prices during parts of the 1992–2005 period may have contributed to increased financial productivity over and above any gains in biophysical productivity, but this was not the case for wool. Hence, there must be some concern about the long-term viability of some pastoral enterprises.
- The considerable differences among jurisdictions in the way in which pastoral land values are provided makes cross-jurisdictional comparisons difficult. The NSW system of reporting the indicative market value of properties by district could be an effective model for improving cross-jurisdictional consistency.

4 Focus bioregions

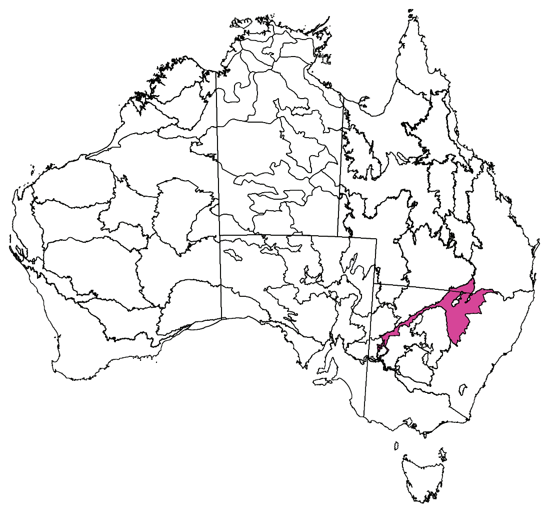
To illustrate how data and information can be compiled for regional rather than national purposes, five focus bioregions (one in each rangeland state and the Northern Territory, NT) were nominated for presentation by each state/NT member of the Australian Collaborative Rangeland Information System Management Committee (ACRIS-MC):

- New South Wales (NSW) — Darling Riverine Plains
- South Australia (SA) — Gawler
- Queensland — Mitchell Grass Downs
- Western Australia (WA) — Murchison
- NT — Sturt Plateau.

Shortened versions of the information presented in this chapter are available for all 52 rangeland bioregions on the CD accompanying this report.

Darling Riverine Plains bioregion (NSW and Queensland)

Figure 4.1 Darling Riverine Plains bioregion in the NSW and Queensland rangelands



Note: Area = 103 329 km^2

The Darling Riverine Plains bioregion includes the Darling River and its tributaries in NSW and Queensland (Figure 4.1). Ninety per cent of the area of this rangeland bioregion (93 316 km^2) is in NSW; the remaining 10 013 km^2 is in Queensland. Most results reported here relate specifically to NSW, but some also include the Queensland portion.

This bioregion includes the extensive alluvial plains of the network of rivers and creeks that flow into the Darling River, together with its floodplains (Figure 4.2). Vegetation includes river red gum, blackbox and coolibah woodlands with inliers of poplar box, belah, redbox and ironbark woodlands on higher parts of the landscape. Major tenure is leasehold in the Western Division and freehold in the Central Division of NSW. Sheep and cattle grazing is the main land use; other land uses include dryland cropping, irrigated cotton, horticulture and, at Lightning Ridge, black opal mining. Major population centres are Wilcannia, Bourke, Brewarrina and Nyngan.

Regional issues

- Upstream diversion of river flows for irrigation is reducing the size, frequency and effectiveness of downstream flooding. This has reduced pastoral productivity and altered the floodplain ecosystem, particularly that of riparian corridors and wetlands.
- The merino wool industry has been in decline for most of the reporting period. That decline initiated a trend into cereal cropping in the eastern margins of the rangelands, peaking in the late 1990s before the implementation of native vegetation legislation. Cropping has focused on certain soil types, especially those of grasslands. Properties with the capacity to crop have greater options to maintain financial viability.

Figure 4.2 Characteristic landscapes of the NSW Darling Riverine Plains bioregion

Woodland of eucalypts and acacias

Photo: NSW Department of Environment and Climate Change

Coolibah

Photo: NSW Department of Environment and Climate Change

Myall

Photo: NSW Department of Environment and Climate Change

Darling River near Louth

Photo: Arthur Mostead

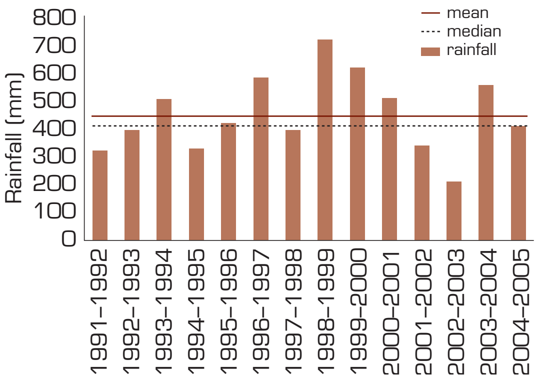
- A large loss of social infrastructure (eg families, Landcare network, social groups) was evident during the late 1990s and early 2000s, particularly in areas without cropping. Very few young people are now returning to properties.
- Thickening of black box (*Eucalyptus largiflorens*) and coolibah (*E. coolabah*) affects pastoral management in areas where flooding has initiated dense regeneration.
- Perennial grasses appear to have declined across the bioregion in the longer term. The main species, curly Mitchell grass (*Astrebla lappacea*), appears to have remained stable over the 1992–2005 reporting period.
- The bioregion generally has low numbers of feral goats, but feral pigs are associated with the watercourse areas. Rabbits generally have a low impact.

Further information relevant to recent change in the bioregion is available in Grant (2006).

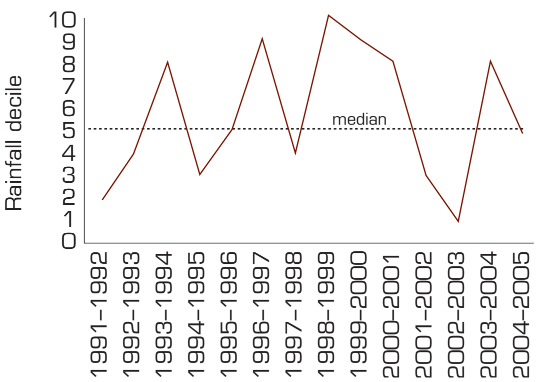
Seasonal quality — 1992–2005

Rainfall was quite variable through the 1992–2005 period and fluctuated both above and below the long-term (1890–2005) median (Figure 4.3, top left and centre). However, the 1992–2005 period as a whole was among the wetter 14-year periods since

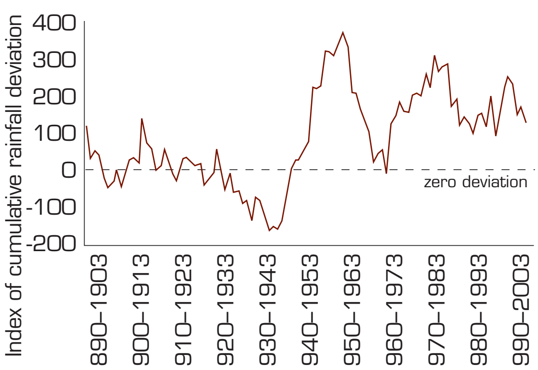
Figure 4.3 Indicators of *seasonal quality* for the entire Darling Riverine Plains bioregion



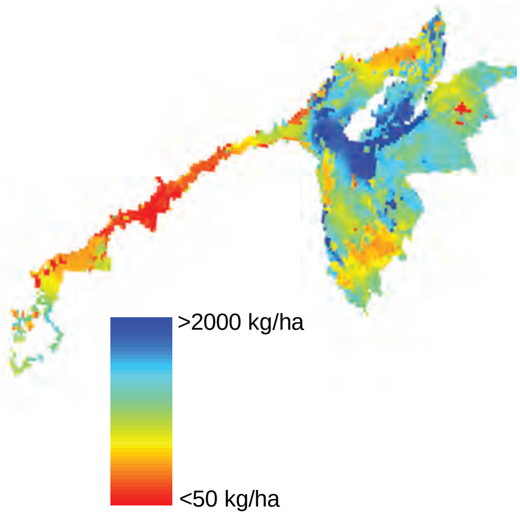
Annual rainfall, long-term (1890–2005) mean and median



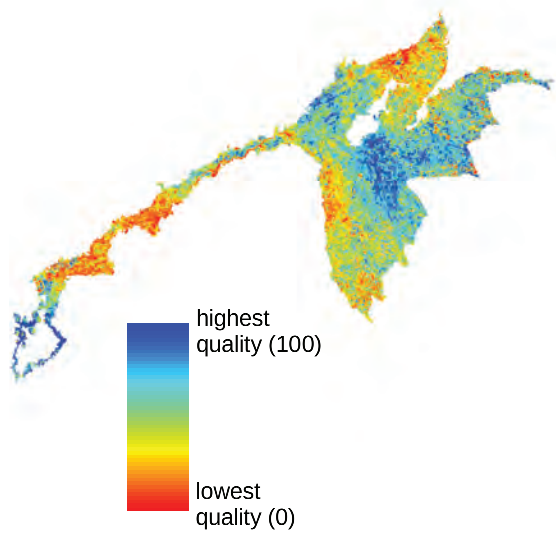
Annual rainfall as deciles of the long-term (1890–2005) rainfall record



Cumulative percentage deviations of annual rainfall from the long-term (1890–2005) median for all 14-year periods between 1890–1903 and 1992–2005



Aussie-GRASS simulated total standing dry matter — 1995



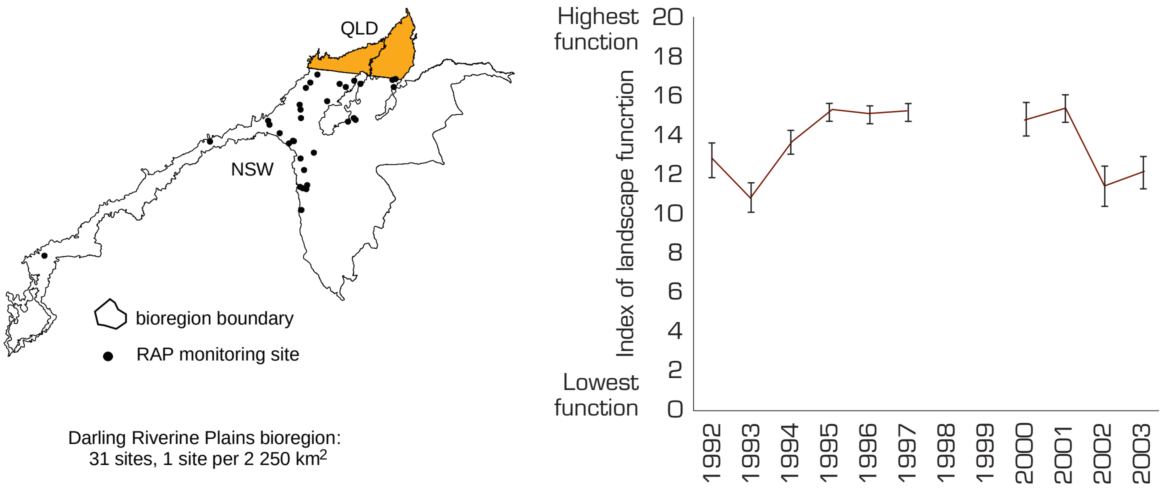
NDVI-based image of 'season quality' for 1995. Each pixel has a relative value according to the greeness of vegetation (ie photosynthetic activity)

Left: Rainfall

Right: Simulated pasture biomass and vegetation greenness (NDVI)

Note: Indicators are based on spatially averaged annual rainfall (April–March) between 1991–92 and 2004–05. For cumulative percentage deviations, periods below the dashed zero line indicate 14-year sequences with generally less rainfall (poorer *seasonal quality*) and periods above the line indicate sequences of increased rainfall (better *seasonal quality*). All data are for the combined NSW and Queensland components of the bioregion.

Figure 4.4 RAP monitoring sites, Darling Riverine Plains bioregion, and reported changes in an index of landscape function



Locations of RAP monitoring sites

Change in an index of landscape function based on the frequency and cover of perennial grasses. Bars show the standard error of the mean for each year. Data not available for 1998 and 1999.

1890. Figure 4.3 (bottom left) demonstrates apparent longer-term change in the pattern of annual rainfall. The first 30 years of available records show that rainfall fluctuated about the line of 'zero percentage cumulative deviation'. The 1920s to 1940s was a much drier period, and in terms of cumulative rainfall deficiency over successive 14-year periods, was much drier than conditions experienced recently. The past 50 years have been generally above average, and exceptional in the 1950s and 1970s. For the 1992–2005 reporting period, there was marked year-to-year variation, indicating highly variable *seasonal quality*. 2002–03 was a very dry year, while the period 1998–99 to 2000–01 was a wetter period. As in most bioregions, *seasonal quality* varied spatially across the Darling Riverine Plains in some years (shown in Figure 4.3, right, for 1995). This assessment of variability is based on simulated pasture biomass produced by AussieGRASS and 'season quality' derived from the Normalised Difference Vegetation Index (NDVI[36]).

Change in landscape function

Change in landscape function is reported from 31 Range Assessment Program (RAP) sites in the NSW part of the Darling Riverine Plains bioregion (Figure 4.4). Each site was assessed at least eight times between 1992 and 2003. An index of landscape function was calculated from the frequency and cover of perennial grasses at each site. Most of the change was probably seasonal, with index values responding to the presence of summer-growing perennial grasses, particularly curly Mitchell grass.

Across all seasonal conditions, 89% of site-time assessments had stable or increased landscape function. Taking account of seasonal conditions prior to each site reassessment, 2% of site-time assessments showed a decline in landscape function (beyond a change threshold) when *seasonal quality* was above average, and 23% of site-time assessments showed an increase when *seasonal quality* was below average (Table 4.1).

Sustainable management

Change in critical stock forage

The frequency of the palatable and perennial (2P) curly Mitchell grass at RAP sites at each assessment is used to report change in critical stock forage. As for landscape function, the same sites were assessed at least eight times between 1992 and 2003 (no data are available for 1998 and 1999) (Table 4.2).

[36] See http://www.environment.gov.au/erin/ndvi.html.

Table 4.1 Seasonally interpreted change in landscape function at RAP sites in the Darling Riverine Plains

Seasonal quality	Number of site by year combinations	Percentage of reassessed sites showing		
		Decline >4 decrease in index	No change	Increase >4 increase in index
Above average	62	2	90	8
Average	62	5	92	3
Below average	93	20	57	23

Note: The light grey cell indicates a likely adverse effect related to grazing management, in that no change or an increase in the landscape function indicator would be expected following above-average *seasonal quality*. The grey cell represents an encouraging result, as a decrease in landscape function would be expected following poor seasonal conditions.

Table 4.2 Seasonally interpreted change in critical stock forage at RAP sites in the Darling Riverine Plains

Seasonal quality	Number of site by year combinations	Percentage of reassessed sites showing		
		Decline >11 decrease in freq	No change	Increase >12 increase in freq
Above average	69	17	71	12
Average	46	17	65	18
Below average	69	9	82	9

Note: The light grey cell indicates a likely adverse effect related to grazing management, in that no change or an increase in curly Mitchell grass frequency would be expected following above-average *seasonal quality*. The grey cell represents an encouraging result, as a decrease in frequency would be expected following poor seasonal conditions.

Table 4.3 Seasonally interpreted change in native-plant species richness at RAP sites in the Darling Riverine Plains

Seasonal quality	Number of site by year combinations	Percentage of reassessed sites showing		
		Decline >12 decr. in no. spp.	No change	Increase >15 incr. in no. spp.
Above average	102	11	77	12
Average	68	24	75	1
Below average	102	11	66	23

See Table 4.2 for explanation of cell colours.

Note that sites selected for reporting change were restricted to those where curly Mitchell grass was present at the start of the period.

Species richness

Site-time assessments at RAP sites were used to determine seasonally interpreted change in native-plant species richness (Table 4.3). A higher percentage of sites had increased species richness following adverse seasons than declined following better *seasonal quality*.

Change in woody cover

The 'annualised rate' of woody vegetation change between 2004 and 2006 was 1468 ha based on analysis of satellite data using Queensland State-wide Landcover and Tree Study (SLATS) methods. Woody vegetation is defined as 'woody communities with 20% crown cover or more (eg woodlands, open forests and closed forests) and taller than about 2 metres'. The 'annualised rate' of clearing represents the 'annual rate of woody vegetation change, which is largely due to cropping, pasture and thinning' (DNR 2007).

It is not possible to report change for earlier years of the 1992–2005 period using this method.

Distance from stock water

Reporting on distance from stock water is for the whole Darling Riverine Plains bioregion.

Based on the locations of stock waterpoints (bores and dams) sourced from Geoscience Australia's Geodata Topo 250K vector product (Series 3, June 2006), the percentage of sub-IBRA area within 3 km and beyond 8 km of permanent and semipermanent sources of stock water is listed in Table 4.4. This analysis does not include the locations of natural waters (eg rivers), which provide many additional sources of water for stock. For some sub-IBRAs, the percentage area within 3 km of water may be understated and the area beyond 8 km overstated.

Table 4.4 Percentage of sub-IBRA area within 3 km or beyond 8 km of permanent and semipermanent sources of stock water (bores and dams only), Darling Riverine Plains

Sub-IBRA	% of sub-IBRA area	
	<3 km from water	>8 km from water
Culgoa–Bokhara (DRP1)	84.1	0.0
Warrambool–Moonie (DRP2)	100.0	0.0
Castlereagh–Barwon (DRP3)	36.5	20.6
Bogan–Macquarie (DRP4)	35.5	28.3
Louth Plains (DRP5)	56.5	0.4
Wilcannia Plains (DRP6)	48.4	4.0
Menindee (DRP7)	50.8	3.6
Great Darling Anabranch (DRP8)	62.9	1.8
Pooncarie–Darling (DRP9)	55.0	0.0

It is not possible to report change in watered area.

Weeds

Weeds known to occur in the bioregion include African boxthorn (*Lycium ferocissimum*), Athel pine (*Tamarix aphylla*), bitou bush (*Chrysanthemoides monilifera* subsp. *rotun*; in NSW), blackberry (*Rubus fruticosus*), mesquite (*Prosopis* spp.), mother of millions (*Bryophyllum tubiflorum* and hybrids), parkinsonia (*Parkinsonia aculeata*), broad leaf or tree privet (*Ligustrum lucidum*), silver leaf nightshade (*Solanum elaeagnifolium*), St Johns wort (*Hypericum perforatum*) and water hyacinth (*Eichhornia crassipes*).[37]

Components of total grazing pressure

Domestic stocking density

Eighty-eight per cent of the area of the Darling Riverine Plains bioregion was under pastoral land use in 1992, reducing to 80% in 2001. Based on Australian Bureau of Statistics (ABS)-sourced data and taking account of this reduced area, stocking density decreased from 11% above the 1983–91 average in 1992 to slightly below the 1983–91 base between 1993 and 2000 when mainly drier seasonal conditions prevailed (Figure 4.5). Stocking density then declined over the next three years to 75% of the base (in 2003). Stocking density increased slightly in 2004 to 77% of the 1983–91 average. Stocking density responded to *seasonal quality* but it is likely that expanded cropping also contributed to the overall decline in stocking density. Spatial averaging conceals likely variation in stocking density trends across the bioregion.

Kangaroo densities (Figure 4.6) were probably affected by changing seasonal conditions although this is not readily apparent from the graphed decile rainfalls. Contributing species to kangaroo density are reds, western and eastern greys.

Invasive animals

Invasive animal species known to occur in the bioregion include pig (*Sus scrofa*), goat (*Capra hircus*), fox (*Vulpes vulpes*), rabbit (*Oryctolagus cuniculus*), wild dog (*Canis lupus familiaris*), feral cat (*Felis catus*), starling (*Sturnus vulgaris*) and carp (*Cyprinus carpio*).[38]

37 See http://www.anra.gov.au

38 See http://www.anra.gov.au

Figure 4.5 Change in domestic stocking density (sheep and beef cattle) and *seasonal quality* as deciles of rainfall, Darling Riverine Plains bioregion

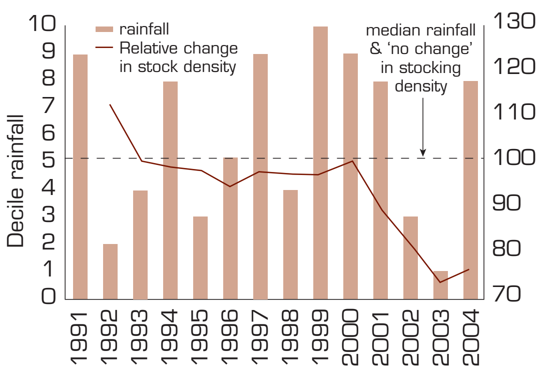
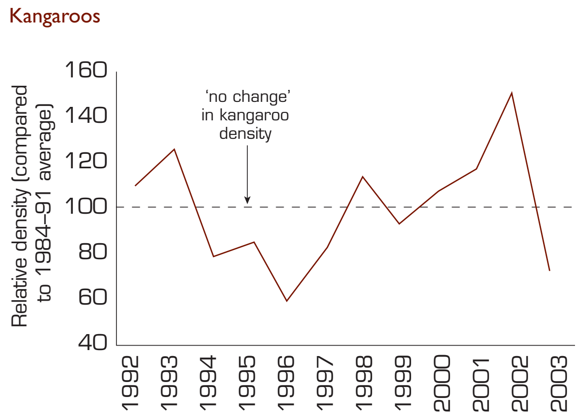


Figure 4.6 Kangaroo density, NSW component of the Darling Riverine Plains bioregion (DSEs)



Fire and dust

Fire

Fire was insignificant between 1997 and 2005 (the period of available data), with a maximum of 1.4% of the bioregion area burned in 2005.

The frequency of fire between 1997 and 2005 was very low compared with all rangeland bioregions (mean frequency ($\log_{10}$ transformed) = 0.07).

Dust

The mean DSI_3 value (1992–2005) was 1.40, a low value among all rangeland bioregions. Dust levels were lowest in the far northeast of the bioregion, near the NSW–Queensland border.

Biodiversity

There are Ramsar-listed wetlands in NSW and case studies of waterbirds (both components of the Biodiversity Working Group's indicator on wetlands).

Change in land use and land values

According to available National Land & Water Resources Audit (the Audit) data, 88% of the area of the Darling Riverine Plains bioregion was under pastoral land use in 1992, reducing to 80% in 2001.

Properties in the NSW part of the bioregion are relatively small compared with pastoral holdings in the northern, central and western parts of the rangelands. Based on all land parcels larger than 10 ha, average property size is 812 ha, with the largest holdings being greater than 30 000 ha (300 km^2). Most grazing enterprises are larger than 10 000 ha.

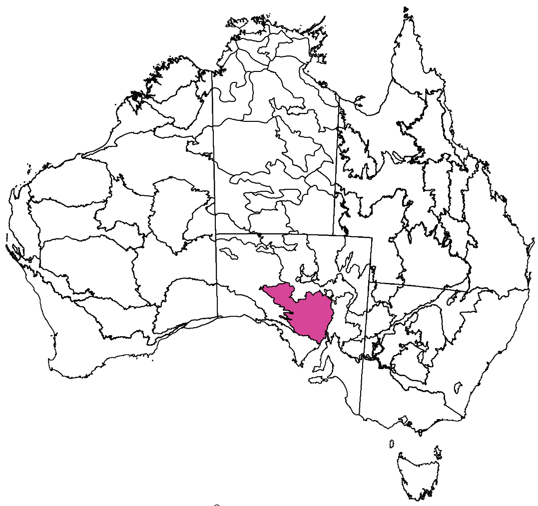
The market value of a typical (ie representative) property in the Brewarrina area increased by ~80% between 1996 and 2005 (values expressed in 2005 dollars).[39]

Gawler bioregion (SA)

The Gawler bioregion is in the southern central portion of the SA rangelands (Figure 4.7). Characteristic landscapes are rounded rocky hills, plains and salt-encrusted lake beds (Figures 4.8 and 4.9). Vegetation types include spinifex grasslands, open woodlands and chenopod shrubs. Sheep grazing and some cattle grazing are the most extensive industries (83% of bioregion area is pastoral lease), but mining (particularly copper, uranium and gold at Olympic Dam) provides the main source of revenue. Iron ore is also extracted in the Iron Knob area, opals at Andamooka and copper at Mt Gunson. Conservation reserves make up 12.9% of the bioregion and include Lake Torrens, Gawler Ranges and Lake Gairdner national parks, Lake Gilles Conservation Park, Lake Gilles Conservation Reserve and the sections of Yellabinna Regional Reserve that are in the bioregion. Tourism interest is focused on

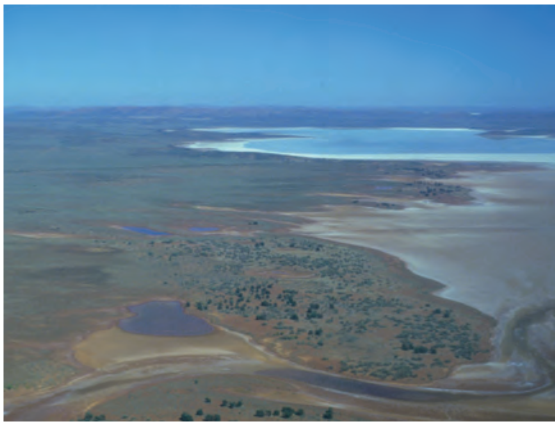
[39] See Table 16, 'Western grazing', at http://www.lands.nsw.gov.au/valuation/nsw_land_values for typical property values at other locations in the NSW Western Division.

Figure 4.7 Gawler bioregion, SA



Note: Area = 123 600 km^2

Figure 4.9 Lake Gairdner, Gawler bioregion



Lake Gairdner is a prominent lake in the Gawler bioregion. This photo is of the southeastern corner, looking west.

Photo: Peter Canty, SA Department for Environment and Heritage

the Gawler Ranges National Park, as well as on Olympic Dam and the Andamooka and Coober Pedy opal fields. Active Australian Defence Force and aerospace facilities are located at Woomera. Major population centres are Whyalla, Port Augusta, Roxby Downs and Woomera.

Regional issues

- The Gawler bioregion lacks landscape diversity, being dominated by chenopod shrublands and low woodlands. Sheep are the predominant species of livestock.

Figure 4.8 Rocky hills and shrubby plains of the Gawler bioregion

Photo: Pastoral Land Management Group, SA Department of Water, Land and Biodiversity Conservation

Figure 4.10 Change at a photopoint in the Gawler bioregion, 1955 to 1992

In 1955, the area had a reduced density of bluebush (*Maireana sedifolia*) as a result of high grazing pressure.

By 1992 there had been significant colonisation by valuable saltbushes (*Atriplex stipitata* and *A. vesicaria*).

Photos: Pastoral Land Management Group, SA Department of Water, Land and Biodiversity Conservation

- Some increases in woody cover are evident, possibly due to the effects of continual grazing pressure.
- There have been historically high levels of stocking.
- Available water supplies are fully exploited. Groundwater is limited in extent and is generally of poor to marginal quality.
- Rabbit numbers are recovering following the spread of rabbit haemorrhagic disease (calicivirus) in the 1990s.
- Feral goats persist in the more inaccessible areas.
- This region has the most extensive rangeland monitoring program in SA (Figure 4.10). The second round of condition assessments on pastoral leases is under way.

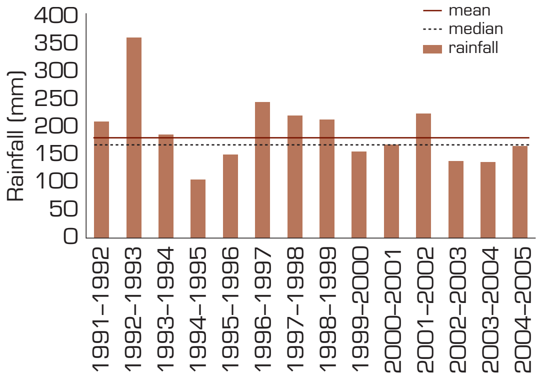
Further information relevant to recent changes within the Gawler bioregion is available in Della Torre (2005).

Seasonal quality — 1992–2005

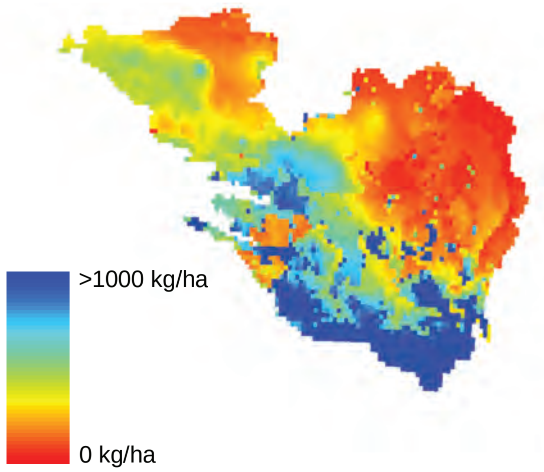
Rainfall was above the long-term (1890–2005) median for 8 of the 14 years between 1992 and 2005, and the period as a whole was better than many other 14-year periods since 1890 (Figure 4.11, left). The past 45 years have been generally wetter, apart from a return to more average *seasonal quality* in some years in the 1980s (Figure 4.11, left). For the 1992–2005 period, several years had better than the median rainfall, while 1994–95 was very dry. As in most bioregions, *seasonal quality* varied spatially across the Gawler bioregion in some years. This assessment of variability is based on simulated pasture biomass produced by AussieGRASS and 'season quality' derived from the NDVI[40] (Figure 4.11, right panels). Note that much of the south to north decrease in total standing dry matter is due to changing vegetation structure and composition with increasing aridity.

[40] See http://www.environment.gov.au/erin/ndvi.html.

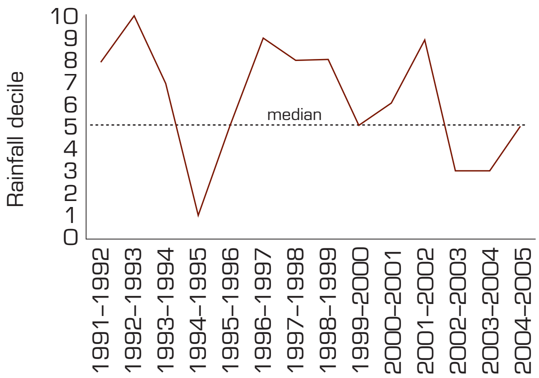
Figure 4.11 Indicators of *seasonal quality* for the Gawler bioregion

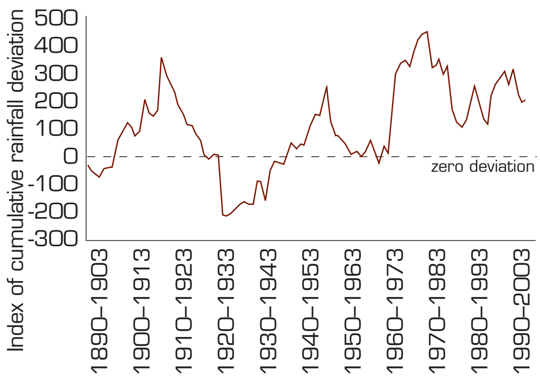


Annual rainfall. Long-term (1890–2005) mean and median

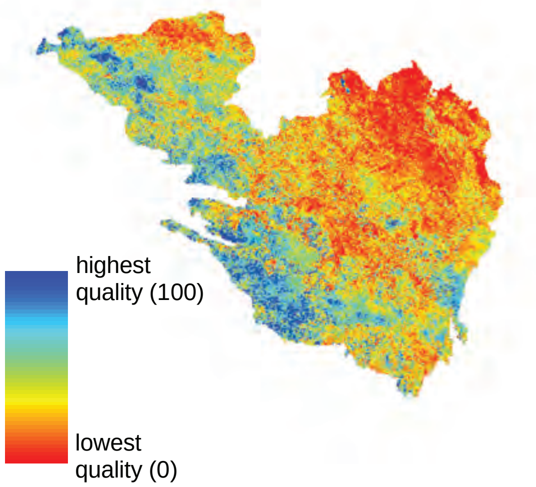


Aussie-GRASS simulated total standing dry matter — 1998





Cumulative percentage deviations of annual (April–March) rainfall from the long-term (1890–2005) median for all 14-year periods between 1890–1903 and 1992–2005



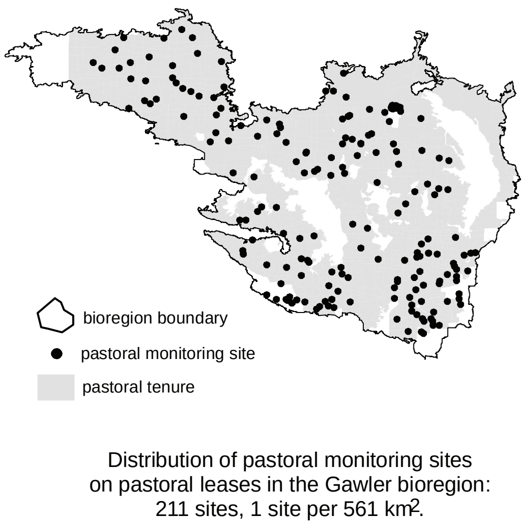
NDVI-based image of 'season quality' for 1998. Each pixel has a relative value according to the greeness of vegetation (ie photosynthetic activity)

Left: Rainfall

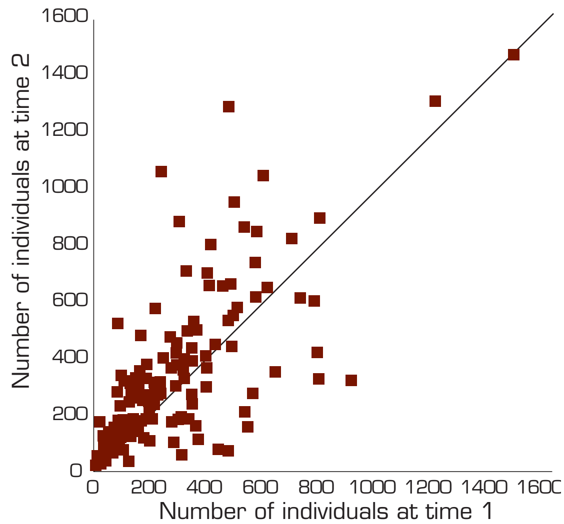
Right: Simulated pasture biomass and vegetation greenness (NDVI)

Note: Indicators are based on spatially averaged annual rainfall (April–March) between 1991–92 and 2004–05. For cumulative percentage deviations, periods below the dashed zero line indicate 14-year sequences with generally less rainfall (poorer *seasonal quality*). Periods above the dashed zero line indicate sequences of increased rainfall (better *seasonal quality*).

Figure 4.12 Pastoral monitoring sites and changes in landscape function, Gawler bioregion



Locations of pastoral monitoring sites



Changes in the density of perennial shrubs. Time 1 assessments made between 1990 and 2002, Time 2 assessments between 1994 and 2004. Sites plotting above the 1:1 (diagonal) line have increased shrub density, and inferred increased landscape function.

Table 4.5 Percentage of pastoral monitoring sites assessed following variable *seasonal quality* where there was a change in the density of decreaser perennial shrubs

Seasonal quality	Number of sites	Decline. Density <90%	No change. Density between 90% and 110%	Increase. Density ≥110%
Above average	107	16%	25%	59%
Average	56	21%	25%	54%
Below average	2	n.a.	n.a.	n.a.

n.a. = not applicable
Note: The light grey cell indicates a likely adverse effect related to grazing management.

Change in landscape function

Based on the density of longer-lived shrubs measured in fixed (Jessup) transects, ~60% of sites showed an increase in plant density (Figure 4.12), which is assumed to be an increase in landscape function. Taking account of seasonal conditions, 18% of 123 sites assessed following above-average rainfall showed reduced landscape function (ie improved landscape function would have been expected). Insufficient sites were assessed following below-average *seasonal quality* to report change.

There is a high degree of confidence in reporting change in landscape function for the Gawler bioregion: there is a good density of sites that are well distributed (Figure 4.12, left panel), shrub density reliably indicates landscape function in this environment, and quantitative recording methods ensure good repeatability among observers measuring sites.

Sustainable management

Change in critical stock forage

The density of perennial decreaser shrubs declined at 16% of sites following above-average *seasonal quality* (Table 4.5). Insufficient sites were assessed following below-average *seasonal quality* to report change at this time.

Table 4.6 Percentage of the pastoral lease area of each sub-IBRA within 3 km or beyond 8 km of stock water, Gawler bioregion

Sub IBRA	% sub IBRA area included	% area ≤3 km from stock water	% area >8 km from stock water
Myall Plains (GAW1)	77.7	69.4	2.4
Gawler Volcanics (GAW2)	87.3	52.5	8.2
Gawler Lakes (GAW3)	55.1	44.6	12.6
Arcoona Plateau (GAW4)	90.6	45.6	6.5
Kingoonya (GAW5)	89.3	30.2	15.2

Change in woody cover

Based on the Australian Greenhouse Office definition and mapping of forest extent[41], there is a very small area of forest in the Gawler bioregion and there was very little change in that area between 1991 and 2004. Forest cover increased from 1.90% of the bioregion area in 1991 to 2.09% in 2004, an increase of 0.19%. Reporting is based on analysis of Landsat data; there is high reliability in reporting results because complete coverage of satellite imagery was available.

Distance from stock water

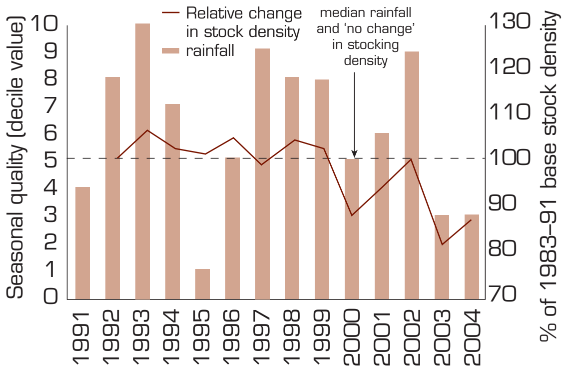
Eighty-three per cent of the Gawler bioregion is occupied as pastoral lease, and most of that area is within grazing distance of stock water (Table 4.6). The non-pastoral area in the Gawler bioregion consists mostly of salt lakes.

It is not possible to report change in distance from stock water for the 1992–2005 period.

Weeds

Weeds known to occur in the bioregion include African boxthorn (*Lycium ferocissimum*), African love grass (*Eragrostis curvula*), Athel pine (*Tamarix aphylla*), Bathurst burr (*Xanthium spinosum*), bridal creeper (*Asparagus asparagoides*), kochia (*Bassia scoparia*), mesquite (*Prosopis* spp.), Noogoora burr (*Xanthium occidentale*), pampas grass (*Cortaderia* spp.), parkinsonia (*Parkinsonia aculeata*), Patersons curse (*Echium plantagineum*), silver leaf nightshade (*Solanum elaeagnifolium*) and wild mignonette (*Reseda luteola*).[42]

Figure 4.13 Change in domestic stocking density (sheep and beef cattle), Gawler bioregion, 1991 to 2004



Note: *Seasonal quality* as deciles of rainfall is also shown.

Components of total grazing pressure

Change in domestic stocking density

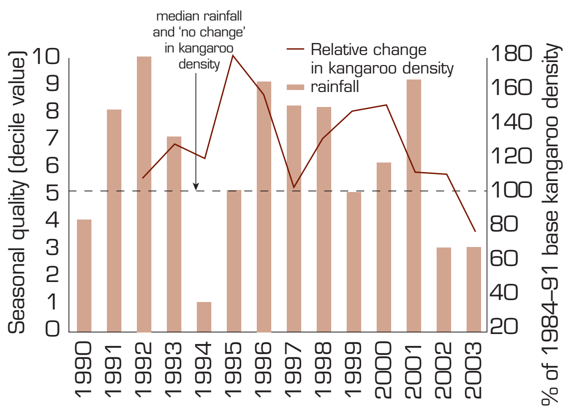
Fluctuations in stocking density, based on ABS-sourced data, are shown in Figure 4.13. The decline in the latter half of the reporting period was probably largely driven by declining *seasonal quality* (indicated here by rainfall deciles). It is probable that spatial variation in stocking density across the bioregion is concealed by the spatially averaged data presented here.

Change in kangaroo density

The combined density of red and western grey kangaroos (expressed as DSEs) fluctuated considerably throughout the 1992–2003 period (Figure 4.14). The initial increase and later decrease were related to *seasonal quality* and broadly correspond with the changes in domestic stocking density reported above.

41 See http://www.greenhouse.gov.au/ncas/reports/tech09.html.
42 See http://www.anra.gov.au

Figure 4.14 Change in kangaroo density, Gawler bioregion, 1990 to 2003



Invasive animals

Invasive animal species known to occur in the bioregion include goat (*Capra hircus*), fox (*Vulpes vulpes*), rabbit (*Oryctolagus cuniculus*), wild dog (*Canis lupus familiaris*), feral cat (*Felis catus*), starling (*Sturnus vulgaris*) and camel (*Camelus dromedarius*).[43]

Fire and dust

Fire

No fires were recorded in the bioregion for any year during the1997–2005 period.

Dust

Atmospheric dust levels based on the Dust Storm Index (DSI) were low to moderate compared with all rangeland bioregions (mean DSI_3 of 1.75 for 1992–2005, where the maximum value among all bioregions was 8.44). Dust levels were higher in the northeast part of the bioregion and negligible in the vicinity of Kingoonya.

Change in biodiversity

By 2005, there were over 200 bird records (Biodiversity Working Group indicator: Fauna surveys), over 200 flora survey sites and more than 200 flora records (Biodiversity Working Group Indicator: flora surveys) for the bioregion.

The bioregion has 8 plant, 3 mammal and 7 bird species and 1 species of reptile, amphibian or fish listed as threatened (Biodiversity Working Group indicator: Threatened species).

Change in land use and land values

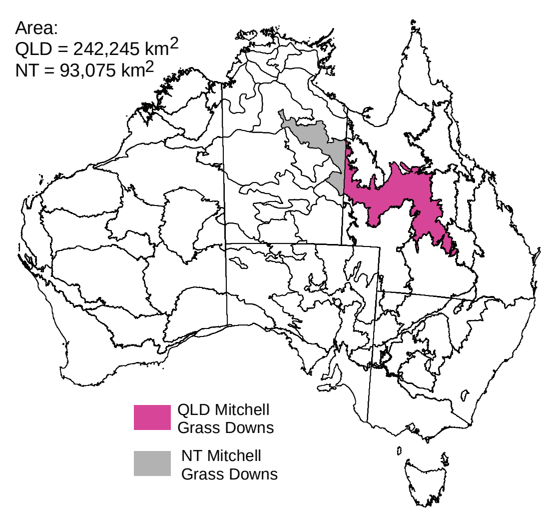
According to available NLWRA data, there was no change between 1992 and 2005 in the percentage area of the bioregion under pastoral land use (83%).

The unimproved value of pastoral land has increased, on average, by ~65% between 1998 and 2004 (values expressed in 2005 dollars).

Mitchell Grass Downs bioregion (Queensland and the NT)

The Mitchell Grass Downs bioregion extends across central Queensland into the NT (Figure 4.15). Reporting here is confined to the Queensland portion except where otherwise stated. The bioregion encompasses rolling, largely treeless, plains with cracking clay ('black') soils. The predominant vegetation is Mitchell grass tussock grassland with some low-tree overstorey of gidgee (*Acacia cambagei*) and other species (Figure 4.16). Most of the bioregion is under either leasehold or freehold tenure and is grazed by cattle and sheep. There has been a gradual movement out of woolgrowing in recent years. Major population centres are Longreach, Blackall and Hughenden.

Figure 4.15 Mitchell Grass Downs bioregion



[43] See http://www.anra.gov.au

Figure 4.16 Landscapes of the Mitchell Grass Downs bioregion, Queensland.

Central western Queensland Mitchell Grass Downs in a good season. The shrub is mimosa bush (*Acacia farnesiana*), which provides winter protein and shade.

And when it rains!

Photos: Queensland Department of Primary Industries and Fisheries

Regional issues

Regional issues in the Mitchell Grass Downs bioregion include:

- high levels of pasture utilisation (in two sub-IBRAs and in individual years), which have implications for persistence and recovery of palatable and productive perennial grasses
- Mitchell grass death, with areas of non-recovery to date
- pasture composition changes to more *Aristida* species
- increasing woody Weeds of National Significance (WoNS), particularly prickly acacia (*Acacia nilotica*)
- increasing cover of trees and shrubs in former grassland areas (eg mimosa and gundabluey).

Seasonal quality — 1992–2005

Annual rainfall, as an indicator of *seasonal quality*, was quite variable throughout the reporting period (Figure 4.17, left). The period from April 1998 to March 2001 was wetter (deciles 9 and 10 in terms of the 1890–2005 record). Rainfall was quite variable at other times. Several years in the 1990s and at the end of the reporting period had below-median rainfall. Despite these drier years, the 1992–2005 reporting period as a whole had a significantly positive cumulative rainfall deviation from the long-term median, and *seasonal quality* for the whole period was considerably better than for some other blocks of 14-year periods in the past (ie 1918 to 1940 and 1955 to 1973 were much drier periods than in the recent past).

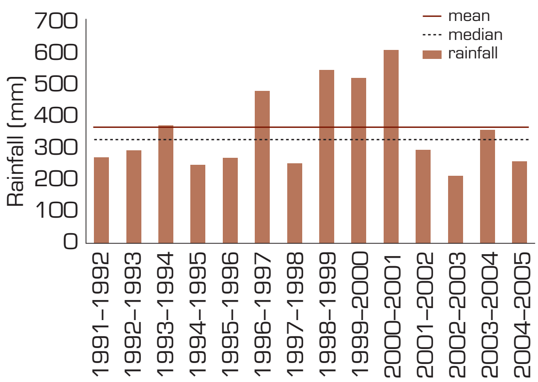
Spatial averaging of rainfall conceals spatial variation in *seasonal quality* for the Queensland portion of the bioregion. The variability shown for 1997 (as an example) was based on simulated pasture biomass produced by AussieGRASS and 'season quality' derived from the NDVI[44] (Figure 4.17, right panels).

Change in landscape function

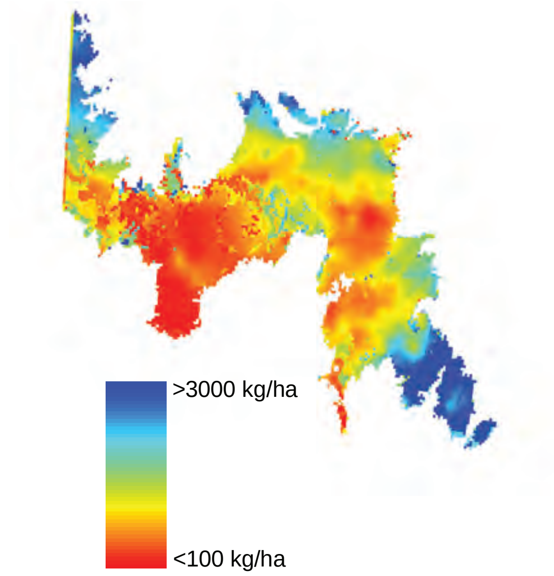
Landscape function declined across most of the bioregion between 1994 and 2005 (Figure 4.18), and significantly so in the Georgina Limestone sub-IBRA. The underlying data to support this assessment were extracted from the Rapid Mobile Data Collection database (Hassett et al 2006). These data were collected along repeat road traverses.

44 See http://www.environment.gov.au/erin/ndvi.html.

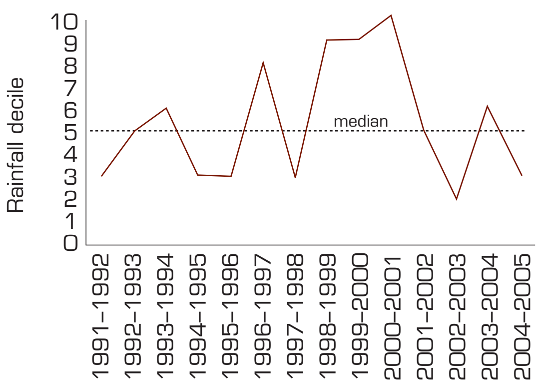
Figure 4.17 Indicators of *seasonal quality*, Mitchell Grass Downs bioregion



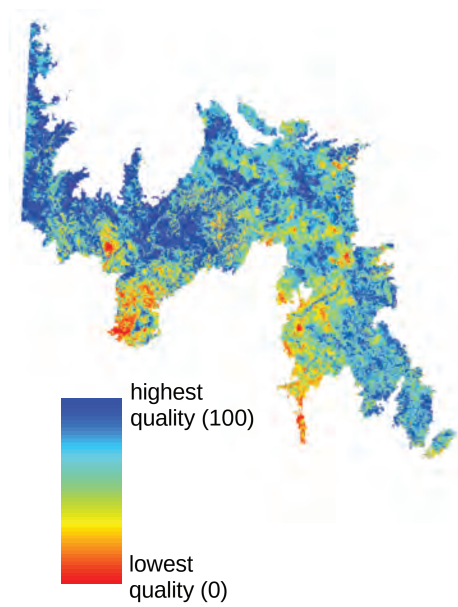
Annual rainfall. Long-term (1890–2005) mean and median



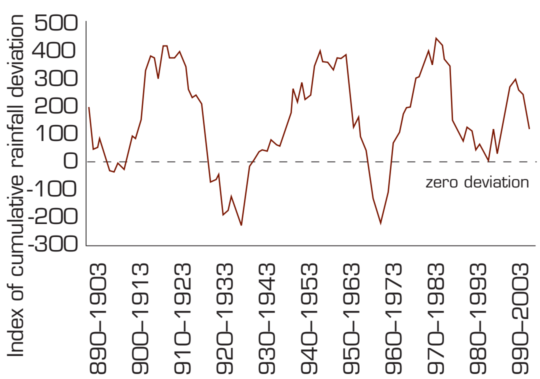
Aussie-GRASS simulated total standing dry matter - 1997



Annual rainfall as deciles of the long-term (1890–2005) rainfall



NDVI-based image of ‘season quality’ for 1997. Each pixel has a relative value according to the greeness of vegetation (ie photosynthetic activity)



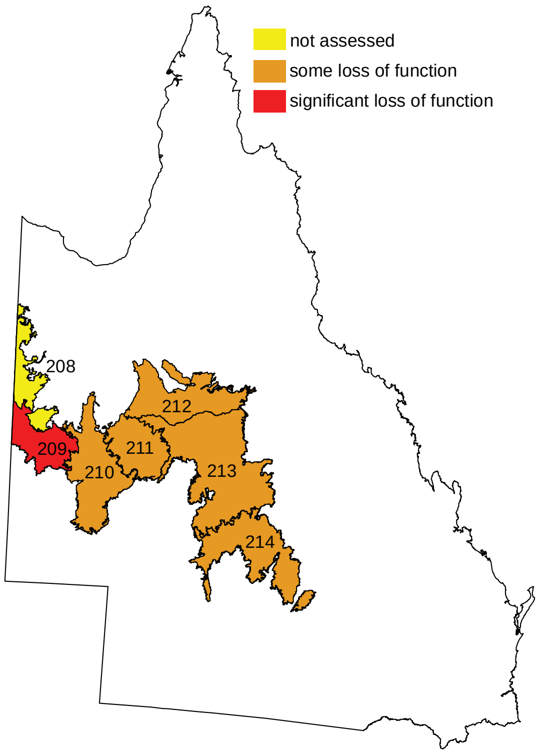
Cumulative percentage deviations of annual (April–March) rainfall from the long-term (1890–2005) median for all 14-year periods between 1890–1903 and 1992–2005

Left: Rainfall

Right: Simulated pasture biomass and vegetation greenness (NDVI)

Note: Indicators are based on spatially averaged annual rainfall (April–March) between 1991–92 and 2004–05. For cumulative percentage deviations, periods below the dashed zero line indicate 14-year sequences with generally less rainfall (poorer *seasonal quality*) and periods above the line indicate sequences of increased rainfall (better *seasonal quality*). All data are for the Queensland part of the bioregion.

Figure 4.18 Change in landscape function, Queensland sub-IBRAs of the Mitchell Grass Downs bioregion



Sub IBRA #	Name
208	Barkly Tableland
209	Georgina Limestone
210	Southwestern Downs
211	Kynuna Plateau
212	Northern Downs
213	Central Downs
214	Southern Wooded Downs

Note: Based on rapid mobile data collection

Source: Queensland Department of Natural Resources and Water.

This summarised reporting of change in landscape function is moderately reliable. Sub-IBRAs where change is reported were surveyed moderately intensively at various times between 1994 and 2005 by the same highly competent observer. Reliability is constrained because assessments were confined to paddock edges fringing roads, and because the index compiled from the available data has not yet been thoroughly tested for its robustness in indicating actual change in landscape function.

Sustainable management

Change in critical stock forage

Three sub-IBRAs (Georgina Limestone, Northern Downs and Barkly Tableland; Figure 4.19a, brightest green) had levels of AussieGRASS simulated annual pasture utilisation between 1991 and 2005 that were less than the specified safe threshold. The utilisation level for the Barkly Tableland sub-IBRA was considerably less than the threshold, implying relatively conservative (and sustainable) grazing management. The Kynuna Plateau and Southern Wooded Downs sub-IBRAs had the highest utilisation levels during the same period (27% and 26%, respectively, darkest green, Figure 4.19a). Those utilisations are at a level that causes loss of palatable perennial grasses and are of considerable concern. Average utilisation elsewhere (Southwestern Downs and Central Downs) was close to the safe threshold.

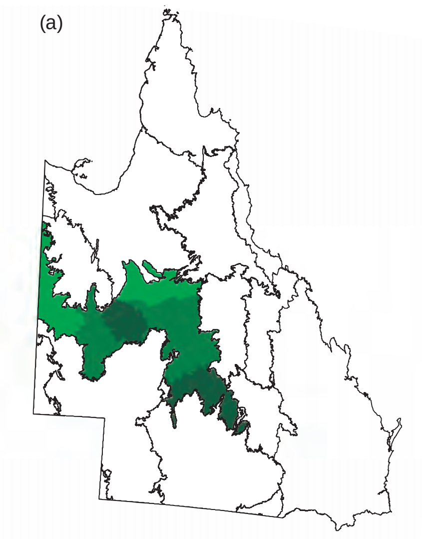
Time-averaged utilisation levels declined between 1976–90 and 1991–2005 in the Barkly Tableland, Northern Downs, Central Downs and Southern Wooded Downs sub-IBRAs (bright red in Figure 4.19b). The Georgina Limestone, Southwestern Downs and Kynuna Plateau sub-IBRAs had lesser decreases in average utilisation between the two periods and were assigned a neutral trend.

Combining the two maps shows that the Barkly Tableland and Northern Downs sub-IBRAs had lower (more conservative) levels of pasture utilisation in the 1991–2005 period and a decrease in mean utilisation between the 1976–90 and 1991–2005 periods (yellow in Figure 4.19c). This suggests that those two regions have the most sustainable management in terms of stock forage.

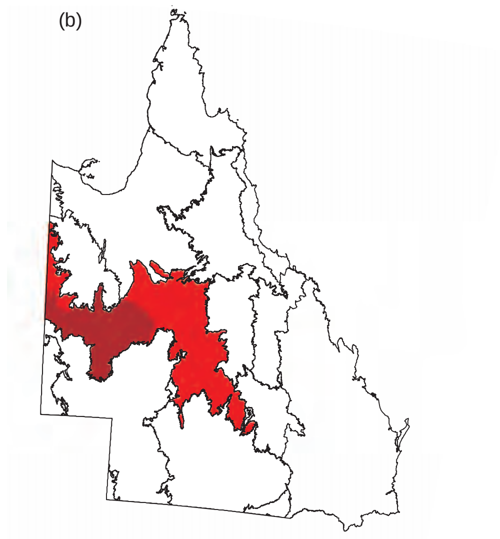
Change in woody cover

The SLATS data show that the Southern Wooded Downs sub-IBRA has relatively high woody cover compared to other regions (Table 4.7). This sub-IBRA also experienced the greatest area of clearing during the 1991–2003 period. By comparison, the Kynuna Plateau and Georgina Limestone sub-IBRAs have moderate levels of woody cover and have undergone little change. Remaining sub-IBRAs have low levels of woody cover that has changed little, apart from some clearing in the Central Downs sub-IBRA.

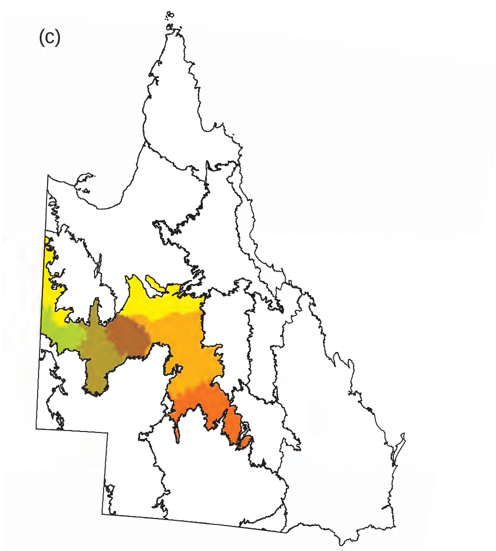
Figure 4.19 Change in stock forage, sub-IBRAs of the Mitchell Grass Downs bioregion



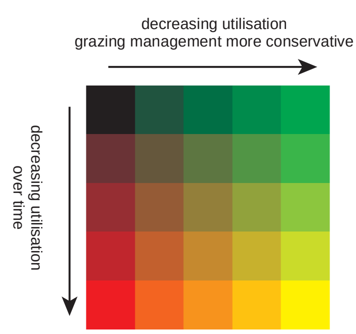
Sustainability of pasture utilisation based on Aussie-GRASS simulation for the 1991–2005 period. Increasing brightness of green means decreased utilisation relative to the safe threshold. Grazing is more conservative (ie sustainable).



Trend: ie change in mean level of pasture utilisation based on Aussie-GRASS simulation between1976–90and 1991–2005. Increased brightness of red means reduced average utilisation in the latter period.



Pasture sustainability and trend combined. Darker colours indicate high utilisation (relative to the safe threshold) and increased utilisation over time. Yellow indicates conservative grazing and decreased utilisation over time.



Colour scheme for interpreting sustainability of pasture utilisation and trend in sustainability

a: Sustainability of stock forage based on levels of pasture utilisation for the 1991–2005 period (increasing sustainability shown by increased brightness of green)

b: Degree of sustainability (ie change in utilisation) between the 1976–90 and 1991–2005 periods (decreasing utilisation shown by increased brightness of blue)

c: Combined sustainability and trend information. Darker coloured sub-IBRAs represent a low level of sustainability and increased utilisation; green indicates sustainable utilisation but a trend towards reduced sustainability (increased utilisation); red shows low sustainability and improving trend (decreased utilisation); yellow depicts sub-IBRAs with both sustainable and decreasing utilisation (ie improving trend).

Note: Based on AussieGRASS simulation of pasture utilisation. Utilisation levels were space- and time-averaged for the two periods: 1976–1990 and 1991–2005.

Table 4.7 Percentage change in woody cover for Queensland sub-IBRAs of the Mitchell Grass Downs bioregion

Sub-IBRA	SLATS woody cover 1991	SLATS woody cover 2003	Change 1991–2003	Cumulative clearing, 1991–2003
Southern Wooded Downs	29.96	26.15	–3.81	4.61
Kynuna Plateau	17.28	17.08	–0.20	0.25
Georgina Limestone	14.89	14.89	0.00	0.00
Central Downs	8.31	7.42	–0.89	1.03
Northern Downs	6.20	5.92	–0.28	0.31
Southwestern Downs	3.85	3.84	–0.01	0.01
Barkly Tableland	3.65	3.64	–0.01	0.00

Source: SLATS data

Table 4.8 Percentage of sub-IBRA area within 3 km and beyond 8 km of permanent and semipermanent sources of stock water, Mitchell Grass Downs bioregion

Sub IBRA	% of sub IBRA area <3 km from water	% of sub IBRA area >8 km from water
Southern Wooded Downs	85.9	0.0
Central Downs	82.5	0.0
Northern Downs	67.0	0.5
Kynuna Plateau	34.5	11.3
Barkly Tableland	31.6	4.6
Southwestern Downs	29.2	14.1
Mitchell Grass Downs P1	25.8	7.2
Georgina Limestone	16.9	30.9

Distance from stock water

Table 4. 8 shows the percentage of sub-IBRA area within 3 km and beyond 8 km of permanent and semipermanent sources of stock water. Waterpoint data (bores and dams) were obtained from Geoscience Australia's Geodata Topo 250K vector product (Series 3, June 2006).

Areas more than 8 km from stock water are less likely to be grazed by cattle and are beyond the normal grazing range of sheep. This analysis does not include the locations of natural waters or bore drains, the latter being a very significant source of stock water across much of the bioregion. Thus, the percentage area within 3 km of stock water for some sub-IBRAs is probably significantly understated and the proportion beyond 8 km may be overstated.

It is not possible to report change in watered area. This is a significant issue in parts of Queensland where numerous formerly free-flowing bores (and their associated bore drains) now have controlled flows and water is now reticulated by polythene pipe, tanks and troughs.

Weeds

Weeds known to occur in the Queensland part of the bioregion include Athel pine (*Tamarix aphylla*), mesquite (*Prosopis* spp.), parkinsonia (*Parkinsonia aculeata*), prickly acacia (*Acacia nilotica*) and rubber vine (*Cryptostegia grandiflora*).[45]

Components of total grazing pressure

Change in domestic stocking density

Based on ABS-sourced data, relative stocking density in the Queensland part of the Mitchell Grass Downs bioregion was initially (until 1997) in line with generally

[45] See http://www.anra.gov.au

deteriorating *seasonal quality* (Figure 4.20). Stock numbers then increased appreciably between 1999 and 2001 during wetter years and then declined markedly with drier years in 2002 and 2003. Spatial averaging conceals likely variation in stocking density trends across the bioregion.

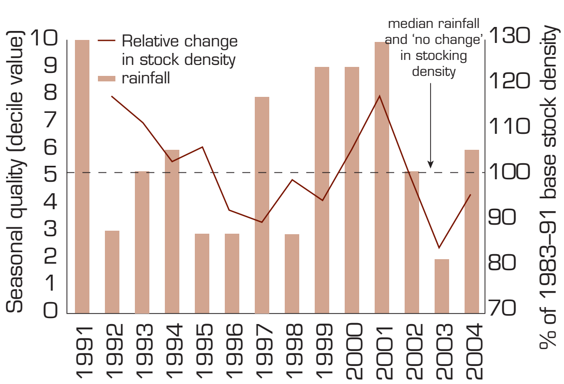
Kangaroo density

Kangaroo density data are available for all or most of the Southern Wooded Downs, Central Downs, Northern Downs and Kynuna Plateau sub-IBRAs. The relative density of red and eastern grey kangaroos (combined and expressed in DSEs) decreased, in a fluctuating manner, between 1993 and 1997 (Figure 4.21). It then increased rapidly and markedly to 2000 (>1.5 times the 1984–91 average) before decreasing in the early years of this decade, particularly due to poorer *seasonal quality* in 2002 and 2003 (see Figure 4.17).

Invasive animals

Invasive animal species known to occur in the Queensland part of the Mitchell Grass Downs bioregion include pig (*Sus scrofa*), goat (*Capra hircus*), deer (*Cervidae* spp.), fox (*Vulpes vulpes*), rabbit (*Oryctolagus cuniculus*), wild dog (*Canis lupus familiaris*), feral cat (*Felis catus*), starling (*Sturnus vulgaris*) and cane toad (*Bufo marinus*).[46]

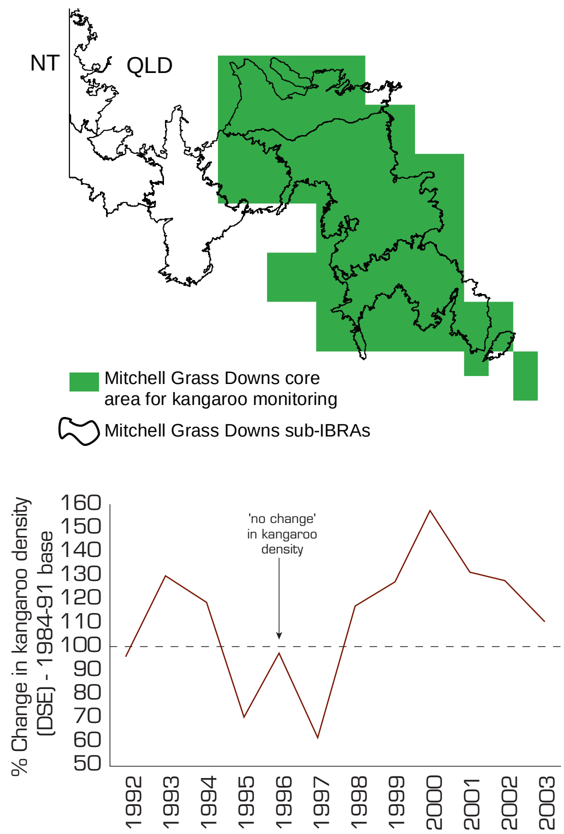
Figure 4.20 Change in domestic stocking density (sheep and beef cattle), Queensland part of the Mitchell Grass Downs bioregion, 1991 to 2004



Note: *Seasonal quality* as deciles of rainfall is also shown.

46 See http://www.anra.gov.au

Figure 4.21 Change in kangaroo density, Mitchell Grass Downs bioregion, 1992 to 2003, relative to the average density for 1984–91 (DSE basis)



Note: Density data (bottom) are for the Mitchell Grass Downs core monitoring area (shown in green above).

Fire and dust

Fire

Fire was generally insignificant: less than 1% of the whole bioregion area burned each year between 1998–2000 and 2002–05. Fire was a feature in 2001, when 5.5% of the entire bioregion burned following three wetter years (Figure 4.17). However, extensive wildfires appear to have been confined to sub-IBRAs predominantly in the NT. Apart from 3.1% of the Central Downs sub-IBRA burning in 1997, other Mitchell Grass Downs sub-IBRAs exclusively in Queensland had less than 0.5% of their area burned in any year between 1997 and 2005.

Figure 4.22 Pitfall and funnel trapping — part of a fauna survey in the Mitchell Grass Downs bioregion, Queensland

Photo: Teresa Eyre, Queensland Environmental Protection Agency

Dust

The mean DSI_3 value (1992–2005, entire bioregion) was 1.69, a low to moderate value among all rangeland bioregions (maximum value, 8.44). Dust levels were higher in the central portion of the bioregion (Barkly Tableland sub-IBRA in the vicinity of the NT–Queensland border, Georgina Limestone and Southwestern Downs sub-IBRAs). Dust levels were negligible further into the NT and were low in the far east of the bioregion (Central Downs and Southern Wooded Downs sub-IBRAs).

Change in biodiversity

Fauna and flora surveys have been conducted across much of the bioregion (Figure 4.22). Under the Biodiversity Working Group indicator: Threatened species (for the entire bioregion), there are:

- 12 threatened plant species
- 8 threatened mammal species (which includes two extinct species, the desert rat-kangaroo and the lesser stick-nest rat); also included in the list is the western quoll, which is listed as vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999*, but is extinct in this bioregion
- 9 threatened bird species
- no threatened reptile or amphibian species
- 2 threatened fish species.

Fifty-four regional ecosystems have been described for Queensland sub-IBRAs of the Mitchell Grass Downs bioregion. Under the *Vegetation Management Act 1999* (Qld), four of them are listed as 'of concern' and one is listed as endangered. For two of these regional ecosystems, less than 10% of their pre-clearing distributions are currently represented in reserves (Accad et al 2006) (Biodiversity Working Group indicator: Threatened communities). Descriptions of regional ecosystems are available at the Queensland Environmental Protection Agency website.[47]

47 http://www.epa.qld.gov.au/nature_conservation/biodiversity/regional_ecosystems/how_to_download_REDD/

Change in land use and land values

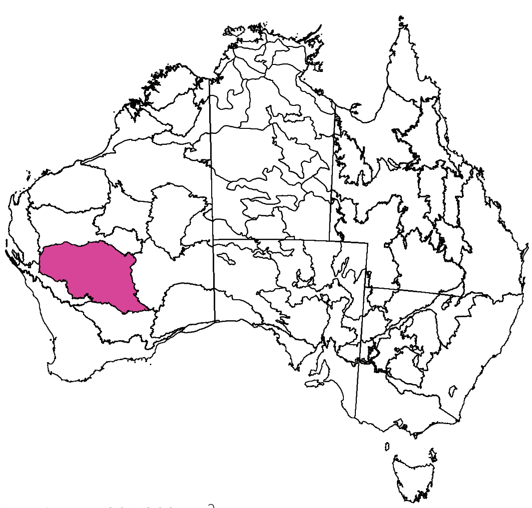
Ninety-six per cent of the entire bioregion area is under pastoral land use. There was no significant change in this area over the 1992–2005 reporting period.

For the Queensland Mitchell Grass Downs, unimproved rangeland values at June 2006 were, on average, $4792 ± $261/km^2 (2005 dollars). There was a large range in average unimproved value across sub-IBRAs ($333/km^2 to $6668/km^2). It is not possible to report change in land values.

Murchison bioregion (WA)

The Murchison bioregion encompasses much of the mulga country in the southern rangelands of WA (Figure 4.23) and is 281 200 km^2 in area. The climate is arid with predominantly winter rainfall. Landscapes comprise low hills and mesas separated by flat colluvium and alluvial plains. Mulga low-woodlands dominate. Other vegetation types include saltbush shrubland on calcareous soils, saline areas with samphire, and hummock grassland on red sandplain. The Murchison is one of the main pastoral (sheep and cattle) areas in WA, but mining (gold, iron and nickel) contributes more to the region's economy. Major population centres are Meekatharra, Leonora, Cue and Mount Magnet.

Figure 4.23 Murchison bioregion, WA

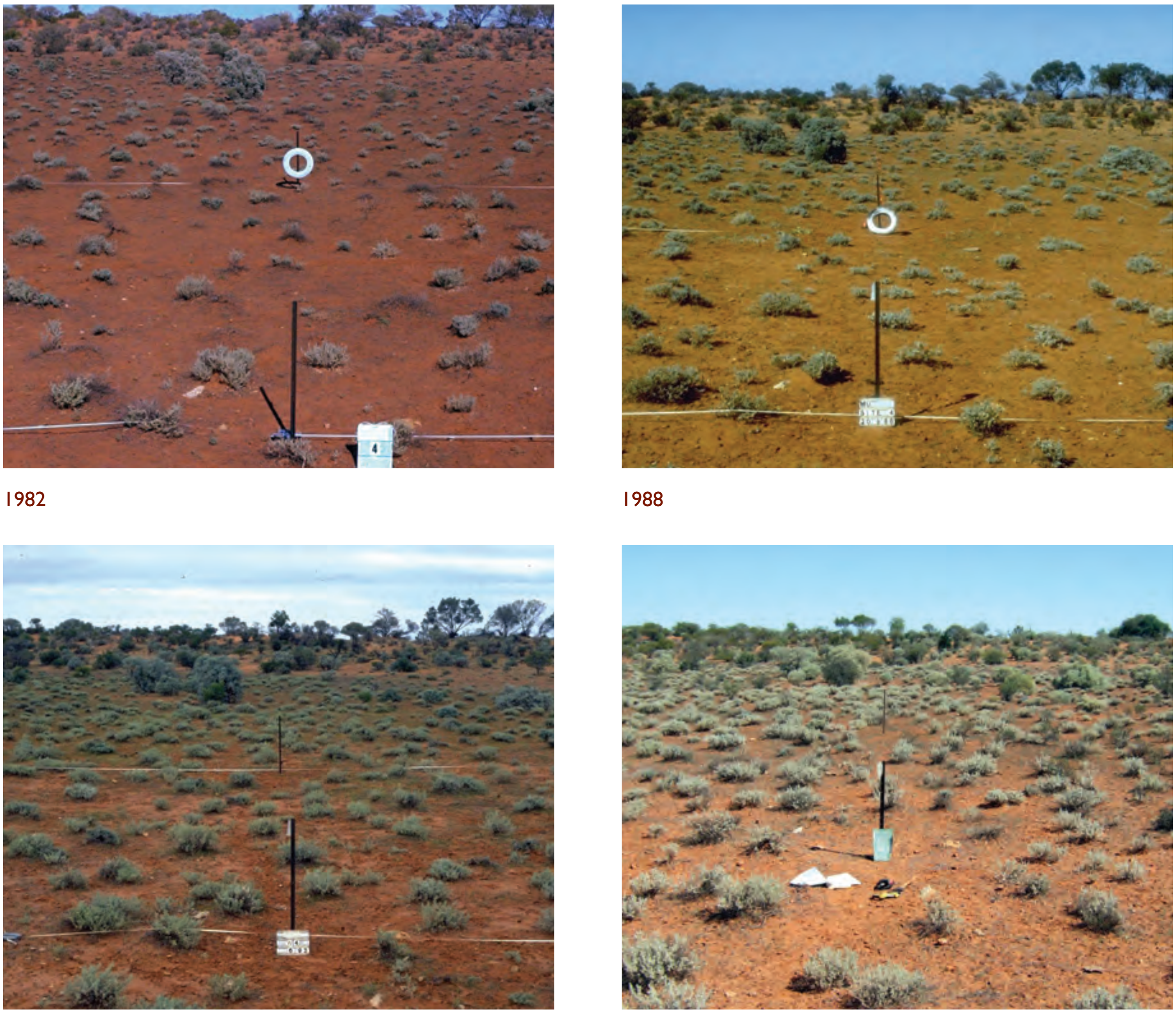


Note: Area = 281 200 km^2

Regional issues

- Over approximately the past decade, the cover and density of shrubs and trees on Western Australian Rangeland Monitoring System (WARMS) sites increased. At other sites, cover and density remained stable (Figure 4.24).
- In general, grazing-sensitive species were not adversely affected on WARMS sites. However, on sites where overall decline was observed, the decline was greatest for grazing-sensitive species.
- Species richness of native shrubs (all species) on WARMS sites increased slightly.
- The apparent positive trends provided by WARMS data apply at a site level. Ecosystem Management Understanding (EMU) Project data, collected at the landscape to patch scale by Pringle et al (2006), generally contradict those findings and conclude that increased erosion, hydrological dysfunction and habitat homogenisation are increasing features of the bioregion.
- About 6% of the pastoral leases are under Indigenous ownership and 22% are under mining company ownership, and are either destocked or running low numbers of livestock.
- There has been a strong trend in enterprise type away from merino sheep to cattle, meat sheep (Figure 4.25) and rangeland goats. This is due to low wool prices, high meat prices, difficulty in finding labour for wool enterprises and wild-dog predation on sheep. Infrastructure on many stations, especially fencing, is not being maintained. This is partly the result of the move away from merino sheep. The region has also seen a large increase in the number of self-mustering yards (Figure 4.26), which enable total grazing pressure (TGP) to be better managed as well as decreasing mustering and labour costs.
- An increasing percentage of pastoralists expect to earn significant off-station income, principally from supporting the mining industry. Many leases are unviable as pastoral enterprises on their own.
- Unmanaged goats contribute a large proportion of the TGP and landscape degradation, but their contribution to station income can be high. A large number of trap yards have been built in the

Figure 4.24 WARMS site in the Murchison bioregion, showing little change from 1982 to 2006



1982 | 1988 | 1993 | 2006

Most of the low vegetation is either bladder saltbush (*Atriplex vesicaria*) or low bluebush (*Maireana platycarpa*). Both species are decreasers and are preferentially grazed by livestock.

Photos: WA Department of Agriculture and Food

past 10 years as a way of lowering the cost of mustering and for better control of TGP (Figure 4.26).

- Wild dog numbers and their impacts have increased markedly in recent years.
- There has been an expansion of mining interest to banded ironstone ranges in recent years. This is significant for conservation, as those systems are highly restricted in area and frequently support endemic biota or assemblages.
- Sandalwood harvesting persists as an industry but will be unsustainable in the longer term if lack of recruitment cannot be addressed.
- About 6.7% of the region is within the conservation estate, but that proportion is inadequate under the principles of CAR (comprehensiveness, adequacy and representativeness).
- More than 40% of the original mammal fauna is now regionally extinct, including almost all medium weight-range species.

Figure 4.25 Dorper and damara meat sheep

Dorpers

Damaras

Photos: Mark Alchin, WA Department of Agriculture and Food

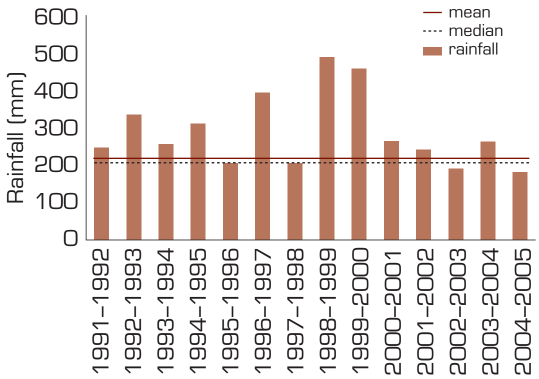
Figure 4.26 Feral goats mustered in a trap yard to help control total grazing pressure

Photo: Mark Alchin, WA Department of Agriculture and Food

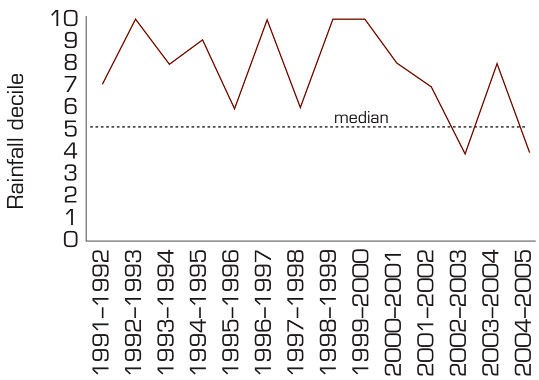
- Three mammals, three birds and one reptile are listed as vulnerable, and one reptile is listed as endangered. Three species of plant are listed as declared rare flora and many more have priority status, although most of them have not been studied well enough to determine their current condition and trend.
- As long as goats remain unmanaged, they will continue to be one of the more significant threats to biodiversity conservation through broadscale impacts on vegetation associations, cascading influences on landscape function, and grazing of environmentally sensitive sites.
- Although there are no formally listed threatened ecosystems, more than 52 vegetation associations and community types are considered to be at risk from grazing, changed fire regimes and other factors.
- The average 'lease and improvement' value of pastoral land in the Carnarvon–Gascoyne–Murchison region increased by 230% over the period from 1992 to 2005.
- The mid-to-late 1990s was an exceptional sequence of above-average years, particularly in summer rainfall. For part of the bioregion, the period since mid-2001 has been dry.
- The western and southern parts of the region were declared for Exceptional Circumstances drought relief in 2003. Some areas had this declaration extended in 2006.

Further information relevant to recent change in the Gascoyne–Murchison region (which includes the Murchison bioregion) is available in Watson et al (2005b).

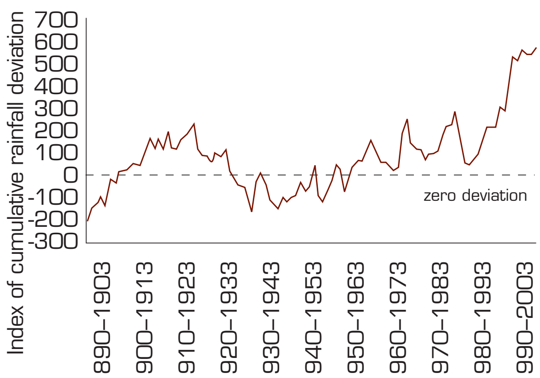
Figure 4.27 Indicators of *seasonal quality*, Murchison bioregion



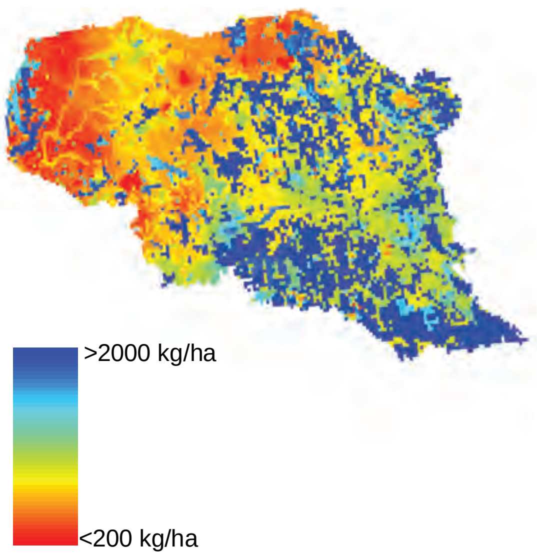
Annual rainfall. Long-term (1890–2005) mean and median rainfalls are also shown



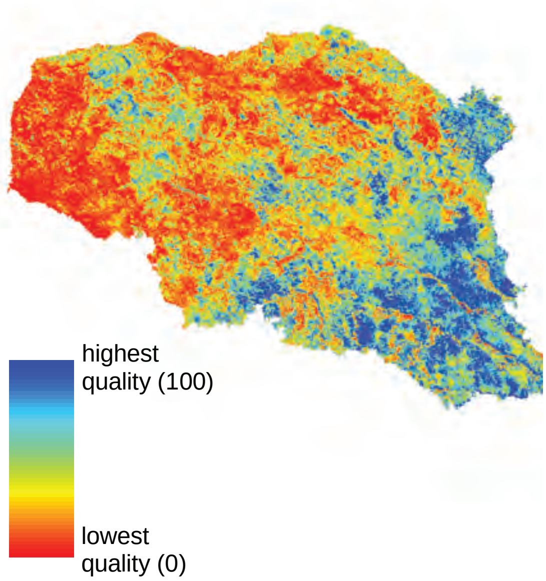
Annual rainfall as deciles of the long-term (1890–2005) rainfall



Cumulative percentage deviations of annual (April–March) rainfall from the long-term (1890–2005) median for all 14-year periods between 1890–1903 and 1992–2005



Aussie-GRASS simulated total standing dry matter — 2001



NDVI-based image of 'season quality' for 2001. Each pixel has a relative value according to the greeness of vegetation (ie photosynthetic activity)

Left: Rainfall

Right: Simulated pasture biomass and vegetation greenness (NDVI)

Note: Indicators are based on spatially averaged annual rainfall (April–March) between 1991–92 and 2004–05. For cumulative percentage deviations, periods below the dashed zero line indicate 14-year sequences with generally less rainfall (poorer *seasonal quality*) and periods above the line indicate sequences of increased rainfall (better *seasonal quality*).

Seasonal quality — 1992–2005

Rainfall was above average for most years, and the 1992–2005 period as a whole was generally wetter than all other 14-year periods since 1890 (Figure 4.27, left panel). Notwithstanding this, the spatial pattern of simulated pasture biomass produced by AussieGRASS and 'season quality' derived from the NDVI show that there was considerable regional variation in some years (Figure 4.27, right panel); that is, some parts of the region were much drier than others (and not all parts can be considered to have had such a good run of seasons).

Change in landscape function

Change in landscape function at the site scale can be reported in a number of ways using WARMS data. Here, we report on the basis of the Resource Capture Index (RCI) and shrub density (Figure 4.28, the latter for consistency with reporting by other jurisdictions).

WARMS data have high reliability for each site: there are many well-distributed sites in selected parts of the landscape; quantitative data are collected; the focus is on longer-lived plant species, which helps to filter short-term seasonal variability; and both indices (RCI and shrub density) usefully indicate landscape function. WARMS sites report change for the local areas they represent and should not be considered as representing the entire landscape (Pringle et al 2006).

Shrub density

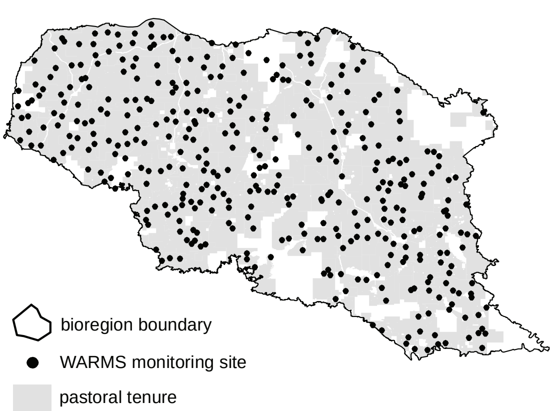
Based on the density of long-lived perennial plants recorded at WARMS monitoring sites, landscape function at those sites generally improved

Table 4.9 Seasonally interpreted change in landscape function at WARMS sites in the Murchison bioregion, based on change in density of longer-lived perennial vegetation

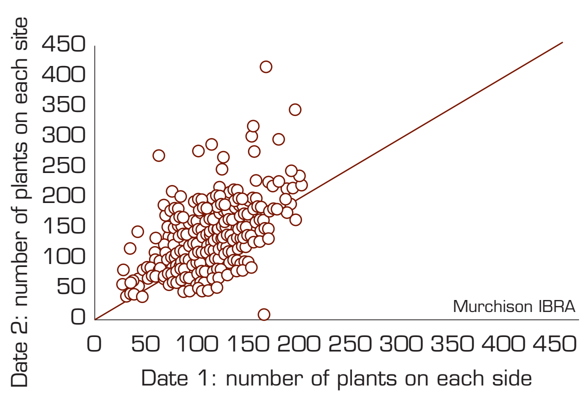
Seasonal quality	Number of sites	Decline. Density <95%	No change. Density between 95% and 105%	Increase. Density >105%
Above average	157	14%	15%	71%
Average	167	30%	23%	47%
Below average	62	60%	19%	21%

Note: The light grey cell indicates a likely adverse effect related to grazing management, in that no change or an increase in the landscape function indicator would be expected following above-average *seasonal quality*. The grey cell represents an encouraging result, as a decrease in landscape function would be expected following poor seasonal conditions.

Figure 4.28 Changes in landscape function, Murchison bioregion



WARMS sites used to report changes in landscape function



Changes in density of long-lived perennial plants

Table 4.10 Seasonally interpreted change in landscape function at WARMS sites in the Murchison bioregion, based on change in the Resource Capture Index (RCI)

Seasonal quality	Number of sites	Decline. RCI < 0.90	No change. 0.90 ≥ RCI <1.10	Increase. RCI ≥ 1.10
Above average	94	60%	9%	32%
Average	141	55%	15%	30%
Below average	62	68%	11%	21%

Note: See Table 4.9 for an explanation of cell colours.

Table 4.11 Seasonally interpreted change in critical stock forage at WARMS sites in the Murchison bioregion

Seasonal quality	Species group	Number of sites	Decline. Density < 0.95	No change. 0.95 ≤ density < 1.05	Increase. Density ≥ 1.05
Above average	Decreaser	153	17%	11%	73%
	Intermediate	151	16%	19%	65%
	Increaser	74	7%	36%	57%
Average	Decreaser	165	33%	20%	47%
	Intermediate	166	25%	31%	44%
	Increaser	108	12%	34%	54%
Below average	Decreaser	61	67%	10%	23%
	Intermediate	58	45%	34%	21%
	Increaser	43	28%	33%	40%

Notes: Critical stock forage is based on the frequency of decreaser species. See Table 4.9 for an explanation of cell colours.

(Figure 4.28), in that there was a higher population at the second assessment (1999–2005) at most sites compared with the initial assessment (1993–2001).

Fourteen per cent of sites showed a decline in the density of longer-lived perennial vegetation when *seasonal quality* was above average, and 21% of sites showed improvement when *seasonal quality* was below average (Table 4.9). Interpretation of these seasonally adjusted changes would be enhanced with knowledge of the grazing pressure exerted at each site, but stocking density data at that resolution are not available. Regional livestock numbers decreased between 1998 and 2004, particularly in the west, in response to poorer *seasonal quality* (see Figure 4.29). However, data are lacking on TGP, particularly for feral goats and kangaroos. It is not possible to convert regional livestock trends to an estimate of stocking density at WARMS sites.

Resource Capture Index

Sixty per cent of sites showed a decline in the RCI when *seasonal quality* was above average, and 21% of sites showed an improvement when *seasonal quality* was below average (Table 4.10).

Sustainable management

Change in critical stock forage

The density of long-lived decreaser shrubs declined at 17% of sites following above average *seasonal quality* (Table 4.11). The density of decreaser shrubs increased at 23% of sites following below-average *seasonal quality*.

Native shrub species richness

The richness of native shrub species recorded at WARMS sites provides insight into one aspect of sustainable management: a greater diversity of species provides increased grazing choice for sheep

Table 4.12 Seasonally interpreted change in native-shrub species richness at WARMS sites in the Murchison bioregion

Seasonal quality	Number of sites	Decline. Richness index < 0.80	No change. 0.80 ≤ Richness index < 1.20	Increase. Richness index ≥ 1.20
Above average	157	3%	67%	31%
Average	167	3%	83%	14%
Below average	62	5%	81%	15%

Note: See Table 4.9 for an explanation of cell colours.

Table 4.13 Percentages of pastoral lease area of each sub-IBRA within 3 km and beyond 8 km of permanent or semipermanent sources of stock water, Murchison bioregion

Sub IBRA	% sub IBRA area included	% area ≤3 km from stock water	% area >8 km from stock water
Eastern Murchison (MUR1)	78.3	38.3	11.1
Western Murchison (MUR2)	90.9	48.6	0.3

or cattle and improved ecosystem health. Based on 386 sites, the average ratio of species richness at first assessment (December 1993 to April 2001) to richness at second assessment (September 1999 to November 2005) was 1.08 ± 0.01 (SE). Three per cent of sites had decreased species richness following above average *seasonal quality*, whereas 15% had increased species richness following below-average *seasonal quality* (Table 4.12).

Change in woody cover

Based on WARMS data, cover of woody species increased on average by 28% and remained the same or increased on most sites (68%). On only 3% of sites did cover drop below 50% of the initially recorded value. These results were similar whether large overstorey species were considered or not. Much of the increase in canopy area was driven by *seasonal quality*. Canopy area decreased markedly for those sites that experienced below-average seasonal conditions.

Distance from water

Based on the locations of stock water sources (derived from WA mapping of lease infrastructure), Table 4.13 lists the percentages of pastoral lease areas within each sub-IBRA that are less than 3 km and more than 8 km from waterpoints (water-remote). The Western Murchison sub-IBRA had almost no areas remote from water.

These analyses do not include the locations of ephemeral natural waters, which can provide additional sources of water for stock, particularly in the early dry season.

It is not possible to report change in watered area for the 1992–2005 period.

Weeds

Weeds known to occur in the bioregion include African boxthorn (*Lycium ferocissimum*), Patersons curse (*Echium plantagineum*), Bathurst burr (*Xanthium spinosum*), mesquite (*Prosopis* spp.) and Mexican poppy (*Argemone ochroleuca*).[48]

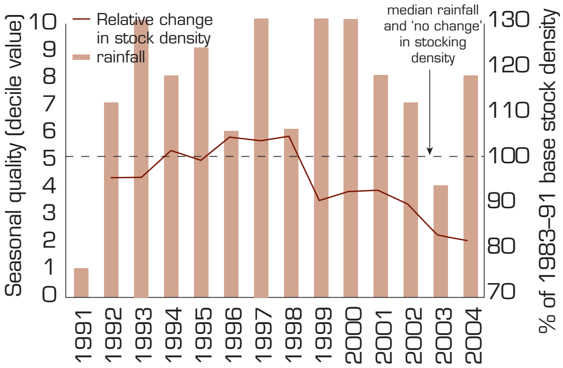
Components of total grazing pressure

Domestic stocking density

Eighty-eight per cent of the Murchison bioregion was pastoral land in the period from 1992 to 2001, reducing to approximately 83% of the bioregion in 2005. Based on ABS-sourced data and taking account of the reduction in grazed area, domestic stocking

48 See http://www.anra.gov.au

Figure 4.29 Changes in domestic stocking density (sheep and beef cattle), Murchison bioregion, 1991 to 2004



Note: *Seasonal quality* as deciles of rainfall is also shown.

density was slightly above the 1983–91 average between 1996 and 1998 but decreased sharply in 1999 and then decreased further by 2003 and 2004 (Figure 4.29). The decrease reflects destocking of leases in the western part of the bioregion from 1999–2000 onwards as drought set in. All but the eastern parts of the region were drought declared in 2003. For some areas, this declaration was extended in 2006. Spatial averaging of stocking density across the large extent of this bioregion conceals variation in actual stocking density in parts of the region.

Feral goats contribute significantly to TGP in some parts. There are insufficient reliable data to report goat numbers or their change in density through the 1992–2005 reporting period.

Kangaroos

No suitable data are available to report change in kangaroo density.

Invasive animals

Invasive animal species known to occur in the bioregion include goat (*Capra hircus*), fox (*Vulpes vulpes*), rabbit (*Oryctolagus cuniculus*), wild dog (*Canis lupus familiaris*), feral cat (*Felis catus*), camel (*Camelus dromedarius*), donkey (*Equus asinus*), horse (*Equus caballus*) and feral sheep (*Ovis* spp.).[49]

[49] See http://www.anra.gov.au

Fire and dust

Fire

Fire was insignificant, with a maximum of 1.9% of the bioregion area burned in both 2000 and 2001. Based on the month of burn, fires between 1997 and 2005 were of both hot and cool types; both types occurred each year to varying extents. The frequency of fire between 1997 and 2005 was insignificant; the mean frequency ($\log_{10}$ transformed) was 0.03.

Absence of fire under present-day pastoral management may also be significant, as there may be many plant associations that would have burned under non-pastoral regimes but now rarely burn.

Dust

Atmospheric dust levels based on the DSI were relatively low (mean DSI_3 of 1.43 for the 1992–2005 period, in which the maximum value for all bioregions was 8.44). The spatial distribution map (Chapter 3) shows that the most dust occurs in the eastern area of the bioregion and is probably associated with mining activity in and around Kalgoorlie, which is just south of the bioregion boundary in the Coolgardie bioregion. Dust reporting for the Murchison bioregion has moderate reliability.

Change in biodiversity

The area set aside for conservation purposes increased from about 0.5% of the bioregion in 1998 to 6.7% in 2004, due to the purchase of pastoral leases by the WA Government.

Two plant species are listed as threatened in the Murchison bioregion. There are also 7 mammal species, 2 bird species and 3 species of reptile listed as threatened (Biodiversity Working Group indicator: Threatened species).

Change in land use and land values

Approximately 14 800 km^2 of pastoral land (5.3% of the bioregion) has been acquired for conservation purposes from 1998 onwards.

It is not possible to describe change in land values for the Murchison region alone, but land values for the Carnarvon–Gascoyne–Murchison region have increased by approximately 230% since 1992.

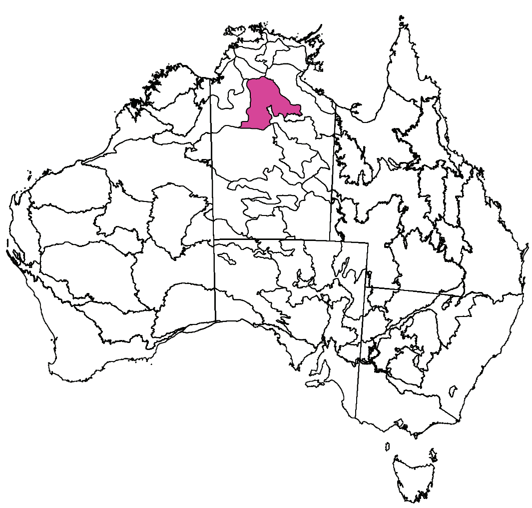
Sturt Plateau bioregion (NT)

The Sturt Plateau bioregion in the northern half of the NT (Figure 4.30) is predominantly eucalypt woodlands or tall shrublands and woodlands of bullwaddy (*Macropleranthea kekwickii*) and lancewood (*Acacia shirleyi*) on flat to gently undulating plains. In more open areas, perennial grasses predominate. Soils are mainly lateritic, but deep sands occur in the south and cracking clays in the southeast. Grazing by cattle is the principal land use (77% of the bioregion area is under pastoral tenure). Aboriginal freehold covers almost 20% of the bioregion, and there is a small area within reserves. Larrimah and Daly Waters are small settlements within the bioregion.

Regional issues

- Historically, pastoral development of the Sturt Plateau bioregion was hindered by water supply problems. There has been considerable development in the past 30 years, mainly through water development and extensive fencing (Figure 4.31).
- Compared with neighbouring productive bioregions, the Sturt Plateau bioregion has a higher proportion of smaller family-owned and operated properties and a lower proportion of larger company-owned stations.
- Increased groundwater information has led to better success rates for drilling bores, and hence to further development.

Figure 4.30 Sturt Plateau bioregion, NT



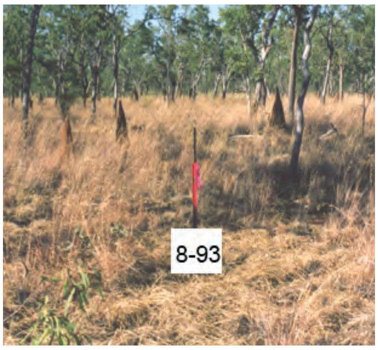
Note: Area = 98 575 km^2.

Figure 4.31 New waterpoint infrastructure on the Sturt Plateau

Photo: NT Department of Natural Resources, Environment and the Arts

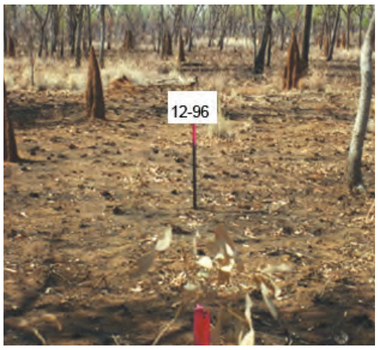
- Infrastructure development has included the strategic location of waterpoints and the use of polypipe and tanks to better distribute and control grazing.
- Landscape condition (Figure 4.32) and management have improved due to increased infrastructure. This has provided better control of cattle grazing and improved access to control wildfires, which are now less frequent and less intense. There is now less patch grazing by feral animals of new pasture growth after fire and less associated land degradation, as there are now fewer burns.
- The region has a very vocal and proactive 'best practice' group. This has assisted intensification and the further development of properties and the region.
- Stock carrying capacities of the region are being reviewed to take into account infrastructure development and better management of the land (Figure 4.33).
- A major concern is the introduction and spread of weeds along the recently completed Alice Springs–Darwin rail corridor. The region has relatively few weed problems, and properties with infestations are very proactive in management and eradication.
- Some Aboriginal leases are being used for pastoral purposes.

Figure 4.32 Changes at a Tier 1 monitoring site, Sturt Plateau bioregion, 1993 to 2004



August 1993

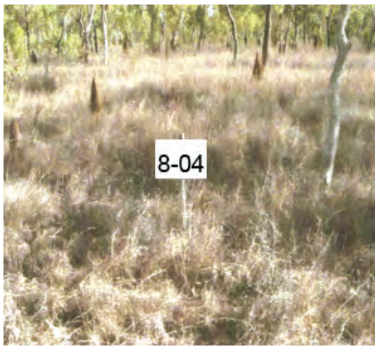
June 1995



December 1996

August 1999

August 2000



August 2004

The site has been able to recover from fire and increased grazing pressures to record similar cover levels to those present 10 years earlier.

Photos: NT Department of Natural Resources, Environment and the Arts

Figure 4.33 Infrastructure developments in the Sturt Plateau bioregion

Trap yards and other infrastructure developments, including increased water supply, paddocking and increased track access for fire control, have improved land management in the Sturt Plateau bioregion.

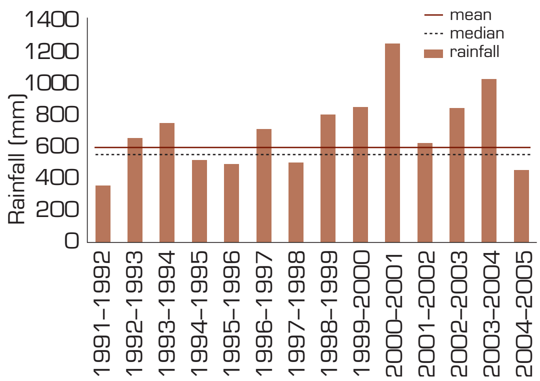
Photo: NT Department of Natural Resources, Environment and the Arts

Seasonal quality — 1992–2005

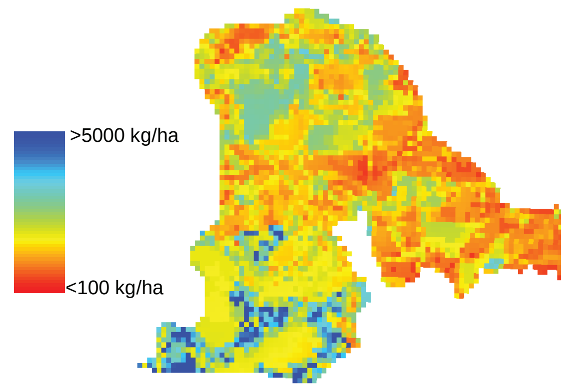
Rainfall was generally above the long-term (1890–2005) median throughout the 1992–2005 period, indicating above-average *seasonal quality*, and the 14-year period as a whole was better than most other 14-year periods since 1890 (Figure 4.34, left). The past 45 years have been generally wetter, apart from a return to more average *seasonal quality* in some years in the 1980s (bottom left panel, Figure 4.34). As in most bioregions, *seasonal quality* has varied spatially across the Sturt Plateau in some years. This assessment of variability is based on simulated pasture biomass produced by AussieGRASS and 'season quality' derived from NDVI[50] (Figure 4.34, right panels).

[50] See http://www.environment.gov.au/erin/ndvi.html.

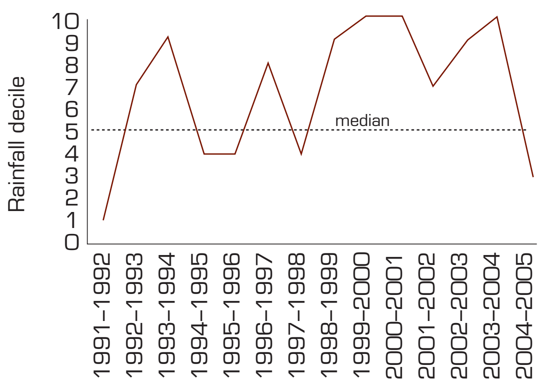
Figure 4.34 Indicators of *seasonal quality*, Sturt Plateau bioregion



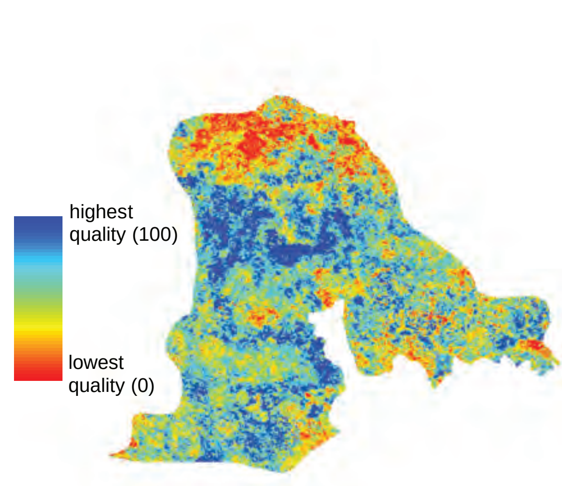
Annual rainfall. Long-term (1890–2005) mean and median



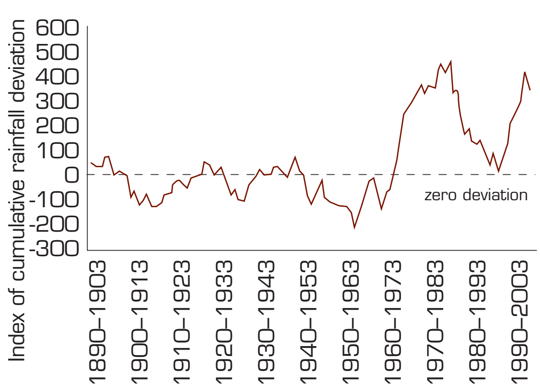
Aussie-GRASS simulated total standing dry matter — 2002



Annual rainfall as deciles of the long-term (1890–2005) rainfall



NDVI-based image of 'season quality' for 2002. Each pixel has a relative value according to the greeness of vegetation (ie photosynthetic activity)



Cumulative percentage deviations of annual (April–March) rainfall from the long-term (1890–2005) median for all 14-year periods between 1890–1903 and 1992–2005

Left: Rainfall

Right: Simulated pasture biomass and vegetation greenness (NDVI)

Note: Indicators are based on spatially averaged annual rainfall (April–March) between 1991–92 and 2004–05. For cumulative percentage deviations, periods below the dashed zero line indicate 14-year sequences with generally less rainfall (poorer *seasonal quality*) and periods above the line indicate sequences of increased rainfall (better *seasonal quality*).

Change in landscape function

Using the percentage of groundcover and composition (by biomass) of perennial herbage species (mainly grasses) estimated at Tier 1 monitoring sites as an index, landscape function initially declined (between 1993 and 1996) and then increased to a moderately stable and relatively high value over most of the remainder of the reporting period (Figure 4.35). Taking account of seasonal conditions, 6% of 167 sites assessed following above-average rainfall showed reduced landscape function (ie improved landscape function would have been expected at this time). Decline in landscape function at some sites in the early years of the current decade was due to extensive wildfire following the extended period of above-average rainfall. Perennial grasses were temporarily replaced by annual sorghum on burnt areas. This decline appeared to be temporary — landscape function, on average, was largely restored at those sites assessed in 2004. No sites were assessed following any periods of below-average *seasonal quality* between 1992 and 2005.

There is a moderate degree of confidence in these data. There is a reasonably high density of Tier 1 sites, but their distribution is clumped to some degree, and the index is based on observer estimates, rather than quantitative measured data. The derived index has not yet been tested to determine its ability to indicate landscape function reliably, compared to the established method of formal ground-based landscape function analysis used in the WARMS monitoring system.

Sustainable management

Change in critical stock forage

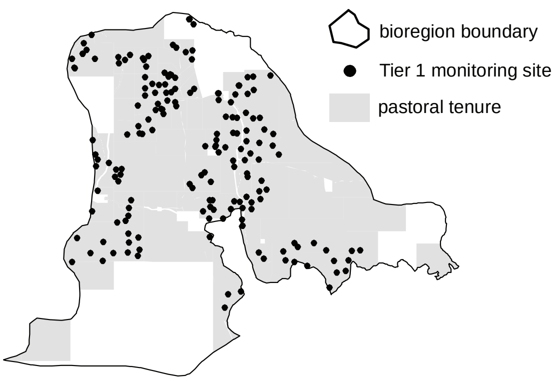
Changes in estimated composition, by biomass, of palatable perennial (2P) grasses were mainly in accord with seasonal expectations (Table 4.14). Across both average and above-average seasonal conditions, 93% of the 183 sites providing suitable data for reporting change showed no change or an improvement in the composition of 2P grasses. Composition is adjusted for utilisation (ie it is adjusted to the composition estimated to be present at the end of the growing season).

Change in woody cover

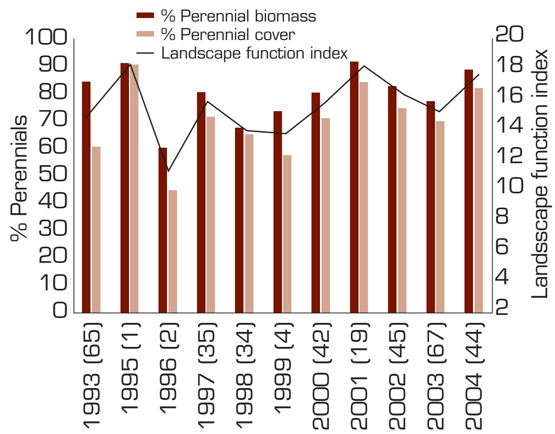
Based on the Australian Greenhouse Office's definition and mapping, forest extent is negligible in the Sturt Plateau bioregion.[51] Forest covered 0.04% of the bioregion area in 1991, and that proportion remained relatively unchanged at 0.05% in 2004. Reporting is based on analysis of Landsat data and is highly reliable because almost complete coverage of satellite imagery was available (more than 90% of the bioregion area).

51 http://www.greenhouse.gov.au/ncas/reports/tech09.html

Figure 4.35 Changes in an index of landscape function, Sturt Plateau bioregion



Tier 1 monitoring sites used to report changes in landscape function



Change in landscape function is based on the combined estimated percentage cover and composition (by biomass) of perennial herbage species (mainly grasses). Biomass composition is adjusted for grazing to remove any short-term utilisation effects. Figures in parentheses along the horizontal axis show the number of sites assessed each year.

Table 4.14 Percentage of Tier 1 sites assessed following variable *seasonal quality* where there was a change in the estimated composition of palatable perennial (2P) grasses, Sturt Plateau bioregion

Seasonal quality	Number of sites	Percentage of reassessed sites showing		
		Decline >20% decrease in 2P grasses	No change	Improvement >20% increase in 2P grasses
Above average	171	8	67	25
Average	12	0	92	8
Below average	n.a.	n.a.	n.a.	n.a.

n.a. = not applicable
Note: The light grey cell indicates a likely adverse effect related to grazing management, in that no change or an improvement in the composition of 2P grasses would be expected following above-average seasonal conditions.

Table 4.15 Percentages of sub-IBRA area within 3 km and beyond 8 km of permanent and semipermanent sources of stock water, Sturt Plateau bioregion

Sub IBRA	% of sub IBRA area	
	<3 km from water	>8 km from water
Sturt Plateau P1	0.7	96.9
Sturt Plateau P2	7.0	66.7
Sturt Plateau P3	6.4	69.3

Distance from stock water

Based on the locations of stock waterpoints (sourced from Geoscience Australia's Geodata Topo 250K vector product, Series 3, June 2006), Table 4.15 lists the percentages of sub-IBRA areas within 3 km and further than 8 km of permanent and semipermanent sources of stock water. This analysis does not include the locations of natural waters, which can provide additional sources of water for stock, particularly in the early dry season. Available waterpoint data are probably out of date, as they do not reflect recent infrastructure development in the bioregion.

It is not possible to report change in watered area.

Weeds

Weeds known to occur in the bioregion include bellyache bush (*Jatropha gossypifolia*), Chinee apple (*Ziziyphus mauritiana*), grader grass (*Themeda quadrivalvis*), hyptis (*Hyptis suaveolens*), mission grass (*Pennisetum polystachion*), Noogoora burr (*Xanthium occidentale*), parkinsonia (*Parkinsonia aculeata*), prickly acacia (*Acacia nilotica* subsp. *indica*) and sicklepod (*Senna obtusifolia tora*).[52]

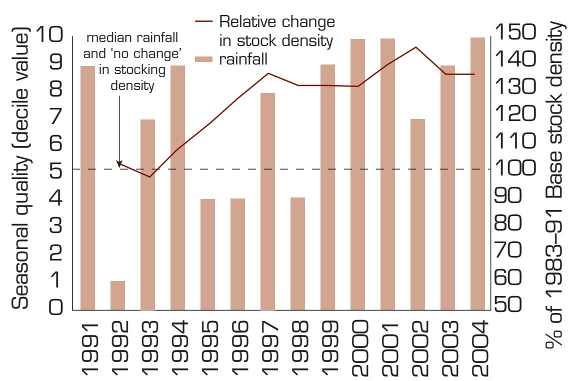
[52] See http://www.anra.gov.au

Components of total grazing pressure

Change in domestic stocking density

Approximately 77% of the Sturt Plateau bioregion is pastoral land. Based on ABS-sourced data, domestic stocking density increased between 1993 and 1997 (Figure 4.36).

Figure 4.36 Change in domestic stocking density (beef cattle), Sturt Plateau bioregion, 1991 to 2004



Note: *Seasonal quality* as deciles of rainfall is also shown.

Table 4.16 Percentage area of Sturt Plateau bioregion burned, 1997 to 2005

1997	1998	1999	2000	2001	2002	2003	2004	2005
7.9	13.2	41.4	20.2	61.1	27.0	18.2	63.7	2.1

Source: WA Landgate data based on fire-scar mapping from National Oceanic and Atmospheric Administration AVHRR satellite images

This approximate density was maintained until 2000 and then increased to 2002. In both 2003 and 2004, stocking density was 37% above the 1983–91 base. This large increase in stocking density was probably helped by some better seasons but also continued through some seasons of average *seasonal quality*. Apart from the better seasons, the increase was also driven by land use intensification in the region. Spatial averaging conceals likely variation in stocking density trends across the bioregion.

Invasive animals

Invasive animal species known to occur in the Sturt Plateau bioregion include pig (*Sus scrofa*), wild dog (*Canis lupus familiaris*), feral cat (*Felis catus*), cane toad (*Bufo marinus*) and water buffalo (*Bubalus bubalis*).[53]

Fire and dust

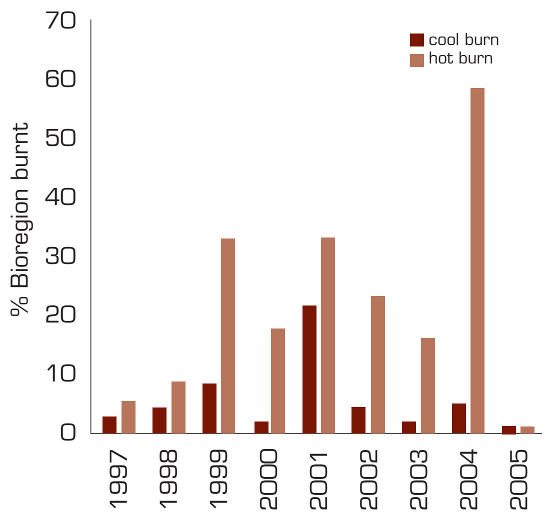
Fire

Large areas of the bioregion were burned in 1999, 2001 and 2004 (Table 4.16). During the most fire-active years (1999 to 2004), hot late dry-season (August–December) fires were predominant (Figure 4.37). Fire frequency was moderate compared with the rangelands as a whole (mean frequency ($\log_{10}$ transformed) = 0.435).

Dust

Atmospheric dust levels based on the DSI were among the lowest levels of all rangeland bioregions (mean DSI_3 of 0.47 for the 1992–2005 period, when the maximum value for all bioregions was 8.44).

Figure 4.37 Area of Sturt Plateau bioregion burned in 'cool' (January–July) and 'hot' (August–December) fires, 1997 to 2005 (%)



Change in biodiversity

Five mammal species and five bird species are listed as threatened for the Sturt Plateau bioregion (Biodiversity Working Group indicator: Threatened species).

Change in land use and land values

Based on available data, there was no change between 1992 and 2005 in the proportion of the bioregion under pastoral land use (77%). Ninety-five per cent of the area contained in pastoral leases was grazed.

The unimproved value of pastoral land increased by 45% between 1991 and 2003. This was the largest increase of all pastorally significant bioregions in the NT. Increased land values were partly driven by intensification resulting from infrastructure development and increased availability of groundwater.

[53] See http://www.anra.gov.au

5 Emerging information needs

Over the past decade, three groups have become increasingly significant stakeholders in the management of large areas of the rangelands:

- *Indigenous land managers* — the land area under control or management of Indigenous landholders has increased in recent years
- *regional natural resource management (NRM) groups* — the regional groups are responsible for implementing Australian Government investments to improve land management and biodiversity conservation
- *the non-government environment sector* — significant areas of land have been acquired for biodiversity conservation purposes by the sector in recent years.

These three groups require information on natural resource conditions and trends to manage their land. Information is often required at a finer scale than that provided by Australian Collaborative Rangeland Information System (ACRIS) reporting (ie at the property and subregional scale, rather than at the bioregional, state or national scale). In some cases, investors require information to demonstrate the effectiveness of management actions at a particular location in meeting wider, long-term resource condition goals.

In compiling this report, the ACRIS Management Committee (ACRIS-MC) has investigated the information needs of the three groups and examined ways in which ACRIS can better deliver the required information.

Figure 5.1 Indigenous management of significant areas of the rangelands

Indigenous people now have responsibility for managing significant areas of the rangelands. This includes fire management in northern Australia.

Photo: Department of the Environment, Water, Heritage and the Arts

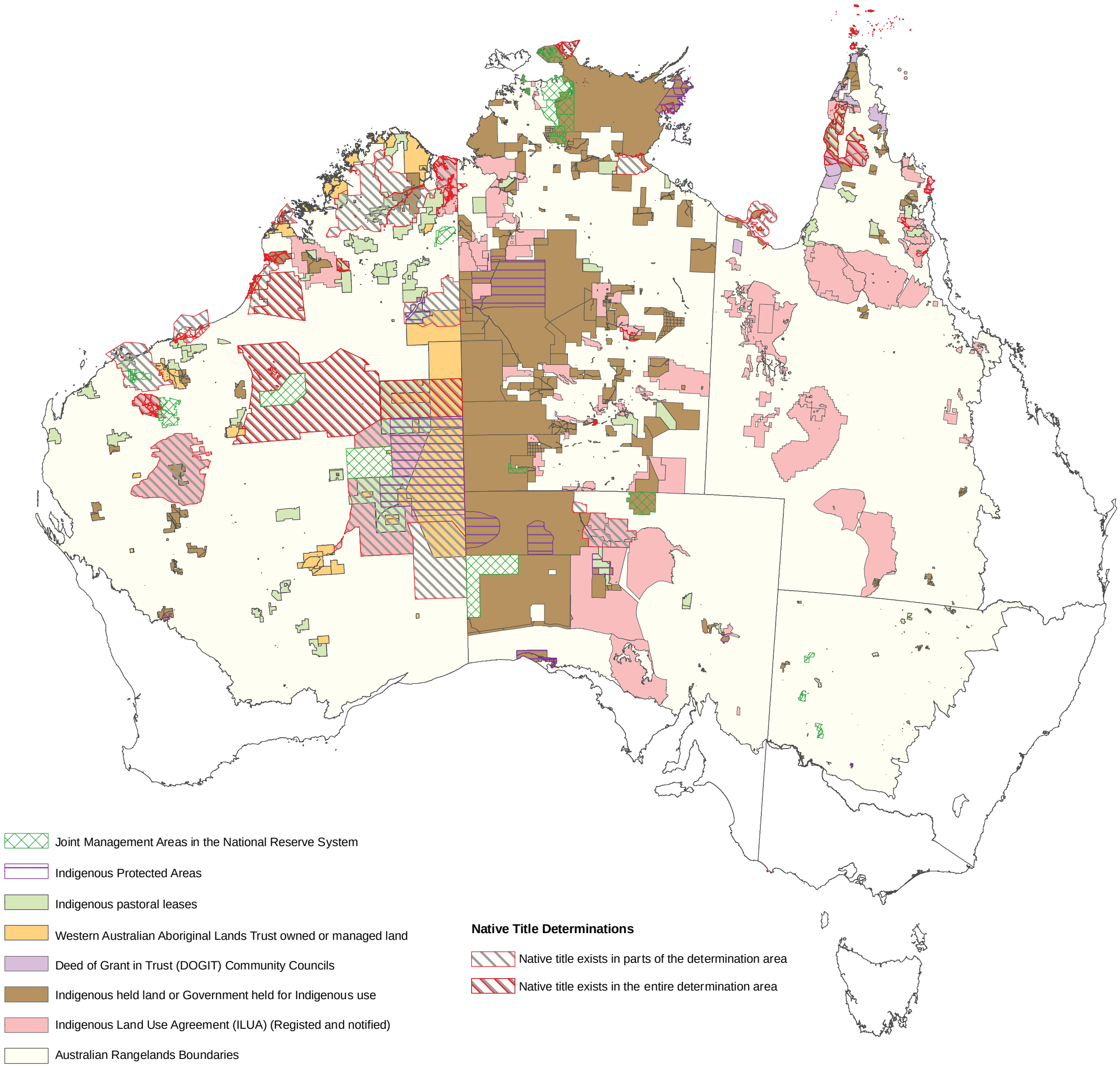
Information needs of Indigenous land managers

Indigenous landholdings in the rangelands

The return of direct responsibility for management of large areas of the rangelands to Indigenous communities is one of the most significant changes in land ownership over the past 30 years (Figure 5.1). Although some land was allocated to Indigenous habitation in the past, the active acquisition of pastoral leasehold land and other traditional lands began only in the 1970s through a range of Australian Government and state/territory government legislation and programs. The Indigenous Land Corporation at the national level and some state and territory agencies are empowered to acquire land for Indigenous people and to support them in the management of that land.

By October 2005, Indigenous people had regained full ownership of, or responsibility for, almost 1.675 million km^2 (27%) of the rangelands. When areas of jointly managed national parks and land covered by Indigenous land use agreements and native title determinations are taken into account,

Figure 5.2 The rangelands Indigenous estate



Source: Department of the Environment, Water, Heritage and the Arts

Aboriginal people have some level of responsibility for and rights to 2.292 million km^2 or nearly 37% of the Australian rangelands. The distribution of those lands is shown in Figure 5.2, and the areas in each category are listed in Table 5.1. An additional category not listed is Indigenous protected areas (IPAs), which are areas where traditional owners have entered into voluntary agreements for the purposes of biodiversity and cultural resource conservation.

Further acquisitions of pastoral leasehold land, joint management arrangements over areas of the conservation reserve system, declaration of more IPAs and commitments through Indigenous land use agreements can be expected in the future.

Statutory land councils support Indigenous land use and management, and a number of Indigenous land management organisations (ILMOs) of diverse natures and capacities have been formed to assist Indigenous custodians with information and advice.

Table 5.1 Categories of Indigenous lands in the rangelands

Category		Area (km²)	Percentage of rangeland area
Total area of the rangelands		6 234 400	100.00
Total area with some level of Indigenous responsibility for, or interest in, management		2 292 100	36.76
Primary responsibility for management	Indigenous owned and leasehold lands	1 675 000	26.87
Shared responsibility for management	Jointly managed conservation lands	100 300	1.61
Varying levels of interest in land management	Indigenous land use agreements — not included in the above categories	516 800	8.29

Source: ERIN, 2007

Indigenous land use and management in the rangelands

The values that Indigenous people hold about rangelands and their relationship with their lands lie at the centre of different and distinctive ways of knowing, using and managing country. Grounded in those values, Indigenous people hold land to achieve a wide range of economic, social, cultural and environmental outcomes, such that there is no singular 'Indigenous land use' or a simple set of 'Indigenous information needs'. For example, the values, aspirations and opportunities of a coastal community in the wet tropics are very different from those of a desert community in central Australia.

Indigenous peoples' interests in land and their associated information needs include:

- *pastoral enterprise development*: rangeland inventory, condition and trend; management guides
- *coastal environment management*: coastal stability, information on coastal flora and fauna
- *tourism enterprise development*: the risk that preferred areas of visitation may be damaged by high visitor pressure, including risks of site-based impacts on flora and fauna
- *cultural aspirations*: spatial description of resources as recognised by Indigenous peoples for their cultural values and threats (fire, weeds, climate change) to special locations and areas
- *part-subsistence living*: resources (fuel, bush foods, fauna); climatic information as it affects availability of resources for subsistence; feral animals, pests and weeds; fire history and patterns
- *nature conservation management*: spatial description of resources as recognised by Indigenous peoples; biodiversity status and trends; climatic information as it affects fire and drought frequency; feral animals, pests and weeds; fire history and patterns
- *building capacity to adjust to climate change impacts*: predicted cyclone frequency and intensity; predicted changes in fire regimes; predicted sea-level changes; predicted changes in flora and fauna availability; human health-related factors (eg mosquitoes, disease incidence).

Information for Indigenous land use and management

In 2007, the ACRIS partners and ILMOs are better placed than previously to work together in addressing Indigenous information needs. Recent research has provided a clearer picture of the distinct and different Indigenous values and aspirations that could be matched with new information products. Collaborative arrangements could be developed between ILMOs and ACRIS partners to build greater understanding of each other's resources, capacities and development needs, for example as shown by the Balkanu Organisation (Box 5.1).

Table 5.2 External land information/data accessed by the larger rangeland Indigenous land management organisations

Data	Providers	Commonly available scales
Vegetation	State/territory government agencies	1:500 000 and finer. Finer resolution preferred
Geology	State/territory government agencies	1:250 000. Suitable, although finer resolution preferred
Digital elevation models	State/territory government agencies	National coverage by 9-second digital elevation models. Finer for some areas (preferred)
Roads, drainage, community locations etc	Geoscience Australia	1:250 000 and finer. Finer scale maps more useful
Fire history	State/territory government agencies	Various
Ramsar or other important wetlands	ERIN, state/territory government agencies	Inadequate
Bore locations	State/territory government agencies	1:250 000 and finer. Finer scale maps more useful
Bioregions	Environment Australia	Poor resolution for ILMOs operating in different boundaries
Land use (eg agriculture, forestry, mining)	State/territory government agencies, NLWRA, DAFF (national scale land use mapping); state and territory finer scale mapping developed under ACLUMP.	National scale land use mapping, and regional scale land use mapping at various scales. Finer scale mapping more useful
Land tenure	State/territory government agencies	Good resolution
Satellite imagery	ACRES	Good resolution
Quick Look mosaics	Geoscience Australia; state/territory government agencies	Poor resolution
Topographic maps	State/territory government agencies	1:250 000 and finer (finer more useful)
Aboriginal heritage sites registers	State/territory government agencies	Good resolution

ACLUMP = Australian Collaborative Land Use Mapping Program; ACRES = Australian Centre for Remote Sensing; DAFF = Department of Agriculture, Fisheries and Forestry; ERIN = Environmental Resources Information Network; NLWRA = National Land & Water Resources Audit

Box 5.1 The Balkanu Organisation

Balkanu is a Cairns-based community and business development organisation set up by the Aboriginal people of Cape York. It works collaboratively with traditional owners and their locally focused organisations (such as the Chuulangun Aboriginal Corporation), as well as with other local, regional and national organisations. One project managed by Balkanu is the development of an ethnoecology database for the Kaanju people. The Kaanju people gave permission for the data to be collected, and the data are already available to local communities at the Chuulangun Aboriginal Corporation.

A GIS system has been built, although further development work is required. The data stored in the GIS are used primarily for land management planning, including weed and feral animal control, and to support planning for sustainable economic development.

Table 5.3 Landscape data types available for monitoring landscape change in the rangelands

Landscape feature	Data types	Availability from ACRIS data
Ethnobotanical (eg bush foods and medicines)	Oral history (audio, CD or documented); photos	No, but available for specific regions through the relevant ILMO
Ethnozoological (eg hunting species, totem species)	Oral history (audio, CD or documented); photos	No, but available for specific regions through the relevant ILMO
Weeds (woody, aquatic etc)	GPS coordinates; aerial photos; photos of vigour; management zones; distribution and relative abundance	No, but available from NLWRA mapping for a selected suite of weeds
Introduced animals	Photos; scats; distribution and relative abundance	No, but available from NLWRA mapping for selected feral animals
Fire history	Photos; aerial photos; management zones (ACRIS information is about area burned, from which fire extent, intensity and frequency can be estimated and reported)	Available from ACRIS or directly from Landgate (Land Information Authority) in WA
Waterways	Aerial photos; photos; topographic maps	Not available from ACRIS but from Geoscience Australia mapping and jurisdictional agencies
Wetlands	Aerial photos; photos; topographic maps	No, but available from ERIN. Some additional information has been compiled for NLWRA.
Waterway flows	GPS coordinates; flow history	Flows are not in the ACRIS datasets but are available from jurisdictional agencies
Water quality	GPS coordinates; photos (turbidity)	Not in the ACRIS datasets but available from jurisdictional agencies
Stocking rates (pastoral areas)	Stocking histories; management zones	Relative change in stocking density is in the ACRIS datasets, and is sourced from ABS Agricultural Census and survey data
Stock forage productivity	Aerial photos; photos; management zones	Information on change in 'critical stock forage' for pastoral lands (ie density, frequency and composition of decreaser species) is available at IBRA scale
Erosion	Aerial photos; photos	Erosion potential is available from jurisdictional agencies that contribute to ACRIS datasets

ABS = Australian Bureau of Statistics; ERIN = Environmental Resources Information Network; GPS = global positioning system; ILMO = Indigenous land management organisation; NLWRA = National Land & Water Resources Audit

Availability of existing information

Land information is available for many regional and subregional ILMOs (Table 5.2). Assisting ILMOs to access these data would help to meet a range of information needs at regional, and sometimes subregional, scale.

As well as requiring access to available map data, Indigenous land managers seek to record and preserve information at subregional and local scales about a range of cultural values, including sites of significance, hunting areas, story places, birth places, rock art sites and camping sites. ILMOs often need further resources for local collection and management of such sensitive data for local purposes, rather than simply for regional-scale or performance reporting purposes.

ILMOs need additional data types and scales at the regional level (Table 5.3). A number of such products can be supplied from the ACRIS datasets, with boundary realignments as required to meet particular organisational needs. While the list of landscape features presented is not exhaustive, those identified are generic to most rangeland areas.

The scale of information needs for ILMOs and pastoralists are largely congruent (ie property to subregional scale), though usually at a finer scale than ACRIS currently requires or delivers. It is worth exploring whether there are specific additional needs of Indigenous land managers that ACRIS could satisfy.

There is a long history of scientific rangeland management in Australia; most has occurred with limited Indigenous involvement. Providing Indigenous land users and managers with access to this management information and the physical legacy of ground-based monitoring sites will be valuable for Indigenous land managers. Data collected at ground-based sites that are no longer used or maintained because of resource constraints in government but that have ongoing value at a local level could be provided to Indigenous people where they have responsibility for the land involved.

Traditional information needs

Many new systems for preserving traditional knowledge are being developed for traditional owners across the rangelands. The enthusiasm and commitment among Indigenous peoples for the capture and use of traditional ecological knowledge is driving projects that record that knowledge in spatial and non-spatial dimensions in many locations (Brown and Creaser 2006).

There is potential to support the development of a nationally applicable platform for the storage and presentation of suitable material (after considering what is culturally sensitive and should not be made available) in a format that provides an overall Indigenous view of rangeland resources. This would involve seeking the views of key Indigenous organisations about the usefulness of such a national platform.

Those working with Indigenous land managers could work to develop a dual system of rangeland environmental knowledge that adds value both to Indigenous and to scientific traditions for understanding and managing the rangelands. The resulting synergies would enhance all stakeholders' capacity to manage the rangelands.

Information needs of regional NRM groups

Over the period 2000–2007, the Australian Government, through the Natural heritage Trust (NHT) and in partnership with state and territory governments and communities, invested considerable funds in NRM programs (Table 5.4). Much of that funding was directed through the regional NRM groups, including those located across Australia's rangelands (Figure 2.3, Chapter 2). The NHT program ceased in June 2008.

The National NRM Monitoring and Evaluation Framework (National M&E Framework) has been established by the Australian Government and state and territory governments to help assess the health of the nation's land, water and biodiversity, and the performance of government programs. The framework sets out broad thematic areas or 'matters for target', which are available for the regional groups to use and to be reported against using a range of associated environmental indicators. The thematic areas are:

- land salinity
- soil condition
- inland aquatic ecosystems integrity (rivers and wetlands)
- nutrients
- turbidity
- surface water salinity
- condition of estuarine, coastal and marine environments
- native vegetation
- significant native species and ecological communities
- invasive species (weeds and vertebrate pests).

A set of community and socioeconomic indicators is being developed and tested with the states and territories through the National Land & Water Resources Audit (the Audit).

Regional NRM groups throughout Australia are developing or refining strategies and investment plans to improve the condition of their assets. Each NRM group establishes a set of 'resource condition

Table 5.4 Australian Government expenditure in rangelands NRM regions, 2002–03 to 2005–06 ($)

State	NRM region	2002–03	2003–04	2004–05	2005–06	Total
NSW	Lower Murray-Darling	251 045	3 534 431	8 564 220	3 331 847	15 681 543
	Western	44 706	3 931 686	2 148 975	6 276 863	12 402 230
NT	Northern Territory	3 600 000	6 734 547	9 278 830	8 822 877	28 436 254
Qld	Burdekin	603 433	2 794 556	2 157 374	4 411 030	9 966 393
	Cape York		2 304 118	2 376 983	642 465	5 323 566
	Desert Channels		3 122 833	1 880 692	496 860	5 500 385
	Northern Gulf		1 648 750	1 905 357	1 675 163	5 229 270
	South West		2 084 615	896 887	2 386 995	5 368 497
	Southern Gulf		1 791 375	2 416 835	241 595	4 449 805
SA	Alinytjara Wilurara	1 937 352	687 415	2 684 286	2 700 000	8 009 053
	SA Arid Lands	677 704	1 103 396	1 762 363	2 363 000	5 906 463
WA	Rangelands	4 910 393	2 248 186	2 773 543	7 401 868	17 333 990
Total		12 024 633	31 985 908	38 846 345	40 750 563	123 607 449

NRM = natural resource management

Note: Includes the 12 regional NRM groups that are entirely or predominantly within the rangelands. An additional 15 NRM regions have a smaller proportion of their area within the rangelands, but information on expenditure is not included, given the difficulty of separating expenditure on rangeland and non-rangeland areas.

targets' (RCTs) and 'management action targets' (MATs) that articulate the management activities and desired condition of the region's resources. Under the government programs, the regions are required to show progress towards those targets.

Rangeland NRM pilot regions

The management of rangeland environments, including monitoring, evaluation and reporting on the status and change in resource condition, often requires integrated knowledge of the environmental and socioeconomic factors influencing sustainability. Suitable indicators for monitoring the condition of natural resources should reflect the relationship that exists between the environment and the people who live and work in the rangelands. The selected indicators must also cope with the high variability of biophysical resources over space and time in rangeland landscapes.

Trials of ACRIS information products

The Audit conducted trials in a number of pilot rangeland regions to assess how relevant and useful ACRIS products are to regional NRM groups, and also to assess the potential for the groups to provide input to ACRIS (Richards 2007). This included assessing the relevance of the National M&E Framework and the capacity of ACRIS information types to fulfil the information and monitoring needs of the National M&E Framework.

The pilot rangeland regions were:

- Northern Gulf (Queensland)
- Burdekin Dry Tropics (Queensland)
- Lower Murray-Darling (NSW)
- Alinytjara Wilurara (SA)
- Arid lands of the Northern Territory (NT).

Findings from the trials

- The trials revealed a number of important findings for improved future alignment of the National M&E Framework and ACRIS. Although both frameworks are useful for higher level reporting on themes of national importance, they have been developed for quite different purposes. Rangeland management is an integrated enterprise, including natural resource assets, their use and the communities that they sustain (Indigenous or non-Indigenous). The indicators that are used should be representative of this integrated management.

- Rangelands have unique biophysical environments, requiring indicators that reflect an understanding of their dynamics and spatial and temporal scales of change.
- There is a very low awareness of the products and information available from ACRIS and the National M&E Framework. Many regions are now developing indicators and programs for monitoring the condition of their natural resource assets, making now an opportune time to increase awareness of National M&E Framework and the ACRIS products and information.
- Regional monitoring and reporting activities are directed by the regional NRM plan and the RCTs and MATs. In particular, MATs direct investment in the landscape and require information at point-of-investment or local levels (paddock or property).
- Many of the National M&E Framework indicators are considered 'state' indicators. Functionally, regional NRM groups are more focused on pressures and threats.
- NRM regions are moving towards using MAT indicators to measure intermediate natural resource condition outcomes, such as land management practice change. The NM&EF is developing the capacity for regional use through the inclusion of socioeconomic indicators.

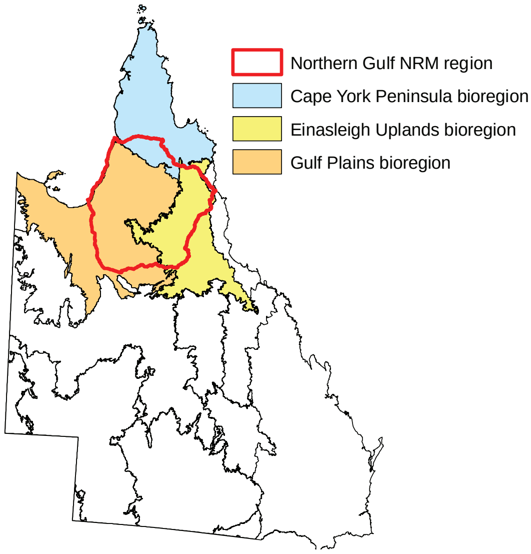
Alignment of ACRIS and NRM regional reporting: a case study for the Northern Gulf NRM region, Queensland

The Northern Gulf NRM region in northern Queensland was selected to test the capacity of ACRIS to integrate with regional NRM information and reporting needs. This included assessing:

- the usefulness of current ACRIS information types at the regional scale
- the potential to provide information to ACRIS.

The Northern Gulf NRM region covers about 194 000 km^2, including the catchments of the Mitchell, Norman, Gilbert and Staaten rivers. The region is characterised by tropical savanna: grassy woodlands are the dominant landscape, with wet rainforest in the northern part of the region.

Figure 5.3 Northern Gulf NRM region and IBRA bioregional boundaries



Four bioregions are represented: Gulf Plains, Einasleigh Uplands, Wet Tropics and Cape York Peninsula; the first two account for approximately 90% of the region (Figure 5.3).

ACRIS currently produces a range of information types at a bioregional level under reporting themes with relevance to the Northern Gulf:

- indices of *seasonal quality* — derived from rainfall and pasture growth data as context for interpreting change in biophysical reporting themes
- landscape function — a measure of the landscape's capacity to capture and retain rainfall and nutrients (based on agency monitoring data)
- sustainable management — change in forage value (from agency monitoring data); domestic grazing pressure; fire extent, intensity and frequency; and dust
- biodiversity — partly based on changes in woody cover due to clearing.

Pastoralism is the predominant land use, with 215 large grazing properties comprising most of the region. The Northern Gulf Resource Management Group, which strives to develop strong relationships with land managers, has a philosophy that effective NRM does not separate biophysical, socioeconomic and cultural environments. This is reflected in the Northern Gulf logo, 'Caring for Country, Caring for

Figure 5.4 NRM investments for management action targets are made at the local (paddock to property) scale

NRM investments should contribute to improved regional resource condition. By reporting to NRM regional boundaries, ACRIS can potentially provide additional context for reporting against resource condition targets.

Photo: Northern Gulf Resource Management Group

Sea and Caring for Community'. This philosophy is carried into the Northern Gulf's regional planning, activities and management objectives for the region.

The Grazing Land Management (GLM) Program is currently operating in the Northern Gulf and other regions throughout Queensland. In the Northern Gulf, the program uses 14 separate land types. For each land type, land condition is assessed according to four criteria:

- perennial, palatable and productive grass abundance
- weed infestation
- soil erosion
- woodland thickening.

The GLM Program is a core monitoring program central to the implementation of the regional plan and forms the basis for the integration of future biodiversity, landscape function, and social and sustainable management programs in the region.

Using ACRIS products for NRM in the Northern Gulf

ACRIS information types in their current form are useful contextual information for the region, but their current bioregional scale of application is too coarse for the Northern Gulf NRM group to use in meeting specified RCTs. In the Northern Gulf, the NRM plan has RCTs and MATs that address several theme areas consistent with the ACRIS themes, including

Table 5.5 Alignment of the ACRIS themes and information types with Northern Gulf resource condition targets and management action targets

ACRIS theme	ACRIS information type	Northern Gulf resource condition targets	Northern Gulf management action targets
Landscape Function	Currently no product directly relevant to Northern Gulf	Soil condition of the Northern Gulf NRM region. 50% of the Georgetown granites to be in A and B condition	By 2010, 50% of graziers to adopt a number of land use management practices consistent with the processes outlined in the current or future drafts of the Leasehold Land Strategy
Sustainable Management	Grazing pressure	70% of the grazed landscape of the Northern Gulf to be in either 'A' or 'B' condition by 2017	15 additional landholders managing stock numbers according to soil and climatic constraints, setting sustainable stocking rates and maintaining an average groundcover greater than 50% at break of season 15 additional landholders engaging in GLM+ and using a satellite image or air photo and property planning kit to map paddocks, infrastructure, land types and land condition.
	Fire extent	Fire regimes in the Northern Gulf NRM region are managed to minimise damage to the ecosystems.	15 additional landholders participating in GLM+ to map paddocks, land types and land condition to plan and implement a burning program depending on land types, timber thickening and patch grazing in each paddock By 2006, 50% of landholders in the region were expected to be computer literate and trained in the interpretation and use of satellite imagery in association with GIS to monitor and respond to fire management issues in the Northern Gulf.
Biodiversity	Woody cover	Maintain and/or improve the long-term viability and stability of 100% of ecosystems and habitats in the Northern Gulf NRM region by 2015	By 2015, 75% of land managers understand which habitats and ecosystems within their properties and catchments are of high conservation value and require special management to enhance and protect their biodiversity values

GLM = Grazing Land Management Program; NRM = natural resource management

landscape function, sustainable management and biodiversity.

RCTs articulate the desired state or condition of a resource at a specified point in the future. Those targets are usually region-wide, as would be the application of the ACRIS information types. However, regional investment and activity are focused on the MAT level. Under the current reporting arrangements, this is also the level of greatest regional accountability. MATs, unlike the RCTs, are generally statements of response involving capacity building of land managers, the community or the regional group. In the Northern Gulf, many of the MATs use the property as the functional unit for implementation (Figure 5.4).

MATs relevant to the ACRIS themes in the Northern Gulf include those relating to:

- property grazing management practices
- landholders' capacity to record change in resource abundance and condition
- landholders' capacity to maintain groundcover levels
- use of appropriate fire regimes
- increasing the information technology skills of landholders.

The alignment of the Northern Gulf RCTs and MATs with the ACRIS themes and information types is shown in Table 5.5. While scale alignment of the ACRIS products may be feasible at the RCT level, there is an obvious need for property-scale information at the MAT level.

Figure 5.5 Recording NRM information

NRM information recorded by individuals within regional groups can potentially increase the richness and relevance of ACRIS reporting.

Photo: Ron Archer

It is possible that ACRIS information types can be used to validate regional data and to provide an 'across the boundary' comparison with neighbouring regions. For example, the distribution of rainfall and pasture growth over several regions can assist with grazing management through agistment.

Transferring regional knowledge to ACRIS

The Northern Gulf is currently investing in a range of activities to provide high-resolution data for the region under a number of the ACRIS themes, including:

- *climate* — enlargement of the rainfall-reporting network, including the subsidising of automatic recording stations on properties
- *fire extent* — funding to support Northern Australian Fire Information products. Provision of GIS software (ARCMAP) to graziers to view near real-time fire extent online for management purposes
- *stock density* — GLM Program property planning and access to cattle barcode data for each paddock under the PHOENIX software system
- *landscape function* — investing in a range of activities with research partners, including remotely sensed erosion mapping (Griffith University), BioTools (CSIRO), Patchkey (CSIRO) and Land Cover Change (Queensland Government).

There is currently little state government NRM monitoring of the grazing lands, so the region is independently developing monitoring activities that integrate with reporting needs. This 'grassroots' approach, integrating the needs of reporting at different levels with the needs of land managers, can provide a long-term, sustainable and accurate base for the collection, collation and reporting of regionally specific resource condition data by ACRIS. The use of the GLM Program to bring land managers on board in capturing resource condition information at the paddock scale is the key to reporting at aggregated levels, such as for the ACRIS-MC.

The Northern Gulf Resource Management Group is moving towards a community-driven NRM information capture system (Figure 5.5). Information such as infrastructure, land types, waterpoints, weed infestations, pasture condition and species abundance is captured in the field by landholders using GPS equipment and downloaded to a central database at the resource management group. Data can be aggregated, sieved, cleaned and uploaded to a state or national framework, such as ACRIS. For example, waterpoint locations and stock density data can be captured at the paddock level using software distributed to private landholders by the Northern Gulf Resource Management Group. These data could be aggregated to a bioregional level for use by ACRIS.

These trials show that ACRIS currently has limited capacity to provide relevant data to assist regional NRM groups with their reporting requirements under the NM&EF. Impediments include scale and regionalisation issues, and lack of clarity in some regions about the data required to report progress towards RCTs specified in regional plans. ACRIS reports at the bioregion scale, while NRM groups require finer-scale (paddock to property) information. These limitations may reduce as ACRIS develops a more flexible information delivery system and regional groups gain competence and confidence in collecting and accessing data to meet their monitoring and evaluation requirements.

Information needs of the non-government environment sector

The non-government environment sector is rapidly becoming a significant land manager in the rangelands. Indigenous communities and organisations are entering into conservation agreements with government as a means of obtaining financial assistance for the management of recently acquired land (IPAs), and non-Indigenous individuals, organisations and charitable trusts are investing in the establishment of private reserves ('private protected areas'), encouraging covenants on existing properties to protect biodiversity values, and assisting in the management of land for biodiversity conservation.

Indigenous protected areas

The Australian Government's IPA program was established in 1995 to support Indigenous landowners in managing their land for biodiversity conservation and for cultural purposes. Since then, 24 IPAs covering some 200 000 km^2 of land have been declared.

Significant rangelands IPAs (Figure 5.6) include:

- Nantawarrina — 580 km^2 in the northern Flinders Ranges (SA)
- Yalata — 4563 km^2 at the head of the Great Australian Bight (SA)
- Watarru and Walalkara — 20 000 km^2 in the Great Victorian Desert (SA)
- Dhimurru — 1000 km^2 in northeastern Arnhem Land (NT)
- Ngaanyatjarra — 98 129 km^2 in the Central Ranges bioregion, plus parts of the Gibson Desert and Great Victoria Desert bioregions (WA)
- Paraku — 2700 km^2 in the Great Sandy Desert (WA)
- Mount Willoughby — 3865 km^2 in the Great Victoria Desert and Stony Plains bioregions (SA)
- Northern Tanami — 40 000 km^2 in the Tanami Desert (NT)
- Warlu Jilajaa Jumu — 16 000 km^2 in the Great Sandy Desert (WA).

Private protected areas

Non-government organisations (NGOs), such as the Australian Wildlife Conservancy, Bush Heritage Australia and Birds Australia, are major players in the acquisition and management of land for biodiversity conservation in the rangelands. Their purchases, assisted by and in partnership with governments, represent a growing land use (Figure 5.7).

The Australian Government, for example through the National Reserve System Program, has provided financial assistance to private conservation organisations for many purchases. Twenty-five properties covering almost 18 000 km^2 were acquired from 1997 to 2007 across Australia (Figure 5.6). For the rangelands, these include:

- Mornington Nature Reserve, 3120 km^2 (WA)
- Newhaven Station, 2620 km^2 (NT)
- Craven's Peak, 2336 km^2 (Queensland)
- Ethubuka, 2140 km^2 (Queensland)
- Wongalara, 1910 km^2 (NT).

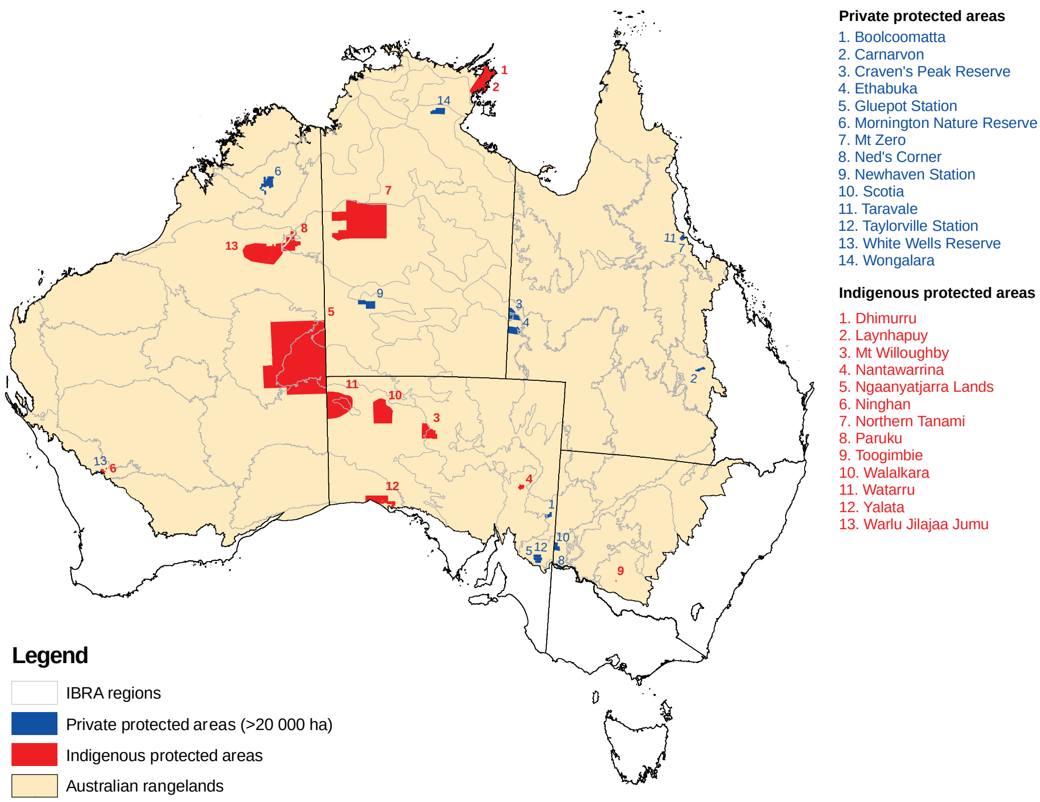
The non-government environment sector recognises the need to be able to report to investors and stakeholders on the benefit and impact of particular acquisitions and resulting management activities. There is scope for this sector to contribute its monitoring data to broader regional knowledge systems.

The 2001 National Forum on Nature Conservation on Private Land listed among the key challenges for the future:

> Ensuring that reporting processes are in place to enable scientifically-based monitoring of both the human aspects of our work and the progress towards on-ground conservation … Beyond the initial act of protection, there is a need to develop a capacity for rating an action (acquisition, stewardship arrangement, management technique in a Reserve) based on cost and increase in viability of target species so there is a rigorous way of rating investments. (Hugh Possingham, University of Queensland, Brisbane, pers comm, 2007)

The continued growth of the non-government environment sector through government partnerships and with new private investors will be partly determined by its capacity to demonstrate effective management and the efficient use of funds in achieving natural resource condition outcomes.

Figure 5.6 Indigenous protected areas and private protected areas in the rangelands



Source: Department of the Environment, Water, Heritage and the Arts

Market-based conservation incentives for private landholders

Several state or territory incentive schemes and programs have been developed to help landholders manage native vegetation on private or leasehold land. In the rangelands of western NSW, the Enterprise Based Conservation Scheme was established to better manage biodiversity and the natural resource base while maintaining the financial viability of landholders. Grants under the scheme provide financial incentives for landholders to actively manage part or all of their property for specific conservation goals.

In Victoria, the Bush Tender process enables landholders to tender competitively for contracts to improve their native vegetation. Similar schemes have been established by the Queensland Murray-Darling Committee and in SA as the Bush Bids program.

Figure 5.7 Cravens Peak in western Queensland, a former pastoral lease purchased by Bush Heritage Australia

The non-government environment sector is making a significant contribution to biodiversity conservation in the rangelands.

Photo: Wayne Lawler, Bush Heritage Australia

Performance reporting

The non-government environment sector is obligated to report to its investors on the effectiveness of its management programs. The value of that information might be increased if it were interpreted within the broader regional context that ACRIS can provide (eg recent *seasonal quality*, trends in regional stocking density, landscape function).

This sector, in particular, is focused on improved environmental outcomes, including biodiversity. There is potential for ACRIS partners and the managers of private protected areas and IPA partners to communicate and share in the development of monitoring methods.

There is potential both for regional NRM groups and for the non-government environment sector to contribute a range of more accurate regional data to ACRIS, which would improve the value of ACRIS as a reliable information system for the rangelands. This requires the infrastructure and commitment to allow for a two-way exchange of information between regional groups and jurisdictional NRM agencies. These developments are occurring in some jurisdictions (see, for example, the Arid Lands Information System reported as part of the SA Update in Appendix 1).

Key points

- Indigenous land managers and regional NRM groups are generating requirements for information on the condition and trend of natural resources in the rangelands.
- A number of organisations, such as Aboriginal land councils, assist Indigenous rangeland custodians with information and advice. ACRIS could contribute information to those organisations, for example by:
  - presenting available ACRIS data in ways that assist individual ILMOs to place their data into regional context
  - assisting Indigenous organisations to assess their NRM performance against the broader state, territory and national perspectives provided by current ACRIS reporting
  - potentially acting as a broker for ILMOs to gain better access to jurisdictional datasets.
- ACRIS has potential to assist regional NRM groups in their planning, investment and reporting by providing relevant information (eg change in landscape function) at a suitable scale.
- Information is required by investors, regional NRM groups, environment NGOs and governments to demonstrate the effectiveness of management actions at particular locations in meeting long-term resource condition targets. ACRIS may be able to assist.
- The three key stakeholder groups require data and information at scales (eg the property scale) and regionalisations different from those currently used by ACRIS. ACRIS has used Interim Biogeographic Regionalisation for Australia (IBRA) bioregions as consistent reporting units throughout the rangelands.
- A challenge for ACRIS is how to report at finer or disaggregated levels for local management needs, and also at broader or aggregated levels to help policymakers develop sound policies and investment decisions.

6 ACRIS — data into information

In Chapter 3, a range of datasets are examined for their capacity to report *changes* in, as distinct from the *state* of, the resource condition of the Australian rangelands. Chapter 3 provided an interpretation of what those data indicate about trends within selected bioregions, while Chapter 5 flagged emerging trends in rangelands resource management. This chapter integrates the results of the more targeted assessments in the earlier chapters to show how insights critical to the needs of the key Australian Collaborative Rangeland Information System (ACRIS) users can be drawn from the data at both the national and the regional scales.

The chapter has two major parts.

- *Data integration* — demonstrating the potential of the various datasets available through ACRIS to inform regional and national rangelands issues in an integrated way
- *Refinements to ACRIS* — the current status of ACRIS as an information system and the actions required to develop its functionality.

Data integration

ACRIS seeks to provide information on change in natural resource condition at a scale that is useful to those needing to develop responses to current and emerging issues. Those users include national, state, territory and local governments, regional natural resource management (NRM) organisations, and local community groups. While ACRIS is not currently able to meet the needs of all these users, this report is a significant step towards providing information required to support government legislative and policy initiatives relevant to the management of the rangelands, including:

- the establishment of policy and program priorities and the evaluation of their outcomes
- the evaluation of regional resource management strategies and investment plans developed in the context of initiatives such as the Australian Government's Natural Heritage Trust, and the equivalent approaches of the state and territory governments
- tracking compliance with jurisdictional legislative regimes
- meeting regional, national and international reporting obligations.

The types of issues that the analyses undertaken by the ACRIS seek to address can be grouped into three general categories:

1. *Understanding biophysical functioning of the rangelands*. While much is known at local and regional scales, there is potential value in integrating that knowledge across regions and jurisdictions. Consistent meta-analysis of jurisdictional monitoring data and the systematic interpretation of emergent trends with data quantifying climate variability, fire regimes and components of total grazing pressure should improve our understanding of how the rangelands change and what biophysical processes most influence those changes. More integrated analysis may provide better answers to questions such as the location of areas where agriculture will be profitable and sustainable, and areas of high biodiversity conservation value, the trend in condition of those areas, and their specific management needs.
2. *Identifying trends in resource conditions in the rangelands*. Identified trends could flag the need for responses or interventions at the relevant scale, such as targeted regional investments, changes

to state/territory land tenure arrangements, or coordinated national responses. Information on trends in resource condition is also required to monitor the effectiveness of existing NRM policies or programs in attaining their original objectives.

3. *The capacity of the current arrangements to meet the needs of the ACRIS partners*. At this stage, the main users of ACRIS are the national, state and territory governments. Comprehensive information that they need for the development of effective responses to current or emerging NRM issues might not currently be available from any information source. Improving the relevance of ACRIS to all rangeland users and managers (for example, the regional NRM groups) requires an assessment of the match between the scale of data collection and the scale at which decision-making occurs.

We present three key findings on change:

1. *Landscape function*. The ACRIS data suggest that landscape function recorded on ground-based monitoring sites improved or remained stable, given the seasonal trends experienced in most rangeland bioregions over the 1992–2005 reporting period. It is not possible to link stocking rates at the local scale directly to those changes. However, at a broader scale, regional livestock numbers have remained relatively high during periods of declining *seasonal quality* in some bioregions, suggesting difficulty in maintaining landscape function in those areas.
2. *Conservation of biodiversity*. The data available for ACRIS purposes indicate that there continues to be a decline in biodiversity.
3. *Land values as an economic indicator*. Land values in many parts of the grazed rangelands have increased in recent years.

These findings are then applied to understanding an emerging issue — the growth of the northern beef industry (see Chapter 3) — and possible implications for sustainable land management.

The data focus is on changes from 1992 to 2005 to give a national view, while regional case studies illustrate the diversity of rangelands' responses.

The context for interpreting the key findings

We have interpreted these key findings about environmental change in the light of the most important and defining characteristic of the Australian rangelands: variability. Variability encompasses not only obvious continental-scale climatic variability or the variability in year-to-year weather patterns recorded at a single site, but also includes significant regional variations in land use intensity that may drive or be driven by yet other variables, such as landscape productivity, market access, property size or land values.

In presenting regional and national changes, it is critically important to emphasise the value of interpreting measures of change within a context of *seasonal quality* (see Box 2.1 in Chapter 2 and the Climate Variability theme in Chapter 3 for details). Interpreting the key findings generated by ACRIS involves 'seeing through' seasonal variations when detecting long-term trends. While the importance of seasonal conditions on natural resource condition cannot be overstated, that ACRIS has demonstrated the ability to identify possible management-induced responses is a significant achievement.

The impact of management on long-term trends can most readily be detected when the trends in observed rangeland attributes are at odds with seasonal conditions over the observation period. Between the early 1990s and 2005, *seasonal quality* was generally above average in the monsoonal north and northwest rangelands. *Seasonal quality* in central Australia varied from dry conditions in the mid-1990s to very wet seasons in 2000–2001. Above-average seasonal conditions occurred in most of the Western Australia (WA) and South Australia (SA) shrublands until 2001, and were followed by a lengthy drier-than-average period. In the eastern grasslands and mulga lands, *seasonal quality* was lower throughout the early 1990s to 2000, with drought conditions prevailing after 2000.

The interpretation of management effectiveness based on monitoring data over the 1992–2005 period needs to be made in the context of seasonal conditions during that time (Table 6.1). This interpretation builds

Table 6.1 Interpreting trends in landscape function and stock forage relative to regional *seasonal quality* over the reporting period

Seasonal quality	Trends in landscape function and critical stock forage: Most of the region showing **decline**	Most of the region showing **no change**	Most of the region showing **increase**
Above average	Management has suppressed the expected response. **Further investigation required.**	Management has not allowed the landscape to respond to favourable seasons. **Further investigation required.**	Management has delivered a response consistent with expectations.
Average	Management has not delivered the expected response. **Further investigation required.**	Management has delivered a response consistent with expectations.	Management has delivered a better than expected response. **Investigate, acknowledge and promote.**
Below average	Management has delivered a response consistent with expectations.	Management has limited the impact of below-average seasons. **Investigate, acknowledge and promote.**	Management has had a significantly beneficial impact on the outcome. **Investigate, acknowledge and promote.**

on the *seasonal quality* matrix for understanding biophysical change presented in Chapter 2 (see Box 2.1), and presents a number of possible outcomes of seasonal condition versus rangeland responses at the regional scale.

Where regional declines in landscape function (and/or critical stock forage) have occurred following above-average seasonal conditions, further investigation is required to identify causes, so that more appropriate management responses can be identified and implemented. Similarly, management actions promoting improvements in landscape function despite low *seasonal quality* should be understood, acknowledged and promoted. Individual or grouped monitoring sites with negative trends at odds with a generally positive regional response suggest the need to work at the local or property scale to improve management practices.

Discussion of the key findings

Landscape function and grazing pressure

Landscape function is the capacity of a landscape to capture and retain rainfall and nutrients (Figure 6.1). Fully functional landscapes have a high cover of patches of perennial vegetation that are spatially arranged to efficiently capture runoff and resist wind erosion.

Figure 6.1 A 'leaking' landscape that has reduced landscape function

Low cover and active erosion mean that rainwater and soilborne nutrients (essential resources for plant growth) are lost from the area.

Photo: CSIRO, Alice Springs

Pastoralists, conservation managers and Aboriginal land managers have a key role in managing landscape function by controlling grazing pressure. Landscape function provides a biophysically integrated assessment of landscape condition and resilience.

Key finding: *The ACRIS data suggest that trends in landscape function recorded on ground-based monitoring sites improved or remained stable, given the seasonal trends experienced in most rangeland bioregions over the 1992–2005 reporting period.*

It is not possible to directly link stocking rates at the local scale to those changes. However, at a broader scale, regional livestock numbers have remained relatively high during periods of declining seasonal quality in some bioregions, suggesting difficulty in maintaining landscape function in those areas.

ACRIS has been able to report change at monitoring sites for 36 Interim Biogeographic Regionalisation for Australia (IBRA) bioregions in WA, SA, New South Wales (NSW) and the Northern Territory (NT). In 75% of those bioregions, 10% or less of all reassessed sites showed decline in landscape function following above-average *seasonal quality*. Those changes apply to the local areas of monitoring sites, not the whole of each bioregion.

The Queensland monitoring data are not directly comparable with the site-based data from other rangeland jurisdictions, and it is more difficult to separate management-induced responses influencing change from those due to variable *seasonal quality*. Results are illustrated in Figure 3.8 and suggest that, for the most part, pastoral management has not been overriding seasonal influences. However, 27 of 80 sub-IBRA regions (across 13 bioregions) had a small decline in landscape function, and a further 24 subregions were rated as having a larger decline.

Comprehensive data for total grazing pressure (TGP) are not currently available. Based on livestock numbers, at least 12 bioregions, primarily across northern Australia, had higher stock densities towards the end of the reporting period even though *seasonal quality* was variable (ie not consistently above average). However, there was no pattern of northern bioregions showing differential seasonally adjusted change in landscape function at monitoring sites compared with other bioregions.

There are a number of reasons why a direct response of landscape function to livestock density, if and where it exists, was not detected:

- Monitoring sites can only report change for the local area assessed. Pastoral monitoring programs use explicit criteria to position sites, so bias in site selection and lack of replication and controls mean that results from site-based monitoring cannot be extrapolated to a bioregional scale. Different (and adverse) changes attributable to elevated livestock densities relative to seasonal conditions may have occurred elsewhere but not been detected.
- Sheep and cattle are but one component of total herbivore numbers and, at least for some bioregions, their contribution to TGP may have been modest in seasonally adjusted terms. This is demonstrated by changes in kangaroo densities in the southeastern rangelands (Figures 3.33 and 3.34), where both absolute and relative densities changed considerably between 1992 and 2003. More importantly, the data indicate that there were considerable differences among neighbouring bioregions within years. Comprehensive density data for feral herbivore species are lacking, but it is known that goats contribute significantly to TGP in parts of the southern rangelands, donkeys in the more rugged northern regions and camels in the interior.[54]
- This report focuses on change and does not fully account for the baseline status or condition of landscape function. Where landscape function had declined before 1992, thresholds of change may have been exceeded (Friedel 1991) such that further changes in landscape function between 1992 and 2005 were not closely aligned with *seasonal quality* or measurable stocking density.

Palatable perennial forage species critical to sustained livestock production are a subset of the site-based monitoring data used to report change in landscape function. Thus, it is possible to report changes in critical stock forage relative to domestic stocking density in a way that is similar to the reporting of landscape function.

54 See maps at http://www.anra.gov.au

Figure 6.2 The rangelands contribute much of Australia's biodiversity

Biodiversity has declined in many areas, but ACRIS is not yet able to systematically quantify where and how biodiversity is changing.

Photo: CSIRO, Alice Springs

> **Additional finding:** *Vegetation species used to indicate critical stock forage have remained stable or improved at monitoring sites in 15 rangeland regions despite periods of low seasonal quality and variable stocking density.*

Based on evidence from site-based monitoring, it appears that managers have adjusted stock numbers downwards when faced with difficult seasons. This is illustrated by patterns in the top panel of Figure 3.13. However, there were also declines in stock forage at monitoring sites in these and other bioregions during periods of above-average *seasonal quality* (Figure 3.13 bottom). Thirty-one pastoral bioregions had an adequate density of monitoring sites to allow reporting. For 14 of those bioregions, 10% or more of reassessed sites recorded a decline in critical stock forage following above-average *seasonal quality*.

Similar caveats apply to site-based monitoring of critical stock forage as for landscape function; that is, bias in site selection and lack of replication mean that reported change applies to the local areas of sites and cannot be inferred as having occurred across the whole of each bioregion.

In Queensland, 15 of 80 sub-IBRA regions across three bioregions had high and increasing levels of simulated pasture utilisation (regarded as unsustainable pasture management, Figure 3.14).

As observed for landscape function, some of the decline in northern Australia was associated with high stocking density relative to seasonal conditions (Figure 3.31). However, there was no consistent relationship, as IBRA bioregions elsewhere with stocking densities more closely aligned with *seasonal quality* showed variable changes in seasonally adjusted indicators of stock forage (for the same reasons provided above for landscape function).

The conservation of biodiversity

Rangelands — Tracking Changes (NLWRA 2001a) highlighted the paucity of consistent and relevant data on trends in rangelands biodiversity. While the ACRIS Biodiversity Working Group has sought to identify and develop effective indicators of biodiversity change, the appropriate systems have yet to be developed fully and implemented to monitor that change. Therefore, the assessments in this report document ongoing and increasing pressures on biodiversity, rather than explicitly demonstrating change (Figure 6.2).

> **Key finding:** *The data that are available for ACRIS purposes indicate that there continues to be a decline in biodiversity.*

For example, data collected by the volunteer participants in the national-scale Birds Australia Atlas project demonstrate declines in detection rates for a number of bird species.

A number of measures of land use intensification may provide surrogate measures of biodiversity decline. This report shows that the number and density of artificial waterpoints in the most productive arid and semiarid pastoral regions have considerably reduced the area of land remote from water and subjected it to increased grazing pressure. Such water-remote areas are recognised as providing de facto refuges for species known to decline in response to grazing pressure (James et al 1999, Landsberg et al 2003). Similarly, while the colonising ability and high productivity of exotic pasture species such as buffel grass enhance their value as a pastoral resource, those same characteristics result in impacts on biodiversity, for example through changes in fire regimes and competition with native plant species and habitat.

One nationally available biodiversity indicator is progress towards the achievement of a national system of protected areas that is comprehensive, adequate and representative of the full range of ecosystems or biomes (CAR).

Additional finding: *The number and extent of areas set aside for the long-term protection and management of biodiversity increased across a number of rangeland bioregions over the period from 2000 to 2004 (Figure 3.52).*

For many rangeland bioregions, however, the percentage area reserved or protected for biodiversity conservation remains inadequate according to CAR principles. Considerable investment has been made in increasing the extent of protected areas within some areas of the rangelands (eg the Gascoyne–Murchison area), but there are still gaps in representativeness and adequacy.

One way to complement the long-term protection of areas with important habitats for biodiversity is through management agreements for biodiversity conservation between governments and individual landholders on pastoral leases. Conservation of biodiversity on privately managed land is being achieved through the use of market-based instruments and stewardship programs in some areas. For example, a stewardship program in which landholders are recompensed for managing for specified biodiversity conservation objectives is being tested in western NSW (see 'Information needs of the non-government environment sector' in Chapter 5). This may be particularly important in those areas where there are limited opportunities for the acquisition of properties for the National Reserve System, or for the protection of species where change due to factors such as enhanced climate variability may impact on the ability of the current reserve system to deliver future conservation objectives.

Land values

Key finding: *Land values in many parts of the grazed rangelands have increased in recent years.*

Increases in land values have been in the order of 150% to 300% over the reporting period (Tables 3.21 to 3.24). In NSW, at least, there is evidence that increased land values are linked to the increase in property values in cities and the more closely settled rural land.

For those wishing to purchase rangeland pastoral enterprises, high land values may impose a substantial financial burden, which could add to existing pressures on the land as purchasers seek a real return on their investment. On the other hand, the increased value of the land may lead to it being managed more sustainably in order to retain its value.

Increasing land values also affect organisations with a primary interest in non-pastoral land uses, for example through property acquisition or stewardship programs for biodiversity conservation. It is often those subregions that are the most productive for pastoral or agricultural purposes (and that have usually shown the greatest price rises) that remain under-represented within the conservation estate.

Understanding an emerging issue: the sustainability of the northern beef industry

Meta-analysis of datasets available to ACRIS provides an improved understanding of emerging issues across broad regions of the rangelands. For example, generally good seasons and buoyant cattle prices have boosted the northern beef industry over most of the 15-year reporting period (Figure 6.3). An important issue for the industry is whether it can remain sustainable (economically and environmentally) in the longer term at current levels of grazing intensity. Evidence of the sustainability of the northern beef industry, based on a synthesis of available and relevant ACRIS data, is presented in this section.

The dramatic improvement in the economics of the northern beef industry has seen stock numbers increase, grazing infrastructure increase and land use intensify in some areas. For example, the number of pastoral leases in the Sturt Plateau bioregion increased from nine in the late 1970s to 27 in 2002. The subdivision of leases into smaller portions and associated infrastructure development (additional waterpoints, fences and yards) have provided better herd and land management and greatly assisted fire control programs across the region.

Figure 6.3 Expanding live exports of cattle from northern ports have boosted the profitability of the northern beef industry

Photo: Arthur Mostead

Thirteen bioregions of the NT are located in northern Australia (ie from the Mitchell Grass Downs north). Nine of the bioregions currently have cattle raising as a major land use, and seven of those had increased stocking densities over the reporting period compared with the average for the 1983–91 period. This intensification has mainly occurred in alignment with good seasons. How management responds to a run of less favourable seasons and whether stock numbers are appropriately reduced will test the sustainability of the northern beef industry. An efficient monitoring system that can deliver timely information to pastoralists and land management agencies about trends in landscape function and critical stock forage is critical to guide high-intensity or high environmental risk management systems in this intensifying industry.

The prospect of increased returns from intensified land use and concerns about associated environmental impacts have prompted new investment in research and development work in the area, supported by at least one corporate cattle company, CSIRO and state/NT agencies (Petty et al 2006). Some of the major pastoral companies are implementing environmental management systems aimed at continuous improvement in resource management.

Integration of data for five bioregions

In this section, we examine five IBRA bioregions to illustrate regional diversity, and show how the integration of data across a number of themes can provide insights into regionally important issues, particularly in relation to varying pastoral management practices.

Some of the selected bioregions coincide with the focus bioregions presented in Chapter 4, but others have been chosen to emphasise regional variation in NRM issues and scale of management across the rangelands. The five case study bioregions were chosen for their national spread, their climatic and environmental variability, and their widely varying NRM history, condition and trends.

Desert Uplands (central Queensland)

The Desert Uplands bioregion covers an area of 68 850 km^2 in central Queensland (Figure 2.3). It is dominated by sandstone ranges and sand plains, and is thickly vegetated with acacia and eucalypt woodlands, often with a spinifex understorey. Rain normally falls over summer. Most of the bioregion is under leasehold tenure and is used for cattle grazing, with some sheep grazing in the west.

Over the past 15 years, leaseholders have intensified their land use to take advantage of improved markets for live cattle. Intensification has involved clearing (particularly in the Jericho sub-IBRA region), establishment of buffel grass pastures, herd upgrading and investment in new fences and waterpoints.

This intensification occurred through a period of good seasons in the late 1990s. However, data collected through ACRIS suggest that stocking densities continued to remain high through the drought years after 2000 (Figure 3.31), when

Figure 6.4 Open woodland in the Desert Uplands bioregion

A deep sandy red Kandosol supports a sparse mid-tall woodland of yellow jacket (*Eucalyptus similis*) and gum-topped bloodwood (*Corymbia brachycarpa*) with an understorey of wattles (*Acacia* spp.) and desert heather (*Calytrix microcoma*) — in flower — and a ground layer of gummy spinifex (*Triodia pungens*).

Photo: Mal Lorimer, Queensland Environmental Protection Agency

seasonal quality markedly declined and modelled levels of pasture utilisation were high (Figure 3.14). Interpreting the reasons for those responses is difficult, but the apparent slow response by rangeland managers to reduce stock densities in line with low *seasonal quality* after 2000 suggests that parts of the Desert Uplands bioregion were under considerable grazing pressure at that time, as evidenced by low levels of stock forage from 2002 to 2004 (right panel, Figure 3.31). Alternatively, it may have been that *seasonal quality* was better than that indicated by rainfall and simulated pasture biomass, or managers were supplementary feeding their stock at increasingly higher rates.

The bioregion is ecologically diverse, with 77 regional ecosystems described. More than 1400 plant species have been recorded, 8 of which are listed as threatened under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) (Figure 3.55), and 33 of which are listed under Queensland's *Nature Conservation Act 1994* as endangered, vulnerable or rare. Thirteen vertebrate species are listed as threatened under the EPBC Act (Figure 3.56), but 33 are listed as threatened under Queensland legislation. Although 28 of the 77 listed regional ecosystems are currently represented in the reserve system, 45% of all regional ecosystems remain outside of protected areas. There has been no increase to the protected area system in the Desert Uplands since 2000 (Figure 3.52). Since the late 1980s, a high rate of tree clearing in the Desert Uplands has led to a 15% reduction in the area of woody habitat through much of the bioregion. Most clearing has been concentrated in the south of the bioregion (Jericho sub-IBRA, Figure 3.64) and in alluvial land systems.

Nevertheless, one of the significant ecosystems for biodiversity in the Desert Uplands — the open woodland of Queensland yellow jacket (*Eucalyptus similis*) and other bloodwoods on deep red earths — is still relatively intact in the bioregion (Figure 6.4). This ecosystem has historically been lightly grazed and is important for declining woodland bird species, as habitat for two rare endemic skinks (*Ctenotus rosarius* and *C. capricorni*), and for a rare species of acacia, White Mountains wattle (*Acacia ramiflora*).

Pilbara (northwest WA)

The Pilbara bioregion in the northwest of Australia (Figure 2.3) is a large and varied region (Figure 6.5) with spectacular mountain ranges, large river catchments and extensive coastal plains. The climate is arid to tropical, with most of the average annual rainfall of about 300 mm associated with cyclones between November and March. Because of the cyclonic nature of the rainfall, annual climate variability is very high. The vegetation consists of tussock and hummock grasslands, with spinifex (*Triodia* spp.) dominating. Buffel grass has extensively colonised the river frontage floodplains in the western area (the most valuable grazing lands) and is encroaching on other riverine systems and transport corridors in the eastern parts.

Based on land use data provided by the Bureau of Rural Sciences (reviewed in Chapter 3), about two-thirds of the bioregion is pastoral leasehold land, with 15% of the leases held by Indigenous communities and a similar proportion held by mining companies. Cattle replaced sheep in the 1970s and 1980s as the terms of trade for wool production in the area deteriorated sharply.

The region has experienced above-average *seasonal quality* for nearly all of the 1992–2005 period, with the exceptions being dry conditions in coastal areas in 2003 and throughout the region in 2004–2005. The reporting period coincided with growth of the live-export market for cattle and improvements

Figure 6.5 Long red dusty outback road in the Karinji National Park in the Pilbara region

Photo: Newspix / Nathan Richter

in cattle husbandry such as more effective weaning, increased fencing and herd upgrading with Brahman-type (*Bos indicus*) genetics.

In response to these favourable conditions, stock numbers rose to be about 40% higher in 2005 than the average for the eight-year period before 1992 (Figure 3.30). This dramatic increase in stock numbers has been encouraged by good seasons, improved markets and intensification. Given that several of the leases held by Indigenous communities are running relatively few cattle, grazing intensity is likely to be even higher on the remainder of the leases.

The data for trends in landscape function and indicators of critical stock forage based on the frequency of perennial grasses suggested that those areas represented by ground-based monitoring sites had either remained stable or improved over the past 15 years (Figures 3.7 and 3.12). However, seasonal conditions were very good throughout much of the mid-to-late 1990s. Since then, conditions have been much drier; however, stock numbers appear not to have decreased in response (Figure 3.30).

Large declines in perennial grass frequency have already been observed on Western Australian Rangeland Monitoring System (WARMS) monitoring sites in the coastal Pilbara. Continued monitoring will show whether those grasses recover when wetter conditions return or the combination of low rainfall and high grazing pressure has resulted in longer-term decline. While the mismatch between grazing pressure and rainfall in the remainder of the Pilbara has not shown up in the monitoring results presented here (to the end of 2005), WARMS monitoring is ongoing. If conditions remain dry and stock numbers remain high, it is likely that perennial grass frequency will decline, with the consequent risk of further rangeland degradation.

Sturt Plateau (NT tropical savannas)

The Sturt Plateau bioregion covers 98 500 km^2 towards the drier margins of the tropical woodlands and savanna lands of northern Australia (Figure 2.3). The landscape is flat to gently undulating plains with little local relief. The vegetation is mainly eucalypt forests and woodlands dominated by bloodwoods over perennial grasses (Figure 4.32).

The main land use is cattle grazing, with pastoral leases covering about 70% of the bioregion. Many of the enterprises have been established over the past 30 years as groundwater investigations, increased drilling activity and water reticulation have provided additional reliable sources of stock water. Most of the enterprises are smaller than elsewhere in the NT (about 1100 km^2), and most are family owned and operated. The improved economics of the cattle industry in the NT over the past decade is encouraging ongoing infrastructure development of waterpoints and improved fire control technologies. Those infrastructure developments have influenced property values, with the unimproved land value of pastoral leases increasing by 45% (Table 3.22) on average between 1991 and 2003 (adjusted to the 2005 dollar value).

In line with much of northern Australia, most of the Sturt Plateau experienced above average *seasonal quality* over the period from 1992–2005 (Figure 4.34). This run of favourable seasons and increased waterpoint distribution has encouraged landholders to increase stock numbers across the region (Figures 3.29 and 4.36), with the domestic stocking density in 1994 being higher than the average for the 1983–91 period. High stock density was maintained until 2000, when the wet years led to a further increase in 2001 and 2002, and then declined slightly through 2003 and 2004.

Based on vegetation data collected at monitoring sites, a small proportion (6%) of sites assessed following above-average *seasonal quality* showed decline in landscape function (Figure 3.8, bottom map). Some of the decline was attributed to extensive wildfire following the extended period of above-average rainfall in the early part of this decade. The decline was temporary, with landscape function found to be restored at most sites when they were reassessed in 2004. There was a similar result for critical stock forage species: 8% of sites had a decline in the composition of palatable perennial grasses following above-average seasonal conditions (Figure 3.13, bottom map).

While there were relatively small adverse changes in landscape function and critical stock forage during the reporting period, the potential impact of excessive grazing pressure on land and vegetation condition with the return of drier years remains to be seen. As for much of northern Australia, land managers in the Sturt Plateau bioregion may need to destock quickly following a failed wet season to avoid resource degradation. The ability of existing monitoring programs to continue to track change is important, in the light of climate variability.

Mitchell Grass Downs (NT and Queensland)

The Mitchell Grass Downs bioregion is one of the largest in Australia, covering 335 000 km^2 and extending from Elliott in the NT to Tambo in Queensland (Figure 2.3). This distinctive landscape is composed of cracking clay soils supporting mostly treeless Mitchell grasslands, crossed by occasional rivers and floodplains, and interspersed with some minor ridges. The climate is dry monsoonal to subhumid tropical, with an average rainfall of 330 mm occurring over the summer months.

There are two main subregions: the treeless, monsoonal northern lands roughly between Winton and Tennant Creek (Figure 6.6) and the open woodlands between Winton and Tambo (Figure 4.16)

The western half of the northern section of this bioregion in the NT is known as the Barkly Tableland. Land use is cattle grazing throughout, with the industry dominated by very large properties operated by corporate businesses. In many cases, the properties on the Barkly Tableland are run in conjunction with cattle properties, feedlots and processing facilities elsewhere in Australia. This makes the region an important link in a national beef-production chain. Stronger terms of trade for beef cattle operations in northern Australia have encouraged investments in intensification.

Stocking density increased consistently with generally above-average rainfall between 1994 and 1997 and then levelled off with close-to-average *seasonal quality* between 1997 and 1999. Density then increased sharply with above-median rainfall in 2000 and 2001 and remained high following the return to more normal rainfall between 2002 and 2004. Stocking density has been much above the 1983–1991 average since at least 1995.

Based on monitoring data collected by the NT Government, 13% of sites showed a decline in landscape function (Figure 3.8, bottom map) and 10% had reduced palatable perennial grass composition — that is, a decline in critical stock forage (Figure 3.13, bottom map) — when assessed following above-average *seasonal quality*. Significantly, 36% of reassessed sites had increased landscape function and 33% had increased critical stock forage after below-average *seasonal quality* (Figures 3.8 and 3.13, top maps, respectively). These relatively large seasonally adjusted changes, compared to those reported elsewhere, suggest considerable within-region variation that possibly relates to management differences among pastoral leases. The changes emphasise the need for

Figure 6.6 Treeless Mitchell grass downs, Barkly Tableland, NT

Photo: NT Department of Natural Resources, Environment and the Arts

continued monitoring (particularly where stocking density is high relative to seasonal conditions) and also suggest that there is value in more local investigation to determine why (and where) changes are counter to seasonal expectations.

In the remaining Queensland area, cattle have now largely displaced sheep as the dominant stock, although the proportion of sheep increases as the likelihood of effective winter rainfall and consequent availability of winter herbage increases towards the southern extremity of the bioregion. Holdings are mostly smaller than on the Barkly Tableland, and mostly owned by family businesses. *Seasonal quality* has been variable over the assessment period, but there were three good years between 1999 and 2001 (Figure 4.17). Combined stock numbers increased in response and then fell in recent drier years, but still remained above the average for the 1983–91 period (Figure 4.20). Ground-based monitoring data indicate a significant decline in landscape function for one subregion and some loss of function for a further five subregions (Figure 4.18). Modelled levels of pasture utilisation (indicating sustainability of stock forage) were close to critical thresholds, and therefore of concern, for two subregions (Figures 3.14 and 4.19).

The invasion of grasslands by transformer weed species — prickly acacia (*Acacia nilotica*) in Queensland, and parkinsonia (*Parkinsonia aculeata)* and mesquite (*Prosopis* spp.) across the whole bioregion — is a significant threat to biodiversity and other ecosystem services. In the Queensland area of the bioregion, 54 regional ecosystems have been described and only one small regional ecosystem involving mound springs, is endangered. Since 2000, there has been an increase of less than 2% in the area protected within the reserve system (Figure 3.52), in which two of the five listed regional ecosystems are represented. The number of standardised flora surveys and, in particular, fauna surveys conducted in the bioregion is extremely small (Figure 3.73). Twelve plant species and 15 vertebrate fauna species found in this bioregion have been listed under the EPBC Act, including the desert rat kangaroo (*Caloprymnus campestris*), believed to be nationally extinct, and the western quoll (*Dasyurus geoffroii*), which is now restricted to south-west Western Australia and listed as vulnerable. A distinguishing feature of the Mitchell Grass Downs biota is the soil-crack specialist, which includes rare endemic species such as Collett's snake (*Pseudechis colletti*) and the endangered Julia Creek dunnart (*Sminthopsis douglasi*).

Mulga Lands (Queensland and NSW)

The Mulga Lands bioregion is in southwestern Queensland and northwestern NSW (Figure 2.3), and has an area of 258 000 km^2. The landscape comprises undulating plains and low hills on Cainozoic

Figure 6.7 Mulga shrubland, Mulga Lands bioregion, NSW

Photo: NSW Department of Environment and Climate Change

sediments with red earths and lithosols. The vegetation is dominated by mulga (*Acacia aneura*) shrublands (Figure 6.7) and low eucalypt woodlands. The climate is semiarid, with highly variable summer-dominant rainfall. The spatially averaged median rainfall is 305 mm per year.

The NSW section of this bioregion lies west of the Darling River. Grazing leasehold is the major tenure, and these rangelands have traditionally been used for sheep production on relatively small family-held properties (average lease area of 3725 ha for land parcels larger than 10 ha; most grazing enterprises larger than the average). Declining profitability of wool growing and inadequate property size to enable economic and environmental sustainability are problems throughout the Western Division of NSW. In recent years, diversification from merino sheep to meat-sheep breeds and meat goats has occurred.

In NSW, landscape function and critical stock forage levels have been assessed annually over the reporting period at 19 sites across the bioregion, providing 249 year-to-year recordings. Annual measurements made at sites between 1992 and 2005 show that landscape function improved at 13% of sites, declined at 9%, and showed no change at 78% (Figure 3.7, top panel). These results seem to reflect the variable seasonal conditions throughout this period; they are supported by seasonally interpreted results that show that, across all years, only 3% of assessed sites had a decline in landscape function following above-average *seasonal quality* and 5% of site-by-year assessments had increased landscape function after below-average seasonal conditions (Figure 3.8).

Notwithstanding the difficulty in interpreting data over time, these examples illustrate how various datasets can be used to highlight regions where further investigation is needed (Table 6.1). Collating better local-scale data to determine whether stock (and kangaroo) densities were actually too high for the seasonal conditions would suggest management actions that might need to be taken.

In the Queensland area of the bioregion, similar industry dynamics apply and a regional strategy attempted to correct some of the most serious concerns. The Queensland area has experienced a protracted period of very dry years during the 1992–2005 reporting period. Low pasture abundance and high woody shrub cover are common. Poor *seasonal quality* over much of the 14-year period accompanied ratings of reduced landscape function and modelled availability of stock forage. However, only two of the 11 Queensland sub-IBRA regions showed an unexpectedly poor change in ratings for landscape function for the prevailing seasons. This is despite the overall assessment that, based on groundcover and predicted forage growth, landscape function and stock forage availability are relatively poor (Figure 3.8).

In the Queensland Mulga Lands, 65 regional ecosystems have been described. Of those, three are considered to be regionally endangered by overclearing or overdevelopment, while five are considered to be of concern because their extent has been reduced to below 30% of their estimated pre-clearing extent. Since 2000 there has been a less than 2% increase in area under protection (Figure 3.52); three of the five Queensland listed regional ecosystems are represented, but at less than 4% of their preclearing extent. Very few standardised biodiversity surveys have been conducted for the bioregion (Figure 3.73). Eight plant species and 14 vertebrate fauna species have been listed under the EPBC Act, including *Sclerolaena walkeri* (a rare chenopod plant) and the greater bilby (*Macrotis lagotis*). Although the rate of clearing in the bioregion was relatively high, particularly in the eastern subregions, in the years 1991–2003 (Figure 3.64), most (80%) of the region remains wooded. Consequently, the bioregion is important for woodland birds, including Hall's babbler (*Pomatostomus halli*), a species with a limited range.

Informing responses to changing pressures on the rangelands

The preceding sections provide examples at national and regional scales of how the various data compiled for this report can be integrated to provide a more complete picture of aspects of environmental, social and economic change in the rangelands. A number of NRM issues, such as invasive animals, weeds and altered fire regimes, continue to threaten both production and biodiversity values in parts of the rangelands. This section discusses those pressures where data compiled in this report (Chapter 3) could help inform the management and policy responses required for control or alleviation.

Fire regimes

High-frequency, high-intensity or large-scale fires can damage rangelands, especially across northern Australia, where up to 30% or 40% of some tropical savanna ecosystems burn each year. The environmental impact of more intense and large-scale fire regimes is uncertain, but there is increasing evidence to suggest that this changed fire regime contributes to the decline in biodiversity at a range of scales (Woinarski et al 2000a). The introduction of fire regimes that reduce large-scale and hot damaging fires, and promote a diversity of burning patterns typically involving small low-intensity burns, offers an opportunity to limit long-term biodiversity decline while achieving adequate tree regeneration control.

A national system for reporting fire extent, intensity and frequency is now in place, and the ACRIS fire information product (Chapter 3) demonstrates emerging information for the rangelands. There is also evidence from the Sturt Plateau bioregion (NT) and elsewhere that regional communities working with government can manage fire in northern Australia for improved production and conservation outcomes.

Climate variability

Chapters 2 and 3 document the importance of rainfall variability as one of the major drivers of change in the rangelands. Managing the land to take account of that variability and longer-term climate change in order to ensure sustained production and biodiversity conservation is a key challenge for the future.

Predicted changes in climate include increased rainfall intensity and cyclone incidence across northern regions, and decreased rainfall amounts and changing seasonal patterns across southern and southeastern regions. It is possible that the above-average *seasonal quality* and consequent increased fires in the northern rangelands over the past 15 years are part of longer-term climate change. If these trends continue, flora and fauna dynamics will undoubtedly change in ways that are not yet clear. This increases the importance of ACRIS providing information on changes as they occur.

Grazing pressure from stock and kangaroos

The long run of good seasons in many regions has encouraged landholders to increase stock numbers and intensify land use, especially in the northern beef industry. This has potential to increase the environmental risk associated with higher grazing pressures. Land management agencies need to be alert to the higher risk, particularly if drier conditions are experienced in the immediate future.

Pastoral development has increased artificial sources of water in the rangelands, contributing to increased kangaroo numbers and the expansion of domestic grazing and feral herbivore populations.

Kangaroos continue to be a significant component of TGP in the southern and eastern rangelands, where they contribute between 20% and 40% of the livestock grazing pressure. This contribution is higher in the more arid, predominantly sheep-grazed, bioregions. There is considerable year-to-year variation in the relative contributions of kangaroos and livestock to TGP. It is important that data from the continuing surveys of kangaroo populations conducted by most rangeland jurisdictions are analysed and reported using agreed standardised methods in order to quantify the seasonally and regionally variable contribution of kangaroo species to TGP.

The other significant contributor to TGP in the rangelands is regionally significant populations of feral herbivores. As yet, density data are inadequate to quantify their contribution to TGP in standardised units (eg dry sheep equivalents). Information is accumulating (Chapter 3), and updates will be largely web based.[55]

Water remoteness

Increased water distribution in many regions (Figure 6.8) has reduced the area of land remote from water — a critical refuge for biodiversity. Given that the level of reservation for biodiversity conservation is inadequate in many regions, water-remote areas can make an important de facto contribution to achieving some regional objectives in biodiversity conservation, provided those areas are managed with an appropriate fire regime and weeds and other pests are controlled.

[55] http://www.anra.gov.au

Figure 6.8 Waterpoints for stock have favoured some species of plants and animals and have been detrimental to others

Water-remote areas that are managed appropriately can assist in conserving biodiversity.

Photo: CSIRO, Alice Springs

Weeds

According to a recent review of weeds (Grice and Martin 2005), the Australian rangelands currently support more than 640 non-native naturalised plant species, including a diverse range of trees, shrubs, grasses, forbs and aquatic plants, all at various stages of invasion. Of those weeds, 92 species were identified as posing a significant threat to rangeland biodiversity.

Weeds tend to be highly habitat dependent and context specific. As a general rule in the subtropics, a perennial tall tussock or rhizomatous grass, with its main growing period in summer, can be guaranteed to reduce the richness of native plant species (Grice and Martin 2005).

The developing capacity to map the current and potential extent of a number of these species has been documented (Chapter 3). As that capacity expands, ACRIS should be better placed to provide more comprehensive information on changes in weed species, and their impact, in the rangelands.

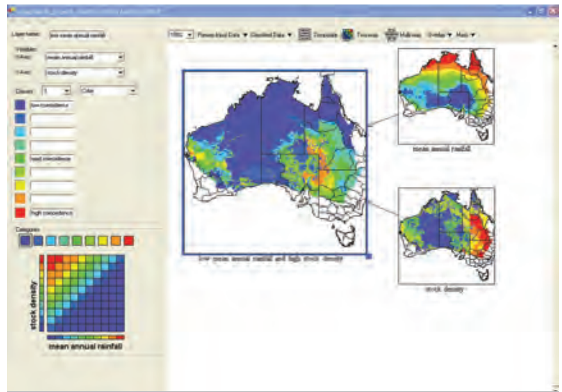
Using ACRIS to inform decision making

By building national capacity to collate rangeland information and monitor and report on conditions on the ground, ACRIS is providing a picture of where changes are occurring in the rangelands. However, charting the course to sustainability requires an understanding of the relationships and processes leading to those changes. Answering such questions as 'What are the constraints and opportunities for further development of grazing and agricultural industries?' or 'Where is there tension between pastoral production and the desire to conserve native flora and fauna?', and then developing an appropriate policy response, involve the integrated analysis of a wide range of social, economic and environmental information. This is a complex exercise for the rangelands because of the diversity of environmental, economic, and social factors affecting outcomes, the limited availability of longer-term pattern and trend information, and the wide range of community views and aspirations.

This complexity points to the need for techniques and tools that can provide a better understanding of the economic, environmental and social factors driving rangelands systems and help in evaluating alternative land use and management options. More tools are needed for examining complex relationships in ways that promote the engagement of stakeholders and allow for alternative views. Multi-criteria analysis (MCA) is one such tool (Figure 6.9).

One area where suitable data and MCA may assist is the complex issue of the extent to which livestock grazing in the rangelands is sustainable. Grazing management can be characterised as sustainable when economic resilience and stability can be achieved in conjunction with regional maintenance of native species and other ecosystem services.

Figure 6.9 Multi-criteria analysis allows complex relationships between economic, environmental and social datasets to be explored



The Multi-Criteria Analysis Shell for Spatial Decision Support (MCAS-S) tool promotes engagement of stakeholders in exploring the alternative views that these data may provide. This example explores the spatial coincidence between relatively low mean annual rainfall and high stock density in the Australian rangelands.

Source: Rob Lesslie, Bureau of Rural Sciences

Sustainability may be under threat where there is potential for pastoral production but ecosystems have limited resilience, creating a threat to the resource base and conservation values. Informed public policy requires an understanding of regional variability and where in the landscape these ecological and economic controls are operating.

Previous work has argued that the trade-off between potential productivity for pastoralism and ecosystem resilience differs by bioregion, and that policy and management responses need to be tailored accordingly (Stafford Smith et al 2000). A spatial multi-criteria modelling approach, using the Multi-Criteria Analysis Shell for Spatial Decision Support (MCAS-S) model (Hill et al 2006, Lesslie et al 2006)[56], was applied to explore regional variability in this relationship. Model outputs may be tested against change data compiled by ACRIS.

Potential productivity for livestock grazing in the rangelands was spatially represented by weighted indices of forage potential, rainfall reliability and

56 http://adl.brs.gov.au/mcass/ (accessed 10 June 2008)

accessibility to services. Ecosystem resilience was similarly mapped using available spatial surrogates. Weighted combinations of mapped values for production potential and ecosystem resilience were then explored for spatial congruency and possible tension.[57]

Policy implications arise from the interplay between potential productivity based on the natural resource base and its sensitivity to risks of damage from livestock grazing. Analysing the relationships between these types of factors can assist in targeting policies more effectively, promoting appropriate development and ensuring that available incentives improve management practices. This could include measures such as specific public investment in regional restructuring and negotiated trade-offs or, at the property scale, application of negotiated stewardship agreements to achieve NRM goals.

ACRIS — refining the information system

The second major part of this integrating chapter summarises the current capacity of ACRIS to transform data into information. It then describes how ACRIS might logically develop to provide a more complete information system for the rangelands.

Producing this report has highlighted the value of long-term, consistent datasets, such as that provided through monitoring the pastoral estate; for example, suitable datasets have enabled reporting on changes in vegetation. Through integration with other datasets, where available (eg domestic stocking density, kangaroo density, fire frequency and wind erosion), analysis can provide more robust interpretations of changes in resource condition and biodiversity assets.

This first attempt to bring rangelands information together in an integrated way does not purport to be a robust product — but it has proved that the task can be achieved. However, the compilation of the report has also highlighted deficiencies, limitations and gaps in existing datasets. The ability to report in a nationally consistent manner on aspects of the rangelands environment has been limited by those deficiencies.

ACRIS in 2008

An 'information system' comprises data, technical infrastructure, institutional arrangements and people. It allows the collection, management, use and dissemination of data and information to report against specific needs and to support decision-making. Currently, the information system element of ACRIS is not a physical, technically integrated system. It is a partnership arrangement that brings together available data and information for manually intensive collation, analysis and reporting, coordinated by the ACRIS-MU (Figure 6.10) on behalf of the ACRIS-MC. ACRIS parallels other information systems for natural resources (Box 6.1); some are well established and others are still developing.

Data contributing to current ACRIS reporting mainly come from two sources:

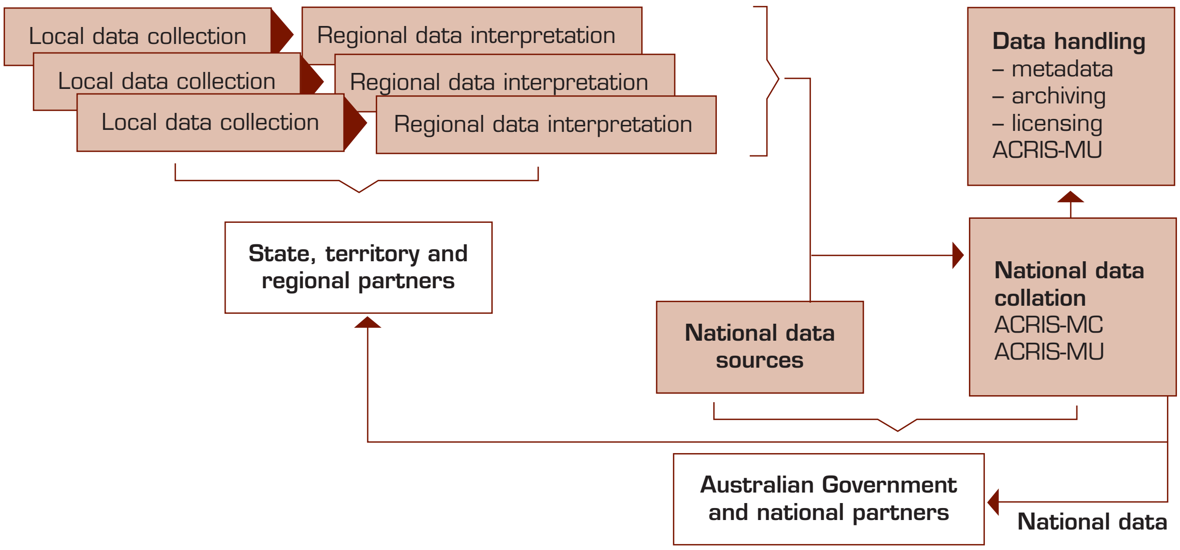
- state and NT data collected by ACRIS partners for their own statutory or advisory monitoring and reporting purposes (eg pastoral monitoring activity undertaken by a state government, see Appendix 1)
- national-level data (eg climate or ABS data), which provide broader context to the state and NT data (nationally collated databases come from Australian Government and in some cases state agencies, depending on the subject matter).

ACRIS is dependent on the ongoing commitment of the states and the NT to maintain (and improve) current monitoring programs and, through participation in the ACRIS-MC, to contribute their data to collaborative and systematic analyses that allow consistent national reporting.

The Australian Government's investment through the Natural Heritage Trust in the collation, integration, synthesis and reporting of the jurisdictional datasets has provided the impetus for establishing a system capable of identifying trends in rangeland condition.

57 The outcome of this analysis, highlighting regions where tensions may exist, can be seen at http://affashop.gov.au/PdfFiles/rangelands.pdf, p 11 (accessed 10 June 2008).

Figure 6.10 ACRIS as a rangelands information system



A future for ACRIS

Data and information reported by the ACRIS are of immediate value to the jurisdictions in meeting their responsibilities for sustainable rangeland management. The relevance of ACRIS to other stakeholders — such as regional NRM groups, industry organisations, Indigenous land managers, the non-government conservation sector and the broader community — is emerging as an important issue. Better understanding of the specific information needs of those users (Chapter 5) and how their needs can be met would further increase the relevance and use of the system, particularly as a repository of interpreted information.

ACRIS could be progressively improved by:

- strengthening the ACRIS partnership, particularly where the current relationship is somewhat peripheral (eg with Indigenous and NRM groups)
- clearly articulating the additional data and information needed for the management of rangelands natural resources
- targeting investment in ongoing and new natural resource monitoring programs
- all partners agreeing to collect data and information independently of any regionalisation (further reporting of change can then undertaken for differing regionalisations depending on the information requirements of the various ACRIS stakeholders).

Conclusions

In producing this report, the ACRIS-MC has used available data to identify the influence of climate variability and better identify trends in natural resources attributable to the actions of land managers.

This first attempt to document these trends at a national scale has shown that, where suitable data are available, it is possible to detect such changes (particularly in relation to pastoral productivity) in a way that can be meaningful to government policy and program managers, regional decision makers and others with an interest in sustainable rangeland management. This is a significant advance on earlier ACRIS products (NLWRA 2001a).

It is important to recognise that these efforts to track natural resource change were undertaken (and to a certain extent achieved) in the context of generally limited reliable data on the base condition of the resource. This is one of the next challenges for ACRIS — to better determine current resource conditions so that future change truly identifies trends.

Both the insights gained through the analysis of currently available data, and the identification of data gaps as documented in this report, provide a sound basis for this rangeland information system to continue to meet emerging information needs in the future.

Box 6.1 Guide to natural resource information systems

Water

Australian Water Resources 2005

Australian Water Resources 2005 provided a baseline assessment of water resources at the beginning of the National Water Initiative. There were two levels of reporting:

- high-level management indicators of water availability and river and wetland health
- water availability, water use, and river and wetland health.

More information is available at the Australian Water Resources website[a].

The Australian Water Availability Project

The Australian Water Availability Project will develop an effective system for estimating soil moisture and other components of the water balance across the continent at 5-km resolution or finer (eg 1 km). Information products (including maps) will provide the water resource information required to increase drought preparedness and improve risk management, and will promote the sustainable use of natural resources. The project will help explain crucial links between water availability and the climate.

More information is available at the project website[b].

Water Resources Observation Network

The Water Resources Observation Network, when developed, will provide information about current water availability, expected future availability, water entitlements (irrigators, industry, urban) and conditions of access. The system is expected to be fully functional by 2010.

More information is available at the network's website[c].

The Great Artesian Basin Sustainability Initiative

The Great Artesian Basin Sustainability Initiative supports artesian bore rehabilitation and bore drain replacement works. The aim is to reduce the amount of Great Artesian Basin groundwater being lost through seepage and evaporation from open bore drains fed from uncontrolled bores.

More information is available at the Queensland Natural Resources and Water website[d] and the SA Department of Water, Land and Biodiversity Conservation website[e].

Land and soil

The Australian Collaborative Land Use Mapping Program

The Bureau of Rural Sciences (BRS), state/territory agency partners and other organisations are working collaboratively to develop a nationally consistent approach for the production of land use information across Australia. National scale land use mapping is available for 1992–93, 1993–94, 1996–97, 1998–99, 2000–01 and 2001–02. Catchment-scale land use data are expected to be completed for Australia by the end of 2007.

More information is available at the BRS website[f].

Australian Soil Resource Information System

The Australian Soil Resource Information System provides online access to the best publicly available information on soil and land resources across Australia in a consistent format. Information is available at seven different scales, from general descriptions of soil types, landforms and regolith across the continent to more detailed information in regions where mapping has been completed.

More information is available at the Australian Soil Resource Information System website[g].

Vegetation

National Vegetation Information System

The National Vegetation Information System (NVIS) is a collaborative initiative between the Australian and state/territory governments to manage national vegetation data to help improve vegetation planning and management. NVIS provides a comprehensive and consistent means of describing and mapping vegetation across jurisdictional boundaries. Further information on NVIS is available at the NVIS website[h].

[a] http://www.water.gov.au (accessed 10 June 2008)
[b] http://www.csiro.au/science/ps2by.html (accessed 10 June 2008)
[c] http://wron.net.au (accessed 10 June 2008)
[d] http://www.nrw.qld.gov.au/water/gab (accessed 10 June 2008)
[e] http://www.dwlbc.sa.gov.au/water/projects/gabsi.html (accessed 4 April 2008)
[f] http://adl.brs.gov.au/mapserv/landuse/ (accessed 10 June 2008)
[g] http://www.asris.csiro.au/index_ie.html (accessed 10 June 2008)
[h] http://www.environment.gov.au/erin/nvis/index.html (accessed 10 June 2008)

Appendix 1 Jurisdictional reporting

This appendix provides an update on the jurisdictional monitoring activity reported in *Rangelands — Tracking Changes* (NLWRA 2001a). Programs provided by Australian Government agencies to support jurisdictional reporting are also described.

Western Australia

Rangelands make up about 87% of WA and include all but the southwest of the state. Livestock grazing on pastoral leasehold land is the dominant commercial land use across about 42% (910 000 km^2) of the WA rangelands. There are about 460 pastoral stations.

The Pastoral Lands Board of WA has responsibility for administering pastoral leases under the *Land Administration Act 1997*. The WA Department of Agriculture and Food provides rangeland monitoring, condition assessment and lease inspection services to the board under a memorandum of understanding.

There are three major components to WA rangeland assessment:

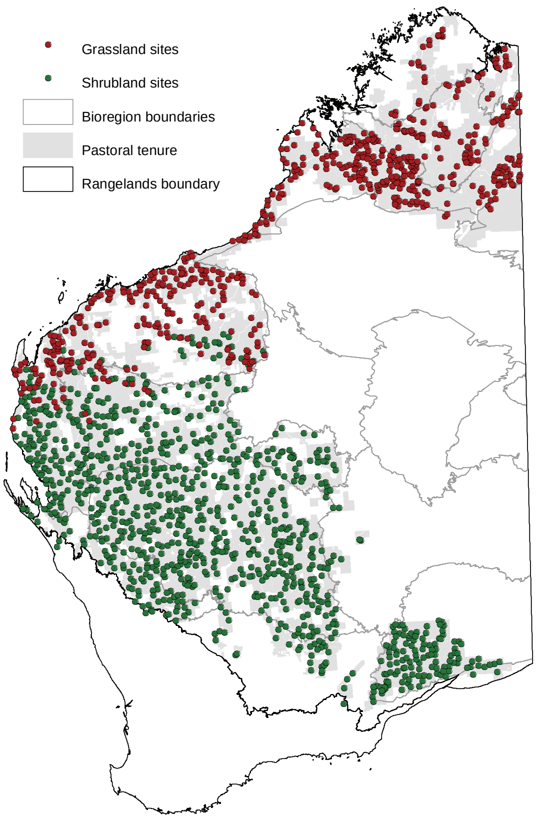
- Regional-scale resource inventory and condition surveys are progressively conducted across all the pastoral areas. The inventories map resources by land system and vegetation type.
- Each pastoral lease is inspected by ground traverse on a one to six-year cycle. The inspection reports are used by the Pastoral Lands Board to determine whether remedial actions are needed on individual leases.
- The pastoral areas are subject to regional-scale range monitoring using the Western Australian Rangeland Monitoring System (WARMS). This regional-scale monitoring has provided much of the data for ACRIS reporting.

WARMS consists of about 1622 permanent ground sites at which attributes of perennial vegetation and soil surface condition are assessed (Figure A1). There are two types of WARMS sites: grassland sites are used in the Kimberley, Pilbara and northern Gascoyne; shrubland sites are used from the southern Pilbara through to the Nullarbor. Grassland sites are assessed on a three-year cycle and shrubland sites on a five-year cycle. The system in its current form began in 1992, although many old monitoring sites were incorporated into the new system and some data and photo records go back to the 1970s. For grassland sites, three complete cycles of assessment (ie four assessment dates) were available for ACRIS reporting (1994–96, 1997–99, 2000–02, 2003–05). For shrubland sites, one complete cycle was available (most sites were established between 1993 and 1999, and reassessed for the first time between 1999 and 2005).

Since *Rangelands — Tracking Changes* (NLWRA 2001a), WARMS has begun reporting regularly to a range of end users, such as the Pastoral Lands Board, the WA Commissioner for Soil Conservation, state of the environment reporting agencies, the scientific community and ACRIS. All data are housed in a corporate Oracle database with access via a user-friendly 'front end'. Analysis procedures have been improved and many of the basic data summaries are now handled through permanent queries in the database. Vegetation types have been assigned to all sites and improvements have been made to the way soil surface condition data are summarised.

The WA Department of Agriculture and Food remains committed to its rangelands activities. It invests about $1.6 million of core funds each year directly into pastoral monitoring, lease inspection and resource inventory projects (not including the costs of maintaining staff and offices in remote locations). WARMS will continue to provide useful information. As each complete cycle of assessment is finished, the ability to separate long-term trend from shorter-term natural fluctuation will be improved and better information will be available on the health of our rangelands.

Figure A1 WARMS grassland and shrubland sites, WA



Source: Ian Watson, WA Department of Agriculture and Food

South Australia

Rangelands cover 85% of SA, including all but the southern portion of the state. The main vegetation types are tussock (spinifex) grasslands, low open woodlands of mulga, mallee and myall, and various chenopod shrublands (saltbushes, bluebushes and cottonbushes).

Pastoralism is the dominant land use over about 60% of the SA rangelands, with sheep predominantly to the south of the dingo-proof fence and cattle to the north. Products of mining activities include oil, natural gas, iron, copper, uranium, silver and gold.

The 40% of the SA rangelands that are not under pastoral lease are mainly the Great Victoria and Simpson sandy desert areas dedicated as conservation or regional reserves, and the northwest ranges forming the Pitjantjatjara lands.

The SA Pastoral Board administers pastoral leasehold land under the *Pastoral Land Management and Conservation Act 1989*. The board performs that function with support from the Pastoral Land Management Group within the SA Department of Water, Land and Biodiversity Conservation. The department also has responsibility for the *Natural Resources Management Act* (2004) and has the lead responsibility for management and monitoring of the rangelands. The Department for Environment and Heritage has the lead role in the development of biodiversity plans and the management of arid zone parks.

Rangeland monitoring program

The Pastoral Land Management Group has a comprehensive, integrated program of:

- resource inventory
- resource condition and lease assessment
- lease inspection
- rangeland monitoring.

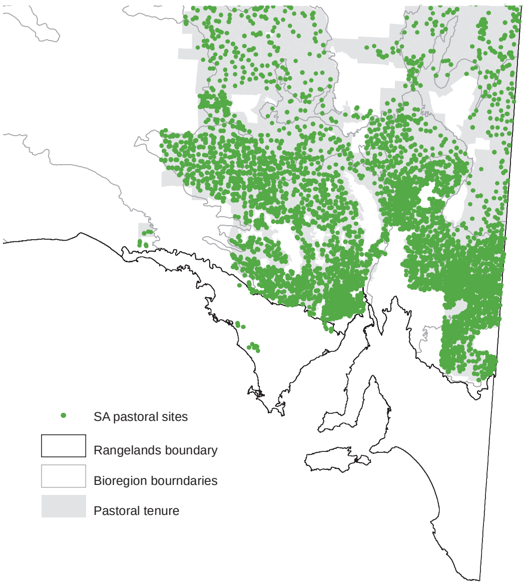
In the past 15 years, SA has established a baseline set of data (associated with an assessment of lease condition) over all pastoral leases in the state (Figure A2). Each of the 219 pastoral properties on 328 pastoral leases covering 409 000 km^2 in total now has:

- resource and lease inventory information
- resource condition assessments
- baseline monitoring sites established
- priority paddocks identified for management action and repeat inspections.

Having completed the first round of assessments in December 2000, the SA Pastoral Board has begun the second round, in which the emphasis has shifted to identifying and reporting changes in land condition and, where possible, identifying trends. The program of work to systematically revisit leases and report to the board is scheduled for completion in 2014.

In the second round of assessments, staff will revisit the approximately 5500 photopoint monitoring sites established in the baseline assessment. Twenty thousand randomly generated Land Condition Index sample points will also be assessed as part of the assessment of land condition. About 4500 individual

Figure A2 Pastoral monitoring sites, SA



Source: Mike Fleming, SA Department of Water, Land and Biodiversity Conservation

paddocks will be reassessed, and the previous priority rating for land management action will be reconsidered by the Pastoral Land Management Group and reported to the SA Pastoral Board for its consideration. This work continues to be driven by the requirements and policies of the board in meeting the requirements of the *Pastoral Land Management and Conservation Act 1989* (SA).

The two techniques used for assessing resource condition are grazing gradient assessment (for land under cattle grazing) and the Land Condition Index (for land under sheep grazing). The techniques are used in conjunction with site measurements and paddock observations.

Grazing gradient assessment

The grazing gradient assessment method (Pickup et al 1994) was used on a proportion of the northern cattle leases. It allows grazing effects on vegetation to be separated from those due to rainfall and local landscape variability by examining patterns of cover change with increasing distance from water and the nature of vegetation response to high rainfall.

It will be some time before leases are revisited under the current schedule of work. The SA Pastoral Board and Pastoral Land Management Group will review the grazing gradient methodology before beginning the work, with a view to refining the methodology or adopting other best-practice monitoring techniques.

Whichever methodology is adopted, it is imperative that change in land condition can be reported. Any changes in methodology will need to account for the previous dataset and reconcile any differences that might result from changing the way in which data are gathered and interpreted.

Land Condition Index

On most of the leases in the sheep production areas south of the dingo-proof fence, the Land Condition Index (Lange et al 1994) is used as the primary assessment of land condition.

The Land Condition Index is based on the condition rating of 80–100 sample sites within each lease. Assessments are made into one of three classes: high, moderate or low disturbance. The three classes are precisely specified for each component of each pasture type within a district. Under the Pastoral Land Management and Conservation Act, the optimal condition for the land is one that maintains the native plant and animal life. This is important, since it suggests that the Land Condition Index is more closely related to the maintenance of biodiversity than to pastoral production or landscape function. In practice, the maintenance of native species, pastoral production values and landscape function are closely related for many pasture types.

The disturbance classes are mostly based on the presence/absence or abundance of perennial plant species, the level of grazing and browsing of palatable species, and some consideration of soil surface condition. The Land Condition Index provides an inherent assessment of the likelihood of the return of the vegetation community to something like undisturbed condition.

Land condition is reported using a combination of site-specific information at the paddock level and management activities at both the paddock and station levels. The Land Condition Index is one part of the overall methodology used in determining change in land condition at the property level.

Reporting activity

Since *Rangelands — Tracking Changes* (NLWRA 2001a), the Department of Water, Land and Biodiversity Conservation has been using the Pastoral Management Information System to report to a range of end users, such as:

- the SA Pastoral Board
- the South Australian Arid Lands Natural Resources Management (NRM) Board
- the Alinytjara Wilurara NRM Board
- national and SA state of the environment reporting agencies
- ACRIS.

Recent initiatives

In partnership with the South Australian Arid Lands and Alinytjara Wilurara NRM regions and the Australian Government, the Pastoral Board and the Department of Water, Land and Biodiversity Conservation are developing the South Australian Arid Lands Information System (ALIS). The ALIS will replace the Pastoral Management Information System with a modern web-based system that will improve the capability of the Pastoral Land Management Group to perform its role as defined in the Pastoral Land Management and Conservation Act. The system will provide a range of functionality that enables the capture, consolidation, storage and reporting of data on SA rangeland assets, including biological, physical, cadastral, tenure, and other related information, pertaining to the South Australian Arid Lands and Alinytjara Wilurara NRM regions.

The users of ALIS will include pastoral landholders, traditional owners, the South Australian Arid Lands and Alinytjara Wilurara NRM boards and groups, the Pastoral Land Management Group, the Pastoral Board and other SA Government agencies and non-government (NGOs).

ALIS is being developed as a web-based system that provides sophisticated spatial and textual data capture, query and reporting functionality based on the particular needs of each user group. It is intended to meet the varying requirements of the mixed audience of government and non-government clients, particularly in the regional areas of SA.

Key planned outcomes of ALIS are to:

- provide an accessible and user-friendly data capture tool
- deliver relevant data and information services (both textual and spatial) to all stakeholders within the SA rangelands
- build such services within a standard software development methodology, and on sound, robust, integrated and scalable infrastructure
- provide a single access point to and data repository for information on the rangelands, thereby avoiding data and functional duplication
- integrate textual and spatial data to provide a more complete and holistic view of rangeland information
- improve access to and reporting of information from across the SA Government and NGOs.

By improving the capability for stakeholders to query currently disparate datasets, ALIS will also provide stakeholders with access to information that will increase their potential to:

- manage biodiversity, particularly with regard to:
  - preventing further decline
  - improving understanding of soil degradation
  - developing sustainable use of water resources
- build community capacity by developing effective information dissemination methods.

Pastoral lease inspections continue on a regular schedule across the pastoral leasehold lands. The resource inventory and condition survey has been working in the Kingoonya and Gawler Ranges areas.

The proclamation of the *Natural Resources Management Act 2004* (SA) created eight NRM regions, along with statutory boards responsible for the management of natural resources in those areas. The rangelands of SA predominantly fall within the South Australian Arid Lands and Alinytjara Wilurara regions. The Pastoral Land Management Group played a strong part in the development of management action targets and resource condition targets, and ALIS and other Department of Water, Land and Biodiversity Conservation activities will be a critical component of delivering and reporting against those targets.

Ongoing institutional commitment

The department and the Pastoral Board remain committed to their rangelands activities. Annually, about $1.3 million of core funds is invested directly in pastoral monitoring, lease inspection and resource inventory projects. In addition, the development of ALIS is an $840 000 partnership between the state and the Australian Government that will streamline information exchange among a range of stakeholders and continue to provide useful information into the future.

As each complete cycle of assessment is finished, the ability to separate long-term trend from shorter-term natural fluctuation will be improved and better information will be available on the health of our rangelands.

Northern Territory

Rangelands make up about 98% of the NT. The pastoral estate, comprising 219 pastoral leases, covers about 619 000 km^2 of the territory. Nearly 46% of the NT is under pastoral production.

One of the main responsibilities of the NT Pastoral Land Board, which was developed to implement the *Pastoral Lands Act 1992* (NT), is to monitor and report on the condition of land under pastoral production. Under the Act, the board is also responsible for the instigation of remedial action and plans to restore pastoral land condition.

The Department of Natural Resources, Environment and the Arts (DNRETA), through the Rangelands Management Branch, implements the rangeland monitoring program and provides the Pastoral Land Board with rangeland management, monitoring and assessment information.

Rangeland assessment programs

The rangeland monitoring program within the NT was set up in 1993 as a result of recommendations from the Pastoral Land Board.

The two major roles of the monitoring program implemented by DNRETA are:

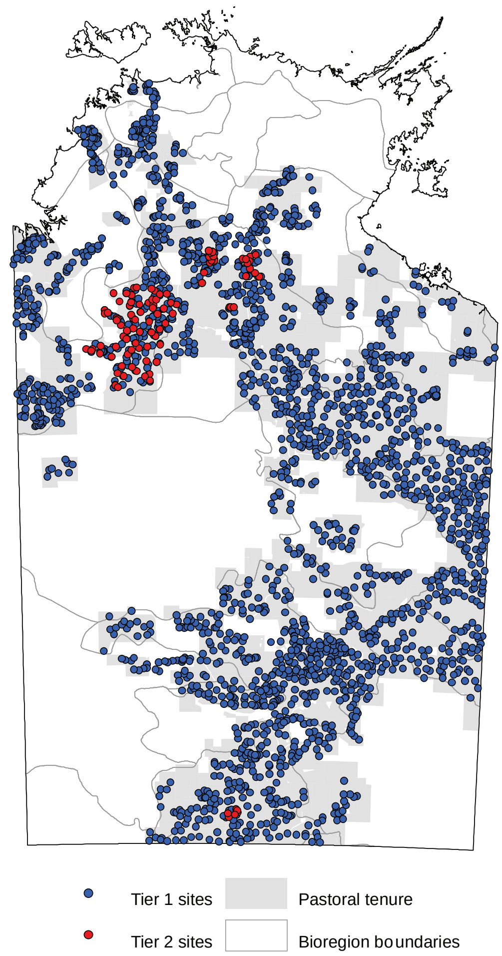
- to meet the needs of the Pastoral Land Board — to establish monitoring programs and to monitor pastoral land use and the effect pastoral management regimes have on the land, and to provide reports on the condition of the pastoral land
- to gain an understanding of landscape processes and the impact the industry has on the land resource.

DNRETA supports the Pastoral Land Board through monitoring the condition of pastoral leases using a two-tiered monitoring system. Combined soil and vegetation data are recorded at a total of 2333 permanent pastoral monitoring sites across the NT (Figure A3).

Tier 1 monitoring

The Tier 1 program is a photopoint monitoring program that uses visual estimates to assess land condition. Land managers are encouraged to use the monitoring sites to become more aware of pasture

Figure A3 Tier 1 and Tier 2 monitoring sites, NT



Source: Kate Richardson, DNRETA

species and pasture utilisation by stock on their properties. A total of 2235 Tier 1 sites are established across 223 properties where pastoral enterprises are undertaken (this includes pastoral and Crown leases and Aboriginal tenures). Sites within the Tier 1 program are reassessed on a rolling three-year program, with some sites now having had five reassessments. Data collected at Tier 1 sites include pasture species composition, presence of weeds, erosion, fire and other ancillary information relating to the site and property. Tier 1 data were used as the basis for ACRIS reporting, as the sites are located across the whole territory.

Tier 2 monitoring

The Tier 2 monitoring program is an integrated monitoring system of remotely sensed images and ground-based data. The satellite images are analysed and correlated with detailed ground-based data collected from permanent sites to provide information on landscape changes. The Tier 2 program uses the field data collection techniques of landscape function analysis. It allows various scales of reporting and assessment to be conducted — from paddock to property and through to region and district. There are currently 98 Tier 2 sites established across the Victoria River District, Sturt Plateau and Alice Springs regions of the NT. The program is currently being extended into the Barkly region.

Recent initiatives

Field data collection enhancements

Modifications to the methods for collecting Tier 1 data reflect changes within DNRETA to develop and implement an integrated monitoring system across the NT.

Changes to the types of field data collected include more detailed vegetation data representing the various types of cover (bare ground, pasture and woody cover). The additional data collected from the new integrated system will help with the analysis of trends in land condition over longer periods and aid in the use of information products derived from satellite data. The data will also allow for more detailed statistical analysis and presentation of results. The improved methods enable more repeatable data to be collected, thus reducing operator bias when comparing many years of collected data.

Extension of the satellite-based land condition monitoring program

DNRETA was successful in a project bid to the Natural Heritage Trust to secure funding for an 18-month project. The project, NT Satellite Based Land Condition Monitoring, aims to develop a monitoring program that provides annual updates of land condition across the whole of the NT based on MODIS (moderate resolution imaging spectroradiometer) satellite data. Currently, only a small percentage of pastoral lands is monitored and updated annually using Landsat satellite data. The project is tasked with the development, assessment and implementation of indices using MODIS data to monitor land condition changes. MODIS is a new generation satellite with increased spectral and temporal capabilities that has the potential to provide information to further enhance the current monitoring program.

At the completion of the project, DNRETA will take up the program as part of its baseline monitoring program.

External project

The VegMachine project was funded by Meat & Livestock Australia. It has successfully delivered satellite-derived information on long-term changes in cover and management impacts on the land resource to pastoralists across the NT, WA and southern central Queensland. Funding has been secured to continue the delivery of land condition and change information to land managers in the NT.

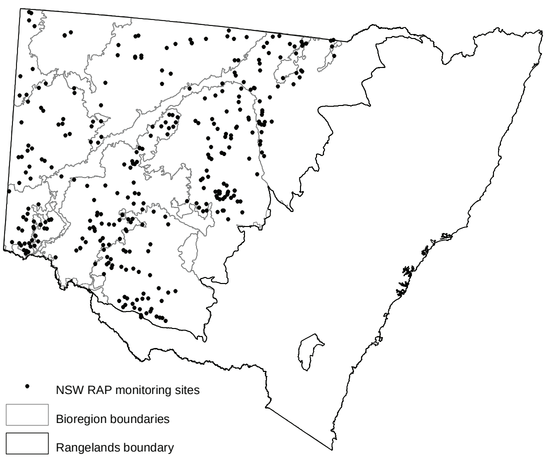
Ongoing commitment

The monitoring of rangelands is part of DNRETA's core business, and the current program has been recognised as an important provider of baseline vegetation and land condition data across the NT. The program is set to continue and, with enhanced data collection methods, provide data to analyse trends in land condition over longer periods.

New South Wales

NSW rangelands have been monitored annually since the early 1990s at 350 representative sites (Figure A4) as part of the Rangeland Assessment Program (RAP), which is managed by the NSW

Figure A4 RAP monitoring sites, NSW rangelands



Source: Richard Hicks, NSW Department of Environment and Climate Change

Department of Environment and Climate Change. RAP sites were selected to be representative of the numerous rangeland types in NSW and also to have a strong correlation with the Interim Biogeographic Regionalisation for Australia (IBRA) regions reported on in this ACRIS project.

RAP has been highly successful in meeting its initial objectives. The program has provided an opportunity to train many staff in plant recognition and assessment, while providing the participating landholders with important feedback and information on the response of their properties to climate variables and their management regimes.

Information from the program has been used to set targets in local catchment action plans, the NSW Monitoring, Evaluation and Reporting Strategy for natural resources, the standards and targets developed by the NSW Natural Resources Commission for catchment management authorities, and the overarching high-level NSW State Plan targets specifically dealing with NRM issues.

RAP has been essential in providing objective information on the condition of plant species and rangeland types across the western half of NSW, and changes in their condition in response to climate and management variables. The dataset is unique in terms of its long timeframe and the large proportion of NSW that has been monitored.

The department hopes to undertake a detailed review of the program in the short term. The review will improve RAP's value to NRM in NSW by identifying ways to improve monitoring and analysis and to provide linkages to additional issues that need consideration.

The reference sites will be used to calibrate various satellite data analysis programs to improve monitoring approaches across NSW.

Queensland

Rangelands make up about 82% of Queensland. Livestock-grazing on freehold and leasehold land is the dominant commercial land use across about 75% (1 212 000 km^2) of the Queensland rangelands, on about 4500 rural holdings. The Queensland Department of Natural Resources and Water (QDNRW) has responsibility for administering pastoral leases under the *Land Act 1994* (Qld). The remaining 44% of entities (only 19% of area) is held under freehold tenure.

The QDNRW and the Queensland Department of Primary Industries and Fisheries (DPI&F) provide rangeland monitoring, condition assessment and lease inspection services. QDNRW uses satellite data to track woody vegetation clearing and regeneration. The *Vegetation Management Act 1999* controls timber clearing; under the Act, broadscale clearing of remnant vegetation effectively ceased in December 2006.

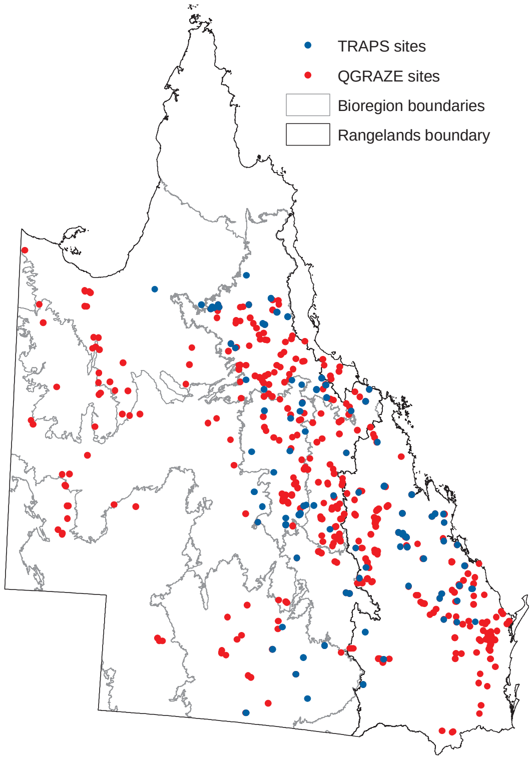
Rangeland assessment programs

- SLATS (the State-wide Landcover and Trees Study) uses Landsat TM imagery to monitor woody vegetation clearing, regrowth and cover annually over most of the state. SLATS is run by QDNRW and underpins the Vegetation Management Act.
- A mapping program managed by the Queensland Environmental Protection Agency (EPA) aims to map regional ecosystems at the scale of 1:100 000 for the whole state. 'Regional ecosystems' are remnant vegetation communities consistently associated with a particular combination of

geology, landform and soil (Sattler and Williams 1999). At this stage, mapping is still under way for much of the Queensland rangelands, and about 1350 individual regional ecosystems are currently listed.

- TRAPS (the Transect Recording and Processing System, managed by DPI&F) monitors woody vegetation dynamics at 84 fixed 1-ha sites in 33 sub-IBRAs from eight bioregions in timbered Queensland rangelands, except in Cape York (Figure A5).
- QGraze is another protocol set up to monitor pasture condition state-wide, currently at some 445 fixed sites. The data, plus photographs, are archived in a database within DPI&F. The data deal with tree cover, pasture composition, groundcover and soil surface condition. The protocol is used by QDNRW for some of its work, but the data are not in the main DPI&F database.
- Shrub monitoring transects stretch over 60 km through the mulga lands of southwest Queensland and provide a 40-year record of woody plant dynamics under normal property management. They have rarely been recorded in the past two decades but provide visual and hard data from 1965 to today at relocatable locations. DPI&F is the current custodian of these data.
- BAMM (Biodiversity Assessment and Mapping Methodology) identifies three levels of biodiversity significance (state, regional and local) based on a number of data queries that simultaneously integrate an array of current biodiversity information on rarity, diversity, fragmentation, resilience, threats, and ecosystem processes for a bioregion. This activity is managed by the Queensland EPA.
- RMDC (rapid mobile data collection) by QDNRW continues to obtain estimates of pasture biomass, composition, cover and other information. From 30 000 to 100 000 geocoded observations are collected each year. These data are used to calibrate and verify interpretations of satellite remote-sensing imagery.

Figure A5 TRAPS and QGraze monitoring sites, Queensland



Data: Madonna Hoffman, Queensland DPI&F. Map: Teresa Eyre, Queensland EPA.

Data from these sources currently feed into Queensland's *State of the Environment* reports. The first report was published in 2003, and the most recent assessment is planned for release in late 2007. The data also link into major national environmental initiatives such as ACRIS, ReefPlan, the Murray-Darling Basin Commission and the Lake Eyre Basin Authority.

Recent initiatives

Proposed new legislation may incorporate more regular and structured monitoring of leasehold lands where lease renewal is occurring. Regular pastoral lease inspections have not been a feature of land administration in Queensland over the past 30 years. QDNRW is enhancing a system to monitor bare-ground levels using Landsat images and will have 20 years of annual assessments with improved calibration for the next reporting period. Annual assessment should allow better identification of trends than the two-yearly data prototyped in this report. DPI&F is also assessing the value of satellite data for pasture condition assessment.

Queensland's monitoring strength is in satellite remote sensing and in primary production modelling based on the GRASP ('grass production') model, backed by significant computer processing power. QDNRW has recently completed a Meat & Livestock Australia research project to assess the use of MODIS satellite data for groundcover and pasture biomass monitoring. Ongoing research will focus on improved correction of problems caused by seasonally varying sun angles, use of 500-m scale MODIS products rather than the 1-km product, and automation of output. QDNRW is heavily involved in the MODIS project, which focuses on the usability of that satellite's data for regular monitoring.

AussieGRASS is following a process of continuous improvement with better inputs for stock distribution, better algorithms for groundcover and plant nitrogen dilution with age, and more extensive calibration with increasing amounts of data from the RMDC program.

The Tropical Savannas CRC (ending in 2008) fostered close Queensland links to the NT and WA and delivered significant synergies to work on improved cattle production systems, fire management and biodiversity documentation. There will be a significant gap in savanna science without further investment, as the Desert Knowledge CRC only deals with the driest fringes of the tropical savannas.

Since *Rangelands — Tracking Changes* (NLWRA 2001a), vegetation and bioregion mapping has continued to be updated, TRAPS woody vegetation assessment has continued but on-ground pasture monitoring (QGraze) has almost ceased. The VegMachine project uses remote sensing data provided by QDNRW to assist landholders to monitor the condition of their property, with Meat & Livestock Australia financial support and links to the NT rangeland monitoring program.

A rapid procedure for the assessment of vegetation condition for biodiversity values is currently being developed and tested by the Queensland EPA in partnership with DPI&F with Meat & Livestock Australia financial support. This project collaborates with a similar project being run by CSIRO with Natural Heritage Trust (NHT2) financial support. The aim of the assessment procedure is to be grazier-friendly, relevant to rangeland ecosystems, and compatible with the four-category ('ABCD') method for rating the condition of grazing lands.

The rangelands of Queensland fall wholly or partly under the ambit of nine regional NRM bodies set up under the National Action Plan and Natural Heritage Trust. QDNRW, Queensland EPA and DPI&F have a significant role in assisting those bodies to deliver their monitoring outcomes. The regional NRM bodies are largely dependent on the three Queensland Government agencies for their base data, underlying resource inventory and maps.

Reporting activity

The TRAPS project has continued reporting to a range of end users on woodland dynamics, such as:

- the Australian Greenhouse Office[58]
- the Queensland Government and the SLATS program[59]
- Queensland state of the environment reporting agencies[60]
- ACRIS.

GRASP has been used to develop aspects of the grazing land management training packages prepared for much of rangeland Queensland and the savannas of the NT and WA. It is also used in the Stocktake program for assessing pasture use at the property scale in Queensland rangelands.

Key publications related to monitoring in Queensland include Back et al (1997), Burrows et al (2002), Carter et al (1998), EPA (2006), Goulevitch et al (2007), Littleboy and McKeon (1997) and Stocktake (2006).

Ongoing institutional commitment

The annual investment by Queensland in rangeland monitoring is currently about $4.7 million. This investment is likely to increase in the future as the new leasehold land strategy is fully implemented. About $1.6 million is invested in SLATS, but nothing else related to rangeland condition monitoring is currently required by statute. Bare-ground monitoring is likely to continue for the life of the Rural Leasehold Land Strategy, with an investment of $0.3 million per year above the SLATS funding for research and

58 http://www.greenhouse.gov.au
59 http://www.nrw.qld.gov.au/slats/
60 http://www.epa.qld.gov.au/environmental_management/state_of_the_environment/

development over the next three years. AussieGRASS has an annual investment of about $0.6 million, some of which comes from other, non-Queensland agencies.

Expenditure on kangaroo monitoring and management by Queensland EPA is about $1 million annually.

An estimated $1 million is spent annually by the state on research and development related to pasture condition, biodiversity and river health. Much of that amount is matched by resources from industry or the Australian Government.

Each completed cycle of assessment improves our ability to separate grazing-induced long-term trends from shorter-term natural fluctuations and climate change. This improved information on the health of our rangelands will be increasingly available if structured monitoring programs are continued.

Australian Government

ACRIS and equivalent systems, such as those required to support the implementation of the National Water Initiative[61], are seeking to establish collaborative mechanisms to enable the identification, collection, storage and use of appropriate datasets. The Australian Government is investing in information systems such as ACRIS and those outlined below to meet environmental and NRM policy needs. ACRIS will draw on these systems as far as possible to inform research on rangelands change. A key ongoing challenge will be ensuring consistency and complementarity between these systems.

New initiatives

Several major new initiatives are expected to deliver significant improvements in the management of information on environmental condition and trends.

Natural Resource Management Spatial Information Strategy

In November 2006, the Natural Heritage Ministerial Board agreed to provide a total of $4 million over 2006–07 and 2007–08 to develop a spatial information system to better inform Australian Government decisions on NRM program investments. The NRM Spatial Information System will incorporate environmental, social and economic data and will also include information on program priorities, investment principles and requirements under legislation.

Australia's Resources Online

Australia's Resources Online (ARO) is a cooperative project being undertaken by the National Land & Water Resources Audit and the Environmental Resources Information Network (ERIN) in the Department of the Environment, Water, Heritage and the Arts. The objective of ARO is to provide a dynamic, online application that enables access to data on the condition and trend of the land, water and biological resources in Australia.

The ARO application is based on interoperable web technologies that allow the integration of data from different locations and different custodians through a single access point. ARO provides the interface through which the distributed data can be viewed, eliminating the need for centralised national collations. Data custodians will be responsible for providing up-to-date information in the agreed standard web service format. The information is then accessed and viewed through ARO when a user submits a request. Data access agreements are a key to the success of the application tool.

[61] http://www.nwc.gov.au/NWI/index.cfm (accessed 10 July 2007)

Existing information programs

Apart from ACRIS, the Australian Government directly supports a range of collaborative information systems developed to address specific NRM needs. These include the:

- National Vegetation Information System (NVIS)[62]
- Australian Soil Resource Information System (ASRIS)[63]
- Australian Collaborative Land Use Mapping Program (ACLUMP).[64]

CSIRO activity to support monitoring

CSIRO has a long history of involvement in and commitment to rangeland inventory and monitoring, although it has no statutory role in monitoring. CSIRO involvement began with land resource surveys in the 1940s and 1950s and continued with the testing and refining of methods for collecting and analysing monitoring data on pastoral lands in the 1980s and 1990s. Throughout, CSIRO staff worked collaboratively with state and NT agency staff to ensure that methods under development were assisting agencies with their monitoring requirements (Foran et al 1985b, Friedel and Shaw 1987, Wilson et al 1987, Bastin et al 1998).

Collaborative development and testing of methods to assist rangeland monitoring continues today.

- The Leakiness Index and calculator (Ludwig et al 2007) for upscaling landscape function assessment (using a digital elevation model and multitemporal cover derived from remote sensing) are being tested in the Burdekin catchment by Queensland DPI&F staff to support their grazing land management program.
- Various projects evaluated the efficacy of indicators and methods for operationally monitoring biodiversity (Smyth et al 2003, Hunt et al 2006).
- Other rangelands research in the biodiversity area is exploring how rewards might be used to more explicitly manage pastoral lands for biodiversity, for example through market-based instruments.

CSIRO has recently expanded its research into the social and Indigenous domains, for example:

- understanding regional viability and resilience, and how both are dependent on sustainable livelihoods
- working with partners to achieve stronger livelihoods for Indigenous people (eg bush foods and their sustainable harvest, fire abatement in Arnhem Land and planning for improved management of land and water resources in the NT Daly River catchment), and developing measures to assess success.

Long-term terrestrial monitoring has recently become a national priority[65]; it will require continued developments such as those above and the ACRIS approach for rangelands.

Supporting role of the Desert Knowledge CRC

ACRIS depends on effective collaboration among its partners; many are also partners in the Desert Knowledge CRC, as is CSIRO. The CRC secretariat, as part of the ACRIS Management Unit, has provided an efficient and effective contracting service to ACRIS partners. This partnership will support future improvements to monitoring to incorporate biodiversity, social issues and matters of concern to Indigenous interests.

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62 http://www.environment.gov.au/erin/nvis/index.html (accessed 10 July 2007)

63 http://www.asris.csiro.au/index_ie.html (accessed 10 July 2007)

64 http://adl.brs.gov.au/mapserv/landuse/index.html (accessed 10 July 2007)

65 http://www.ncris.dest.gov.au/capabilities/tern.htm (accessed 11 July 2007)

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Glossary

2P grasses

Palatable, perennial grasses. A key component of critical stock forage in much of the pastorally productive rangelands.

3P grasses

Palatable, productive and perennial grasses. Synonymous with 2P grasses. Term used in the Queensland rangelands.

ACRIS-MU

The Management Unit of ACRIS. The unit coordinates ACRIS, undertaking duties such as collating relevant available data, conducting meta-analyses and reporting national syntheses of the data.

Advanced Very High Resolution Radiometer (AVHRR)

Radiometer on board the Polar Orbiting Environmental Satellite series of the United States National Oceanic and Atmospheric Administration. The AVHRR instrument has provided radiance data for investigating clouds, land–water boundaries, snow and ice extent, ice or snow melt inception, day and night cloud distribution, temperatures of radiating surfaces, and sea surface temperature. AVHRR data allow monitoring of vegetation conditions in many ecosystems, including rangelands.

age-dependency ratio

Socioeconomic indicator: the ratio of people younger or older than working age (under 15 or over 65 years) to the working-age population.

aquifer

An underground layer of soil, rock or gravel able to hold and transport water. Bores and wells are used to obtain water from aquifers.

arid zone

Remote and sparsely populated areas of inland Australia; defined by the presence of drought-tolerant vegetation and desert landforms as well as by low rainfall (median annual rainfall less than about 350 mm).

artificial water source

Waterpoint such as bore, tank on a pipeline, bore drain or dam constructed to provide water for livestock.

assessment cycle

The period between one assessment and the next for all or most of the monitoring sites in a region.

AussieGRASS

Australian Grassland and Rangeland Assessment by Spatial Simulation. A pasture growth model that takes account of climate variability, soil types (including fertility), pasture communities, recent fire history and grazing pressure. Pasture growth, total standing dry matter and cover are simulated on a ~5 km grid for all of Australia. ACRIS uses recent and historical AussieGRASS data to describe *seasonal quality*.

Australian Bureau of Agricultural and Resource Economics (ABARE)

An applied economic research agency that works with industry and government to provide stakeholders in Australia's rural and resource industries with up-to-date public policy analysis and commodity forecasts.[66]

Australian Bureau of Statistics (ABS)

Australia's national statistical organisation. Statistics covering a wide range of economic and social matters are available.[67]

Australian Collaborative Rangeland Information System (ACRIS)

A partnership between Australian, state and NT government natural resource management organisations that facilitates data collation and documentation for reporting on regional and national changes in the rangelands.

baseline condition

The health status of a biological system (or some component of the system) at the start of a reporting period. For example, in ACRIS reporting, the level of landscape function (dysfunctional, moderately functional, fully functioning) of an IBRA bioregion in 1992.

66 http://www.abareconomics.com (accessed 21 November 2007)
67 http://www.abs.gov.au (accessed 21 November 2007)

biodiversity

Variability among living organisms (including terrestrial, marine and other ecosystems and ecological complexes in which they are part), which includes diversity within species and between species and diversity of ecosystems.

biomass

The quantity of organic matter within an ecosystem (usually expressed as dry weight for unit area or volume).

biome

A climate and geographical area of ecologically similar communities of plants, animals, and soil organisms, often referred to as 'ecosystems'. Biomes are defined based on factors such as plant structures (eg trees, shrubs, grasses), leaf types (eg broadleaf, needleleaf), plant spacing (eg forest, woodland, savanna) and climate.

bioregion (biogeographic region)

A large, geographically distinct area of land and/or water that has assemblages of ecosystems forming recognisable patterns within that landscape.[68]

biota

All of the organisms at a particular locality.

Brucellosis and Tuberculosis Eradication Campaign

A national program carried out between the 1970s and 1990s to eradicate brucellosis and tuberculosis from cattle herds in Australia. The campaign improved herd management across much of the cattle-grazed rangelands.

Bureau of Rural Sciences (BRS)

The scientific bureau within the Australian Government Department of Agriculture, Fisheries and Forestry. Provides scientific advice to government on agricultural, food, fisheries and forestry industries.[69]

CAR (comprehensiveness, adequacy and representativeness)

A term used by conservation agencies.
Comprehensiveness: a measure of how many of the different regional ecosystems in a bioregion are protected within that bioregion.
Adequacy: the capacity of protected areas to sustain protection of biodiversity values.
Representativeness: an assessment of whether the variation in regional ecosystems is covered in the protected area system.

[68] http://www.environment.gov.au/parks/nrs/science/bioregion-framework/ibra/index.html (accessed 4 April 2008)

[69] http://www.daff.gov.au/brs (accessed 22 November 2007)

Collaborative Australian Protected Areas Database (CAPAD)

A database containing information on all protected areas in Australia, including their International Union for Conservation of Nature management categories.[70]

concordance

Statistical procedure for apportioning values among different intersecting regionalisations according to the area of each region. Population statistics for a geographically large statistical local area might be assigned to three intersecting bioregions based on the proportional area of each IBRA. This is area-weighted concordance.

condition

The status or health of a biological system or some component of the system. 'Condition' is generally related to purpose (eg for grazing or conservation). There are many ways of defining and assessing rangeland condition and it is often a subjective process. One approach is to compare the level of a specific indicator (eg vegetation cover) at a particular location to its potential within that vegetation type or compare it to other locations.

conservation

For biodiversity: the protection, maintenance, management, sustainable use, restoration and enhancement of the natural environment.

conservation estate

Those parts of the environment formally reserved for conservation of native species, ecosystems and recreation.

critical stock forage

The abundance of those plants vital for sustaining livestock production. For ACRIS reporting, these are 2P, 3P and 'decreaser' plant species.

decile

The relative position or rank of a set of values based on a 10-point categorisation. Used by ACRIS to report *seasonal quality* based on the long-term rainfall record or historical level of pasture growth (as simulated by AussieGRASS).

[70] http://www.environment.gov.au/parks/nrs/science/capad/index.html (accessed 26 November 2007)

decreaser species

Forage species known to decrease in abundance when grazing pressure is excessive.

DSE (dry sheep equivalent)

A standard unit used to compare the feed requirements of different classes of stock, to assess the carrying capacity and potential productivity of a given area of grazing land or to describe in a standardised way the grazing pressure on that land. The unit represents the amount of feed required by a two-year old, ~45 kg merino sheep (wether or non-lactating, non-pregnant ewe) to maintain its weight.

Dust Storm Index (DSI)

An index developed from Bureau of Meteorology observations to quantify the occurrence and severity of dust storms.

DustWatch

An Australia-wide network of volunteer observers who make simple observations (similar to those used by the Bureau of Meteorology) of the timing and characteristics of dust storms.[71]

ecological community

An assemblage of native species that inhabits a particular area in nature.

ecosystem

A dynamic complex of plant, animal and microorganism communities and their non-living environment that interacts as a functional unit.

ecosystem resilience

The capacity of an ecosystem to cope with disturbances, such as drought, fire or grazing, without shifting into a qualitatively different state.

ecosystem services

The collective benefits that society derives from the resources and processes supplied by natural ecosystems. Services can be divided into five categories: provisioning, such as the production of food and water; regulating, such as the control of climate and disease; supporting, such as nutrient cycles and crop pollination; cultural, such as spiritual and recreational benefits; and preserving, which includes guarding against uncertainty through the maintenance of diversity.

71 http://www.dustwatch.edu.au (accessed 26 November 2007)

El Niño Southern Oscillation

A global coupled ocean–atmosphere phenomenon. El Niño is an extensive warming of the central and eastern Pacific Ocean that leads to a major shift in weather patterns across the Pacific. In Australia (particularly eastern Australia), El Niño events are associated with an increased probability of drier conditions. La Niña is the opposite set of conditions. The Southern Oscillation is the atmospheric component (see 'Southern Oscillation').

employment diversity

A socioeconomic indicator based on the number of people employed by the three main employment sectors in a region.

endemic

Native to a particular area and found nowhere else in the wild.

Environment Protection and Biodiversity Conservation Act 1999

National legislation to protect the environment, particularly matters of 'National Environmental Significance' ('Protected' matters). It streamlines national environmental assessment and approvals processes, protects Australian biodiversity and integrates the management of important natural and cultural places.

environmental indicators

The physical, chemical, biological or socioeconomic measures that best represent the key elements of a complex ecosystem or environmental issue. Indicators can organise environmental information both spatially and over time.

feral herbivore

A domesticated herbivore that has escaped into the wild and now lives and breeds there. Feral herbivores such as goats, horses, donkeys and camels add to total grazing pressure in the rangelands.

fire regime

The pattern of fires at a location, including the frequency and intensity of fire. ACRIS also reports fire extent.

fire scar

Recently burned areas that are visible in aerial photographs and satellite images. The often sharp boundary between burnt and unburnt country is used to map fire extent and calculate fire frequency.

forb

Non-grassy, herbaceous flowering plant.

freehold

Tenure under which land is held for life and owned by individuals or entities.

grass–tree balance

The proportion of grasses and trees in a grazed landscape and the interactions between the two.

grazing gradient analysis

A remote sensing-based method for determining past grazing effects on land condition. In the arid and semiarid rangelands, grazing effects diminish with increasing distance from water. This reduction can be detected as a gradient of increasing vegetation cover in satellite imagery.

grazing land management

Customised practical training courses delivered in Queensland and the NT to help grazing land managers improve profitability in a sustainable way.

groundwater

Water beneath the ground that flows naturally to the earth's surface via seeps or springs and can be collected with wells or bores.

habitat condition

In the context of ACRIS reporting, the extent and type of groundcover available as habitat for biota.

Interim Biogeographic Regionalisation for Australia (IBRA)

Divides the Australian continent into 85 bioregions, 52 of which are either wholly or partly in the rangelands. Most IBRAs are divided into sub-IBRAs. See also 'Bioregion'.[72]

increaser species

Plant species known to increase their abundance when grazing pressure is excessive.

index for socioeconomic disadvantage

A socioeconomic index derived from attributes that indicate relative social and economic hardship. Variables included are low income, low educational attainment, unskilled occupations, high unemployment, one-parent families, renting households and proportion of Aboriginal or Torres Strait Islander people.

Indigenous

Of or relating to the Aboriginal and Torres Strait Islander peoples of Australia.

Indigenous land management organisation

Formal groups that provide information, advice and other forms of support to assist Indigenous custodians in managing their land.

Indigenous land use agreement

An agreement about the use and management of land and waters made between one or more native title groups and other parties. The agreements provide flexibility in resolving native title issues. An Indigenous land use agreement allows developments on land to happen independently of any application for a determination of native title or before a determination of native title is made. The agreements help to create and foster good relations between commercial proponents, government parties and native title groups.[73]

Indigenous Protected Area (IPA)

Land specifically managed for biodiversity conservation objectives which also accommodates the cultural priorities of Indigenous people.

International Union for Conservation of Nature (IUCN)

International organisation whose mission is to influence, encourage and assist societies throughout the world to conserve the integrity and diversity of nature and to ensure that any use of natural resources is equitable and ecologically sustainable.[74]

invasive species

A species spreading beyond its accepted normal distribution and which threatens valued environmental, agricultural or personal resources by the disruption it causes.

kangaroo management zones

Fourteen designated geographic regions for the management of kangaroos in NSW.

La Niña

Warming of the western equatorial Pacific warm pool, north of New Guinea, accompanied by cooling in the equatorial eastern Pacific Ocean. La Niña is often

72 http://www.environment.gov.au/parks/nrs/science/bioregion-framework/ibra/index.html (accessed 26 November 2007)

73 http://www.nntt.gov.au/publications/1021435535_10212.html (accessed 26 November 2007)

74 http://www.iucn.org/en/about/ (accessed 26 November 2007)

associated with above-average rainfall in eastern Australia. La Niña produces the opposite set of conditions to El Niño. See also 'El Niño Southern Oscillation'.

land cover change analysis

Trends in land cover derived from satellite imagery. In the NT, this type of analysis is the principal form of Tier 2 monitoring in the tropical savanna. Cover is derived from yearly Landsat images, and trends in pixel cover values are tracked through time. Cover for different image dates is also spatially averaged by mapped land type and management unit (eg paddock) to help identify grazing effects.

Landcare

A national program to foster improved and sustainable land management. See also 'National Landcare Program'.

Landsat TM

The Thematic Mapper sensor on board the Landsat series of earth-observing satellites. Data have been available in seven spectral bands at 30-m pixel size since the mid-1980s.

landscape function

The ability of landscapes to capture, conserve and use scarce water and nutrients.

leasehold

Tenure under which land is occupied by individuals or entities under a lease agreement with a state or territory government. Conditions of the lease often include the use to which the land can be put.

lithosol

A shallow soil, comprising mostly bedrock or rock fragments with some weathered material. Generally, these soils are young and show little development of profiles.

livestock density

The number of sheep and/or cattle per unit of land area — typically expressed in the rangelands as dry sheep equivalents per square kilometre or hectares per animal equivalent.

macropod

Marsupial belonging to the Macropodidae family, which includes kangaroos, wallabies, tree kangaroos, pademelons and several other groups.

management action target

Under the Natural Heritage Trust, management practices that indicate progress towards agreed NRM outcomes as part of regional NRM plans and investment strategies (eg an agreed length of fencing erected to better manage riparian areas).

mesic

Describes wetter areas in the rangelands (eg habitats with a moderate or well-balanced supply of moisture).

meta-analysis

Higher-order analysis based on available results from a set of related studies or reports. For example, the national synthesis of change for many information types in this report derives from the separate datasets and analyses reported by jurisdictional partners within ACRIS.

multi-criteria analysis (MCA)

A transparent decision-making process developed for complex problems where there is no one clear or agreed outcome. Input data are weighted using value judgments incorporating public opinion and policy and management goals to provide variable outcomes.

Multiple Regression Bare Ground Index (MRBGI)

A remote sensing-based index of the amount of bare ground (as opposed to groundcover); being tested to monitor land condition in the Queensland rangelands.

National Land & Water Resources Audit (the Audit)

An Australian Government agency that works with other national agencies and all states and territories to report on the condition of Australia's land, water and biological resources.[75]

National Landcare Program

A national program that supports the Landcare movement and the sustainable use and management of natural resources. The program encourages landholders to undertake Landcare and related conservation works by supporting collective action by communities.[76]

75 http://www.nlwra.gov.au/ (accessed 27 November 2007)

76 http://www.daff.gov.au/natural-resources/landcare/national-landcare-programme (accessed 4 February 2008)

National Monitoring and Evaluation Framework (NM&EF)

The process established under the Natural Heritage Trust and National Action Plan for Salinity and Water Quality to assess progress by regional NRM groups towards agreed condition targets across broad thematic areas ('Matters for Target'). Uses a range of environmental indicators, such as land salinity, soil condition, native vegetation, water quality and invasive species.

National Reserve System Program

The program established under the Natural Heritage Trust to establish a comprehensive, adequate and representative (CAR) system of terrestrial protected areas.[77]

Natural Heritage Trust (NHT)

The body established by the *Natural Heritage Trust of Australia Act 1997* to stimulate conservation, sustainable use and repair of Australia's natural environment.

natural resource management (NRM)

Actions that improve the long-term sustainability of Australia's natural resources, soil, water, plants and animals. See also 'NRM groups'.

Natural Resource Policies and Programs Committee

High-level committee reporting to the Natural Resource Management Ministerial Council; focuses on high-priority, national issues, including NRM decision-making, biodiversity decline, soil and water quality decline, water policy, climate change and adaptation, and invasive species.

net emigration of young people

A socioeconomic indicator of the numbers of people aged between 15 and 24 leaving rural and regional areas.

non-pastoral agricultural activity (and value)

Agricultural activities other than cattle for meat and sheep for meat and wool (and the value of those activities). Typically, field crops, horticulture and products from livestock other than sheep and cattle.

Normalised Difference Vegetation Index (NDVI)

A measure of the response of vegetation to rainfall based on the level of photosynthetic activity (plant greenness). Derived from satellite imagery, typically AVHRR (1-km pixel resolution), MODIS (~250-m to 1-km pixel resolution) and Landsat TM (30-m pixel resolution).

NRM (natural resource management) groups

The regional groups responsible for implementing Natural Heritage Trust investments to improve land management and biodiversity conservation. There are 12 groups entirely or predominantly within the rangelands and a further 15 groups partly within the rangelands.

pastoral activity (also pastoral value)

The raising of cattle for meat and sheep for meat and wool (and the value of that activity).

Pastoral Monitoring System

The program for monitoring land condition on SA pastoral leases.

perennial grass frequency

The frequency of occurrence of longer-lived grasses recorded in quadrats at sites as part of jurisdictional pastoral monitoring programs. Quadrat size varies according to the monitoring program but is typically 0.25 or 1 square metre. A perennial grass species recorded as present in 40 of 50 quadrats has an 80% frequency of occurrence.

pixel

A single point in a graphic image (eg a satellite image). Abbreviated form of 'picture element' (using the common abbreviation 'pix' for 'picture').

plant species richness

The number of different plant species in an area (eg a monitoring site). There are different indices of plant species richness.

potable water

Water pure enough for humans to drink.

profit at full equity

A socioeconomic indicator that measures return on all resources used in a farm business. Defined as farm business profit, plus rent, interest and finance lease payments, less depreciation on leased items.

property management plans

Formal plans (often including maps) developed by landholders to document property resources and management practices, and to design property changes.

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77 http://www.environment.gov.au/parks/nrs/index.html (accessed 27 November 2007)

protected area

An area dedicated to the conservation of biodiversity.

proxy indicators

Indirect measures of a target or desired outcome (eg the CAR system of reserves as a proxy for biodiversity conservation).

Ramsar Convention

The Convention on Wetlands, signed in Ramsar, Iran, in 1971, providing the framework for the conservation and wise use of wetlands and their resources. Wetlands are referred to as 'Ramsar wetlands' if they are included in the Ramsar list.

rangeland

Native grasslands, shrublands and woodlands (including tropical savanna woodlands) that cover a large proportion of the arid and semiarid zones. Regular cropping is not practised and the predominant agricultural use, if any, is grazing by sheep and cattle on native vegetation.

Rangeland Assessment Program (RAP)

The program for monitoring the NSW rangelands.

rapid mobile data collection (RMDC)

A method for collecting a high volume and frequency of point data along road traverses in Queensland. A vehicle-mounted global positioning system is connected to a laptop computer running customised software for entering observed data about attributes of the land and vegetation.

red earths

The characteristic soil type of mulga country in the arid rangelands. Deep bright red soils of sandy loam to sandy clay loam texture. These soils are very old and have low fertility.

reference area

A relatively undisturbed area used as a benchmark to judge the condition or health of a another area. For example, the groundcover or species composition of an area close to water might be compared with that of a water-remote area to determine the effects of grazing.

refugia

Refuge areas for biodiversity, particularly during times of environmental stress (eg drought).

regional ecosystem

Vegetation communities in a bioregion consistently associated with a particular combination of geology, landform and soil. The concept of regional ecosystems is used for vegetation and biodiversity mapping and management in Queensland.

reliability (reliability scores etc)

The confidence the ACRIS Management Committee has in reporting a result for information products reporting change. A semiquantitative scoring system is used to make this assessment as objective as possible.

remote sensing

Recording of information about an object or phenomenon by a recording or real-time sensing device not in direct contact with the object. Typically, space or airborne instruments are used to measure electromagnetic radiation (eg sunlight) reflected from the earth's surface (passive remote sensing).

resilience

As defined by the Resilience Alliance[78], the 'capacity of an ecosystem to tolerate disturbance without collapsing into a qualitatively different state that is controlled by a different set of processes. A resilient ecosystem can withstand shocks and rebuild itself when necessary. Resilience in social systems has the added capacity of humans to anticipate and plan for the future.'

Resource Capture Index (RCI)

An index used as part of formal assessment of landscape function. It is the proportion of each transect occupied by resource-conserving patches, as distinct from interpatches (ie the proportion of the measured transect that is able to regulate nutrient and water flow). A patch is an area of perennial vegetation, or logs, rocks or stones as semipermanent obstructions to overland flow of water. Interpatches are areas of bare ground, litter or annual (or ephemeral) vegetation.

resource condition

The relative health of natural resources (soil, vegetation, water). See also 'Condition'.

[78] http://www.resalliance.org/1.php (accessed 27 November 2007)

resource condition target

Under the Natural Heritage Trust, specified outcomes for the health or state of natural resources as part of regional NRM plans and investment strategies (for example, improvement in regional water quality or vegetation health).

seasonal quality

Used by the ACRIS Management Committee to describe the relative value of recent climate (principally, rainfall) in biological functioning. Relative value (quality) is judged with reference to the longer-term record. 'Biological functioning' broadly means vegetation growth as a basic resource for both livestock (forage) and fauna (food, shelter) and for soil protection.

seasonally adjusted (also 'seasonally interpreted')

Method used by ACRIS to distinguish the effects of recent rainfall on reported change from those due to grazing management and other causes. For landscape function and critical stock forage, ACRIS emphasises the percentage of reassessed sites that showed improvement following poorer *seasonal quality* (decline expected) and the percentage of reassessed sites that showed decline following better seasons (increase expected).

semiarid zone

Remote and sparsely populated areas of Australia in which median rainfall varies from about 350 mm up to 800 mm in the north and about 500 mm in the east. The variability of annual rainfall is moderate to high. In the north, annual evaporation rates are high. Northern vegetation is typically savanna.

SILO (gridded rainfall)

Online source of a range of historical gridded and interpolated climate data for the Australian continent. Daily rainfall from available records interpolated to a 0.05-degree (~5 km × ~5 km) grid covering Australia.[79]

simulated pasture utilisation

Estimated proportion of pasture growth modelled by AussieGRASS that is consumed by grazing animals. This method has been used by Queensland to indicate levels of stock forage and inferred sustainable management.

[79] http://www.bom.gov.au/silo/ (accessed 23 April 2006)

site density index

The area of pastoral country within a bioregion (or sub-IBRA) divided by the number of pastoral monitoring sites within that area. The index is used to indicate the density of monitoring sites and as input into a calculated reliability score for reporting change in landscape function and critical stock forage.

site-based monitoring

The collection of repeated measurements (or the making of repeated assessments) at fixed locations on the ground.

site-by-year assessment (or site-by-year combination)

The number of repeated assessments at a site or at a group of sites. For example, if change is being reported for three repeat assessments at 12 sites within a bioregion, there are 36 separate site-by-year assessments.

soil crack specialist

Faunal species well adapted to surviving the shrink-and-swell cycles of self-mulching clay soils (ie cracking clays).

soil surface condition

The relative state or quality of the soil surface for capturing rainwater and for conserving soil moisture, nutrients and seeds for plant growth. Soil surface condition is a component of formal landscape function assessment. For each broad soil type, soil surfaces in good condition are stable (ie resist erosion), have high levels of infiltration and have good nutrient cycling properties (including good litter cover).

Southern Oscillation

A fluctuation in atmospheric circulation, in particular over the tropical areas of the Pacific and Indian oceans. In general, when atmospheric pressures are high over the eastern Pacific Ocean they tend to be low in the eastern Indian Ocean and vice versa. The fluctuation between the two produces a marked variation in parameters such as sea surface temperature and rainfall over a wide area of the Pacific. The oscillation has a cycle of two to seven years. The phenomenon is influenced by El Niño.

space- and time-averaged utilisation

The average level of AussieGRASS simulated pasture utilisation for a spatial unit (eg a sub-IBRA) over a specified period. In AussieGRASS, pasture growth and utilisation are simulated for 0.05-degree grid cells on a yearly basis. This can be reported as an average value for each rangeland sub-IBRA over (for example) a 10-year period. See 'Simulated pasture utilisation'.

standard error (SE)

A statistical measure of variation about the computed mean (or average), calculated as the standard deviation of sample values (eg perennial grass frequency at sites) divided by the square root of the sample size (number of sites sampled).

State-wide Landcover and Trees Study (SLATS)

A Queensland monitoring program that provides policymakers, industry, community interest groups and landholders with accurate information on woody vegetation cover, changes in cover, and mapping and statistical information.[80]

statistical local area (SLA)

A reporting unit for Australian Bureau of Statistics statistical (including socioeconomic) data. The boundaries for each SLA are the boundaries of incorporated bodies of local government where those exist. SLAs cover the whole of Australia without gaps or overlaps.

stocking density

See 'livestock density'.

surfaces of interpolated rainfall

See 'SILO (gridded rainfall)'.

sustainable

An activity that can be carried out without damaging the long-term health and integrity of natural and cultural environments.

threatened

Of or relating to a species or community that is vulnerable, endangered or presumed extinct (as defined in legislation).

threatening process

A process that threatens, or may threaten, the survival, abundance or evolutionary development of a native species or ecological community.

80 http://www.nrw.qld.gov.au/slats/ (accessed 27 November 2007)

Tier 1 / Tier 2

The program for monitoring land condition on NT pastoral leases. The Tier 1 system is a photopoint monitoring program supported by visual estimates of pasture species composition (by biomass and cover) and evidence of erosion and weeds. Tier 2 uses more rigorous remote sensing-based methods supported by on-ground validation.

time-integrated average

The average of a series of measurements made over time.

total grazing pressure (TGP)

The cumulative effect of all grazing herbivores on an area of land. Grazing animals may include domestic livestock (sheep, cattle), macropods (kangaroos) and feral animals (goats, rabbits, horses, donkeys, camels etc). If numbers (or density) by species are known, then total grazing pressure can be expressed in standardised units (eg dry sheep equivalents per square kilometre).

total standing dry matter (TSDM)

The amount (biomass) of standing vegetation present (usually, the pasture or herbage layer). Expressed as weight per unit area (typically, kilograms per hectare). Plant moisture is removed (by oven-drying harvested samples or by estimating moisture content) to standardise reporting.

transformer weeds

Invasive plants that change the character, condition, form or nature of ecosystems over a substantial area relative to the extent of that ecosystem.

Transect Recording and Processing System (TRAPS)

A methodology for recording changes in tree and shrub abundance at fixed 1-ha sites.

triple bottom line

Method for measuring organisational (and societal) success in achieving specified or desired economic, environmental and social outcomes. All three outcomes are amalgamated to report an overall outcome.

utilisation (pasture)

The proportion of pasture growth eaten by livestock, kangaroos and feral herbivores (goats, donkeys, horses, camels etc). The term is specifically used as part of Queensland's reporting of critical stock forage (as part of the Sustainable management theme) based on AussieGRASS simulations of pasture growth and estimated consumption (utilisation) by livestock and other grazing animals.

waterpoint

Source of drinking water for livestock. Waterpoints are typically bores, wells, dams (earth tanks), tanks and troughs on pipelines, and natural water supplies (rivers, waterholes, springs, freshwater lakes etc).

water-remote areas

Areas distant (eg more than 8 km) from waterpoints used by livestock. These areas are grazed infrequently and are presumed to have low levels of grazing impact. Water-remote areas may provide refugia for grazing-sensitive species.

Weeds of National Significance (WoNS)

An agreed list of the 20 most serious weeds in Australia, based on an assessment of their invasiveness, production impacts, potential for spread and impacts on socioeconomic and environmental values.

Western Australian Rangeland Monitoring System (WARMS)

The regional-scale, small-plot program used in WA to monitor the condition of its grazed rangelands.

woody weeds

Invasive or undesirable (generally unpalatable) trees and/or shrubs that decrease carrying capacity and livestock production.

References

ABS (Australian Bureau of Statistics) (2001). Census tables. Australian Bureau of Statistics, Australian Government, Canberra, Australia, http://www.abs.gov.au/websitedbs/d3310114.nsf/home/Census%20data (accessed 13 November 2007).

ABS (Australian Bureau of Statistics) (2004). *A Regional Profile — Selected Regions within Australia's Rangelands 2004*. Report compiled for the National Land & Water Resources Audit by the ABS. Commonwealth of Australia, Canberra, Australia.

ABS (Australian Bureau of Statistics) (2006). *Natural Resource Management on Australian Farms 2004–05*. ABS, Canberra, Australia. http://www.abs.gov.au/websitedbs/d3310114.nsf/home/Census%20data (accessed 13 November 2007)

Accad A, Neldner VJ, Wilson BA and Niehus RE (2006). *Remnant Vegetation in Queensland. Analysis of Remnant Vegetation 1997–1999–2000–2001–2003, including Regional Ecosystem Information*. Environmental Protection Agency, Queensland Herbarium, Brisbane, Australia.

Altman JC and Whitehead PJ (2003). *Caring for Country and Sustainable Indigenous Development: Opportunities, Constraints and Innovation*. CAEPR Working Paper No. 20, Centre for Aboriginal Economic Policy Research, Australian National University, Canberra, Australia. http://www.anu.edu.au/caepr/Publications/WP/CAEPRWP20.pdf (accessed 5 July 2007)

Anon (2006). Background information: Commercial kangaroo and wallaby harvest quotas. Report published by Department of the Environment and Water Resources, Australian Government, Canberra, Australia. http://www.dwr.gov.au/biodiversity/trade-use/publications/kangaroo/quotas-background-2006.html (accessed 15 March 2007)

Back PV, Anderson ER, Burrows WH, Kennedy MJJ and Carter JO (1997). *TRAPS (Transect Recording And Processing System) Field Guide and Software Manual*. Queensland Department of Primary Industries, Rockhampton, Australia.

Barrett G, Silcocks A, Barry S, Cunningham R and Poulter R (2003). *The New Atlas of Australian Birds*. Birds Australia, Melbourne, Australia.

Bastin GN and Ludwig JA (2006). Problems and prospects for mapping vegetation condition in Australia's arid rangelands. *Ecological Management and Restoration* 7:S71–S74.

Bastin GN, Pickup G, Chewings VH and Pearce G (1993). Land degradation assessment in central Australia using a grazing gradient method. *Rangeland Journal* 15:190–216.

Bastin GN, Tynan RW and Chewings VH (1998). Implementing satellite-based grazing gradient methods for rangeland assessment in South Australia. *Rangeland Journal* 20:61–76.

Bastin GN, Ludwig JA, Eager R, Liedloff A, Andison R and Cobiac M (2003). Vegetation changes in a semi-arid tropical savanna, northern Australia: 1973–2002. *Rangeland Journal* 25:3–19.

Beeton RJS, Buckley KI, Jones GJ, Morgan D, Reichelt RE, Trewin D (2006 Australian State of the Environment Committee) (2006). *Australia State of the Environment 2006*, Independent report to the Australian Government Minister for the Environment and Heritage, Department of the Environment and Heritage, Canberra, Australia.

Biograze (2000). *Biograze: Waterpoints and Wildlife*. CSIRO, Alice Springs, Australia.

Brown R and Creaser P (eds) (2006). Alinytjara Wilurara NRM Services, South Australia and the Australian Government Department of the Environment and Heritage; Sean Kerins, Northern Land Council; Jane L Lennon, Jane Lennon and Associates; Mona Nugula Liddy, Daly River Community Reference Group. *Indigenous involvement in environmental and heritage management, 2006*. Integrated commentary prepared for the 2006 Australian State of the Environment Committee. http://www.environment.gov.au/soe/2006/publications/integrative/indigenous/index.html (accessed 27 July 2007)

BRS (Bureau of Rural Sciences) (2006). *Guidelines for Land Use Mapping in Australia: Principles, Procedure and Definitions*. A technical handbook supporting the Australian Collaborative Land Use Mapping programme, Edition 3. BRS, Canberra, Australia.

Burrows WH, Henry BK, Hoffman MB, Tait LJ, Anderson ER, Menke N, Carter JO and McKeon GM (2002). Growth and carbon stock change in eucalypt woodlands in northeast Australia: ecological and greenhouse sink implications. *Global Change Biology* 8:769–784.

Butler DW and Fairfax RJ (2003). Buffel grass and fire in a gidgee and brigalow woodland: a case study from central Queensland. *Ecological Management and Restoration* 4:120–125.

Byrne M, Hassett R, Taube C and Henry B (2004). *Objective monitoring of ground cover across the Desert Channels Queensland region*. Final report to Desert Channels Queensland Incorporated prepared by Climate Impacts and Natural Resource Systems, Natural Resource Sciences, Queensland Department of Natural Resources and Mines, Brisbane, Australia.

Carter JO, Hall WB, Brook KD, McKeon GM, Day KA and Paull CJ (1998). Aussie-GRASS: Australian grassland and rangeland assessment by spatial simulation. In: *Applications of Seasonal Climate Forecasting in Agricultural and Natural Ecosystems — The Australian Experience*, Hammer G, Nicholls N and Mitchell C (eds), Kluwer Academic Press, Netherlands, 229–249.

Carter JO, Bruget D, Hassett R, Henry B, Ahrens D, Brook K, Day K, Flood N, Hall W, McKeon G and Paull C (2003). Australian Grassland and Rangeland Assessment by Spatial Simulation (Aussie-GRASS). In: *Science for Drought*, Proceedings of the National Drought Forum 2003, Stone R and Partridge I (eds), Queensland Department of Primary Industries, Brisbane, Australia, 152–159.

Chudleigh P and Simpson S (2004). *Non-Pastoral Agriculture in the Rangelands*. Agtrans Research, Queensland, Australia.

Churchill TB and Ludwig JA (2004). Changes in spider assemblages along grassland and savanna grazing gradients in northern Australia. *Rangeland Journal* 26:3–16.

Cunningham R, Silcocks A, O'Connor J and Weston M (2007). A statistical analysis of temporal trends in detection rates of birds in the rangelands, using Atlas of Australian Birds data, 1999–2006. Report to Department of the Environment and Water Resources, Canberra, by Birds Australia, Melbourne, Australia.

Day L (2007). Audit of biodiversity monitoring in the rangelands. Report for the Department of the Environment and Water Resources, Canberra, prepared by Desert Knowledge Cooperative Research Centre, Alice Springs, Australia.

Della Torre B (2005). Tracking changes in the Gawler bioregion. Report prepared for the Australian Collaborative Rangeland Information System by the SA Department of Water, Land and Biodiversity Conservation. http://www.environment.gov.au/land/management/rangelands/acris/publications-products.html (accessed 15 August 2007)

DIWA (Directory of Important Wetlands Australia) (2001). *A Directory of Important Wetlands in Australia*, 3rd edition. Inland Waters Section, Department of the Environment and Heritage, Canberra, Australia. http://www.environment.gov.au/water/wetlands/publications/diwa/pubs/diwa.pdf (accessed 16 April 2007)

DNR (NSW Department of Natural Resources) (2007). *NSW Woody Vegetation Change, 2004 to 2006*, Report DNR 2006-0175. DNR, Sydney, Australia. http://www.nativevegetation.nsw.gov.au/reports/ (accessed 18 April 2007)

DNRETA (Northern Territory Department of Natural Resources, Environment and the Arts) (2005). *Native Vegetation Clearing Activity within the NT: 2005 Update*. DNRETA, Darwin, Australia.

DNRM (Queensland Department of Natural Resources and Mines) (2005). *Land Cover Change in Queensland 2001–2003, incorporating 2001–2002 and 2002–2003 change periods: a Statewide Landcover and Trees Study (SLATS) report*, DNRM, Brisbane, Australia.

Donohue R (2003). *The Australian Rangelands: A Preliminary Land Use Profile*, Bureau of Rural Sciences, Canberra, Australia.

Dyer R, Jacklyn P, Partridge I, Russell-Smith J and Williams R (2001). *Savanna Burning: Understanding and Using Fire in Northern Australia*. Tropical Savannas Cooperative Research Centre, Charles Darwin University, Darwin, Australia.

Edwards A, Kennett R, Price O, Russell-Smith J, Spiers G and Woinarski J (2003). Monitoring the impacts of fire regimes on vegetation in northern Australia: an example from Kakadu National Park. *International Journal of Wildland Fire* 12:427–440.

EPA (Environmental Protection Agency) (2006). Regional Ecosystem Description Database (REDD). A database describing regional ecosystems. EPA, Brisbane, Australia. http://www.epa.Qld.gov.au/nature_conservation/biodiversity/regional_ecosystems/ (accessed 23 July 2007)

Fairfax RJ and Fensham RJ (2000). The effect of exotic pasture development on floristic diversity in central Queensland, Australia. *Biological Conservation* 94:11–21.

Fensham RJ and Price RJ (2004). Ranking spring wetlands in the Great Artesian Basin of Australia using endemicity and isolation of plant species. *Biological Conservation* 119:41–50.

Fisher A (2001). Biogeography and conservation of Mitchell grasslands in northern Australia. PhD thesis, Faculty of Science and Information Technology, Charles Darwin University, Darwin, Australia.

Fisher A and Kutt A (2006). Biodiversity and land condition in tropical savanna rangelands: summary report. Final report to Land & Water Australia, prepared by Tropical Savannas Cooperative Research Centre, Darwin, Australia.

Fisher A, Hunt L, James C, Landsberg J, Phelps D, Smyth A and Watson I (2004). Review of total grazing pressure management issues and priorities for biodiversity conservation in rangelands: a resource to aid NRM planning. Desert Knowledge CRC Project Report No. 3, prepared for Department of the Environment and Heritage, Canberra, by Tropical Savannas Cooperative Research Centre, Darwin, and Desert Knowledge Cooperative Research Centre, Alice Springs, Australia.

Foran B, Bastin G and Hill B (1985a). The pasture dynamics and management of two rangeland communities in the Victoria River District of the Northern Territory. *Australian Rangeland Journal* 7:107–113.

Foran BD, Bastin GN and Shaw KA (1985b). Range assessment and monitoring in arid lands: the use of classification and ordination in range survey. *Journal of Environmental Management* 22:67–84.

Franks AJ (2002). The ecological consequences of buffel grass (*Cenchrus ciliaris*) establishment within remnant vegetation of Queensland. *Pacific Conservation Biology* 8:99–107.

Friedel MH (1991). Range condition assessment and the concept of thresholds: a viewpoint. *Journal of Range Management* 44:422–426.

Friedel MH and Shaw KA (1987). Evaluation of methods for monitoring sparse patterned vegetation in arid rangelands I. Herbage. *Journal of Environmental Management* 25:297–308.

Friedel M, Puckey H, O'Malley C, Waycott M, Smyth A and Miller G (2006). Buffel grass: both friend and foe. An evaluation of the advantages and disadvantages of buffel grass use, and recommendations for future research. Report 17, Desert Knowledge Cooperative Research Centre, Alice Springs, Australia.

GABCC (Great Artesian Basin Consultative Council) (2000). Online document. http://www.epa.qld.gov.au/wetlandinfo/site/factsfigures/SummaryInformation/springs.html

Garnett ST (1992). Threatened and extinct birds of Australia. RAOU Report 82. Royal Australasian Ornithologists Union and Australian National Parks and Wildlife Service, Melbourne, Australia.

Garnett S and Crowley G (2003). Recovery plan for the golden-shouldered parrot *Psephotus chrysopterygius* 2003–2007. Report for Department of the Environment and Water

Resources prepared by golden-shouldered parrot recovery team, Environmental Protection Agency, Queensland Parks and Wildlife Service, Brisbane, Australia.

Goulevitch BM, Danaher TJ and Walls JW (2007). *The Statewide Landcover and Trees Study (SLATS) — Monitoring Land Cover Change and Greenhouse Gas Emissions in Queensland*. http://www.nrw.Qld.gov.au/slats/pdf/igarss99overview.PDF (accessed 20 July 2007)

Grant AR (2006). Tracking changes: Darling Riverine Plains bioregion, New South Wales, 1992–2002. Report prepared for the Australian Collaborative Rangeland Information System, NSW Department of Infrastructure, Planning and Natural Resources. http://www.environment.gov.au/land/management/rangelands/acris/publications-products.html (accessed 14 May 2007)

Grice A (2004). Weeds and the monitoring of biodiversity in rangelands. *Austral Ecology* 29:51–58.

Grice A (2006). The impacts of invasive plant species on the biodiversity of Australian rangelands. *Rangeland Journal* 28:27–35.

Grice A and Martin T (2005). *The Management of Weeds and their Impact on Biodiversity in the Rangelands*. CRC for Australian Weed Management, Townsville, Australia.

Griffith Taylor T (1947). *Australia: A Study of Warm Environments and their Effect on British Settlement*, Methuen & Co Ltd, London.

Hall WB, McKeon GM, Carter JO, Day KA, Howden SM, Scanlan JC, Johnston PW and Burrows WH (1998). Climate change in Queensland's grazing lands: II. An assessment of the impact on animal production from native pastures. *Rangeland Journal* 20:177–205.

Hannah D, Woinarski JCZ, Catterall CP, McCosker JC, Thurgate NY and Fensham RJ (2007). Impacts of clearing, fragmentation and disturbance on the bird fauna of eucalypt savanna woodlands in central Queensland, Australia. *Austral Ecology* 32:261–276.

Hanslip M and Kelson S (2007). Socio-economic conditions and trends in the rangelands. Report prepared for the Australian Collaborative Rangeland Information System, Bureau of Rural Sciences, Canberra, Australia.

Harrington GN, Wilson AD and Young MD (1984). *Management of Australia's Rangelands*. CSIRO Publishing, Melbourne, Australia.

Hassett R, Carter J and Henry B (2006). Rapid mobile data collection — a technique to monitor rangeland condition and provide quantitative and interpretive information for a range of applications. In: Erkelenz P (ed), *The Cutting Edge*. Conference Papers for the 14th Biennial Conference, Australian Rangeland Society, Renmark, South Australia, 3–7 September 2006, Australian Rangeland Society, Perth, Australia, 202–205.

Hill MJ, Lesslie RG, Donohue R, Houlder P, Holloway J, Smith J and Ritman K (2006). Multi-criteria assessment of tensions in resource use at continental scale: a proof of concept with Australian rangelands. *Environmental Management* 37:712–731.

How RA and Cowan MA (2006). Collections in space and time: geographical patterning of native frogs, mammals and reptiles through a continental gradient. *Pacific Conservation Biology* 12:111–133.

Humphries SE, Groves RH and Mitchell DS (1991). Plant invasions of Australian ecosystems: a status review and management directions. *Kowari* 2:1–134.

Hunt L, Fisher A, Kutt A and Mazzer T (2006). Biodiversity monitoring in the rangelands: a way forward. Vol. II: case studies. Report to the Department of the Environment and Heritage, prepared by the Desert Knowledge Cooperative Research Centre, Alice Springs, Australia.

Jackson J (2005). Is there a relationship between herbaceous species richness and buffel grass (*Cenchrus ciliaris*)? *Austral Ecology* 30:505–517.

James CD, Landsberg J and Morton SR (1999). Provision of watering points in the Australian arid zone: a review of effects on biota. *Journal of Arid Environments* 41:87–121.

Jeffrey SJ, Carter JO, Moodie KB and Beswick AR (2001). Using spatial interpolation to construct a comprehensive archive of Australian climate data. *Environmental Modelling & Software* 16:309–330.

Karfs R and Fisher A (2002). Linking landscape function, land condition, grazing and wildlife. In: *Proceedings, Fire and Heterogeneity in Savanna Landscapes*, 8–12 July 2002, Northern Territory University, Darwin, Australia, 64.

Kingsford RT and Porter JL (2006). Waterbirds and wetlands across eastern Australia. Technical report, Department of the Environment and Heritage, Canberra, Australia.

Kingsford RT and Porter JL (in press). Monitoring water bird populations with aerial surveys – what have we learnt? *Wildlife Research*.

Kingsford RT, Brandis K, Thomas RF, Crigton P, Knowles E and Gale E (2004). Classifying landform at broad spatial scales: the distribution and conservation of wetlands in New South Wales, Australia. *Marine and Freshwater Research* 55:17–31.

Knapp S, Smart R and Barodien G (2006). *National Land Use Maps: 1992/93, 1993/94, 1996/97, 1998/99, 2001/01 and 2001/02*, Version 3, Bureau of Rural Sciences, Canberra, Australia.

Landsberg J and Clarkson J (2006). *Threatened Plants of Cape York Peninsula*. Tropical Savannas Cooperative Research Centre, Charles Darwin University, Darwin, Australia.

Landsberg J, James CD, Morton SR, Müller WJ and Stol J (2003). Abundance and composition of plant species along grazing gradients in Australian rangelands. *Journal of Applied Ecology* 40:1008–1024.

Lang PJ, Canty PD, Nesbitt BJ, Baker LM and Robinson AC (2003). Vegetation. In: *A Biological Survey of the Anangu Pitjantjatjara Lands, South Australia (1991–2001)*, Robinson AC, Copley PB, Canty PD, Nesbitt BJ and Baker LM (eds), Department for Environment and Heritage, Adelaide, Australia.

Lange RT, Lay BG and Tynan RW (1994). Evaluation of extensive arid rangelands: the land condition index. *Transactions of the Royal Society of South Australia* 118:125–131.

Lesslie R, Hill M, Woldendorp G, Dawson S and Smith J (2006). *Towards Sustainability for Australia's Rangelands: Analysing the Options*. Bureau of Rural Sciences, Canberra. http://affashop.gov.au/PdfFiles/rangelands.pdf (accessed 5 September 2007)

Leys JF, McTainsh GH, Strong CL, Heidenreich S and Biseaga K (in press). DustWatch: community networks to improve wind erosion monitoring in Australia. *Earth Surface Processes and Landforms*.

Littleboy M and McKeon GM (1997). Subroutine GRASP: Grass production model; Documentation of the Marcoola version of Subroutine GRASP. Appendix 2 of *Evaluating the risks of pasture and land degradation in native pasture in Queensland*. Final Project Report for RIRDC project DAQ124A.

Ludwig JA and Tongway DJ (2002). Clearing savannas for use as rangelands in Queensland: altered landscapes and water-erosion processes. *Rangeland Journal* 24:83–95.

Ludwig JA, Tongway DJ, Freudenberger DO, Noble JC and Hodgkinson KC (eds) (1997). *Landscape Ecology, Function and Management: Principles from Australia's Rangelands*. CSIRO Publishing, Melbourne, Australia.

Ludwig JA, Eager RW, Liedloff AC, McCosker JC, Hannah D, Thurgate NY, Woinarski JCZ and Catterall CP (2000). Clearing and grazing impacts on vegetation patch structures and fauna counts in eucalypt woodland, central Queensland. *Pacific Conservation Biology* 6:254–272.

Ludwig JA, Bastin GN, Chewings VH, Eager RW and Liedloff AC (2007). Leakiness: a new index for monitoring the health of arid and semiarid landscapes using remotely sensed vegetation cover and elevation data. *Ecological Indicators* 7:442–454.

McIvor J (1998). Pasture management in semi-arid tropical woodlands: effects on species diversity. *Australian Journal of Ecology* 23:349–364.

Mac Nally R, Ellis M and Barrett G (2004). Avian biodiversity monitoring in Australian rangelands. *Austral Ecology* 29:93–99.

McTainsh GH (1998). Dust Storm Index. In: *Sustainable agriculture: Assessing Australia's recent performance, Report of the National Collaborative Programme on Indicators for Sustainable Agriculture*, 56–62.

McTainsh GH, Leys JF and Nickling WG (1999). Wind erodibility of arid lands in the Channel Country of western Queensland, Australia. *Zeitschrift fur Geomorphologie N.F.* 116:113–130.

McTainsh GH, Tews K, Leys JF and Bastin GN (2007). Spatial and temporal trends in wind erosion of Australian rangelands during 1960 to 2005 using the Dust Storm Index (DSI). Final Report to the Australian Collaborative Rangeland Information System, October 2007.

Maron M, Lill A, Watson DM and Mac Nally R (2005). Temporal variation in bird assemblages: how representative is a one-year snapshot? *Austral Ecology* 30:383–394.

Neagle N (2003). *An inventory of the biological resources of the rangelands of South Australia, Report*. Department of Environment and Heritage, South Australia, Adelaide, Australia.

NLWRA (National Land & Water Resources Audit) (2001a). *Rangelands — Tracking Changes, the Australian Collaborative Rangelands Information System*. NLWRA, Canberra, Australia.

NLWRA (National Land & Water Resources Audit) (2001b). *Australian Water Resources Assessment 2000. Surface water and groundwater — availability and quality*. NLWRA, Canberra, Australia.

Norris A and Low T (2005). *Review of the Management of Feral Animals and their Impact on Biodiversity in Rangelands: A Resource to Aid NRM Planning*. Pest Animal Control CRC Report 2005, Pest Animal Control Cooperative Research Centre, Canberra, Australia.

NWC (National Water Commission) (2007a). Australian Water Resources 2005 — A baseline assessment of water resources for the National Water Initiative. NWC, Canberra, Australia. http://www.nwc.gov.au/PUBLICATIONS/index.cfm (accessed 7 November 2007)

NWC (National Water Commission) (2007b). National Water Initiative — First biennial assessment of progress in implementation. NWC, Canberra, Australia. http://www.nwc.gov.au/PUBLICATIONS/index.cfm (accessed 7 November 2007)

Olsen P, Weston M, Cunningham R and Silcocks A (2003). The state of Australia's birds 2003. *Wingspan* 13(4) (Supplement). Also published by Birds Australia, Melbourne, Australia.

Petty S, Ash A, Fisher A, Hunt LP, McDonald N, Poppi D and White IA (2006). Grazing strategies for tomorrow — the Pigeon Hole Project. In: *The Cutting Edge*, Conference Papers for the 14th Biennial Conference, Australian Rangeland Society, Renmark, South Australia, 3–7 September 2006, Erkelenz P (ed), Australian Rangeland Society, Perth, Australia, 326–328.

Pickup G, Bastin GN and Chewings VH (1994). Remote sensing-based condition assessment procedures for nonequilbrium rangelands under large-scale commercial grazing. *Ecological Applications* 4:497–517.

Pople AR (2006). Modelling the spatial and temporal dynamics of kangaroo populations for harvest management. Final report, Department of the Environment and Heritage, Canberra, Australia.

Pringle HJR, Watson IW and Tinley KL (2006). Landscape improvement, or ongoing degradation — reconciling apparent contradictions from the arid rangelands of Western Australia. *Landscape Ecology* 21:1267–1279.

Purvis B (2004). Practical biodiversity. In: *Living in the Outback*, Conference Papers, Australian Rangeland Society 13th Biennial Conference, Alice Springs, Northern Territory, 5–8 July 2004, Bastin GN, Walsh D and Nicolson S (eds), Australian Rangeland Society, Perth, Australia, 305–306.

Reid J and Fleming M (1992). The conservation status of birds in arid Australia. *Rangeland Journal* 14:65–91.

Richards R (2007). Information needs of rangeland NRM regions: assessing links with ACRIS and the NME&F. Report to the National Land & Water Resources Audit, Canberra, Australia http://www.nlwra.gov.au/library/scripts/objectifyMedia.aspx?file=pdf/100.27.pdf (accessed 13 November 2007)

Richardson DM, Pyšek P, Rejmánek M, Barbour MG, Panetta FD and West CJ (2000). Naturalization and invasion of alien plants: concepts and definitions. *Diversity and Distribution* 6:93–107.

Rickert KG, Stuth JW and McKeon GM (2000). Modelling pasture and animal production. In: *Field and Laboratory Methods for Grassland and Animal Production Research*, 't Mannetje L and Jones RM (eds), CABI Publishing, New York, USA, 29–66.

Roshier DA and Rumbachs RM (2004). Broad-scale mapping of temporary wetlands in arid Australia. *Journal of Arid Environments* 56:249–263.

Roshier DA, Whetton PH, Allan RJ and Robertson AI (2001). Distribution and persistence of temporary wetland habitats in arid Australia in relation to climate. *Austral Ecology* 26:371–384.

Sattler PS and Williams RD (eds) (1999). *The Conservation Status of Queensland's Bioregional Ecosystems*. Environmental Protection Agency, Brisbane, Australia.

Scarth P, Byrne M, Danaher T, Henry B, Hassett R, Carter J and Timmers P (2006). State of the paddock: monitoring condition and trend in ground cover across Queensland. In: *Proceedings of the 13th Australasian Remote Sensing Conference*, November 2006, Canberra, Australia.

Smyth AK and James CD (2004). Characteristics of Australia's rangelands and key design issues for monitoring biodiversity. *Austral Ecology* 29:3–15.

Smyth A, James C and Whiteman G (2003). Biodiversity monitoring in the rangelands: a way forward, Vol 1. Report to Environment Australia prepared by Centre for Arid Zone Research, CSIRO, Alice Springs, Australia.

Stafford Smith DM, Morton SR and Ash AJ (2000). Towards sustainable pastoralism in Australia's rangelands. *Australian Journal of Environmental Management* 7:190–203.

Stocktake (2006). 'STOCKTAKE' — Balancing supply and demand, Queensland Department of Primary Industries and Fisheries. http://www2.dpi.Qld.gov.au/stocktake/17094.html (accessed 20 July 2007)

Thorp JR and Lynch R (2000). The determination of weeds of national significance. Paper prepared for the National Weeds Strategy Executive Committee by the Department of Agriculture, Fisheries and Forestry, Canberra, Australia.

Tongway DJ and Hindley NL (2004). *Landscape Function Analysis: Procedures for Monitoring and Assessing Landscape with Special Reference to Minesites and Rangelands*. CSIRO Sustainable Ecosystems, Canberra, Australia.

Tongway DJ and Ludwig JA (1997). The conservation of water and nutrients within landscapes. In: *Landscape Ecology, Function and Management: Principles from Australia's Rangelands*, Ludwig JA, Tongway DT, Freudenberger D, Noble J and Hodgkinson K (eds), CSIRO Publishing, Melbourne, Australia, 13–22.

Valentine LE (2006). Habitat avoidance of an introduced weed by native lizards. *Austral Ecology* 31:732–735.

Valentine LE, Roberts B and Schwarzkopf L (2007). Mechanisms driving avoidance of non-native plants by lizards. *Journal of Applied Ecology* 44:228–237.

Wallace JF, Behn G and Furby S (2006). Vegetation condition assessment and monitoring from sequences of satellite imagery. *Ecological Management & Restoration* 7:S31–S36.

Watson IW, Richardson J, Thomas P and Shepherd D (2005a). Change in the rangelands of the Gascoyne–Murchison. *Range Management Newsletter* 5(3):1–9.

Watson IW, Richardson J, Thomas P and Shepherd D (2005b). Case study of status and change in the rangelands of the Gascoyne–Murchison region. Report prepared for the Australian Collaborative Rangeland Information System, Western Australian Department of Agriculture. http://www.environment.gov.au/land/management/rangelands/acris/publications-products.html (accessed 14 May 2007)

Watson IW, Thomas PWE and Fletcher WJ (2007a). The first assessment, using a rangeland monitoring system, of change in shrub and tree populations across the arid shrublands of Western Australia. *Rangeland Journal* 29:25–37.

Watson IW, Novelly P and Thomas PWE (2007b). Monitoring changes in pastoral rangelands — the Western Australian Rangeland Monitoring System (WARMS). *Rangeland Journal* 29(2):191–205.

Weston MA, Tzaro CL, Silcocks A and Ingwersen D (2006). A survey of contributors to an Australian bird atlassing project: demography, skills and motivation. *Australian Journal on Volunteering* 11:51–58.

Whitehead P, Woinarski JCZ, Fisher A, Fensham R and Beggs K (2001). Developing an analytical framework for monitoring biodiversity in Australia's rangelands. Report to the National Land & Water Resources Audit, prepared by the Tropical Savannas Cooperative Research Centre, Darwin, Australia.

Wilson AD (1991). Forage utilisation by sheep and kangaroos in a semi-arid woodland. *Rangeland Journal* 13:81–90.

Wilson AD, Abraham NA, Barratt R, Choate J, Green DR, Harland RJ, Oxley RE and Stanley RJ (1987). Evaluation of methods of assessing vegetation change in the semi-arid rangelands of southern Australia. *Australian Rangeland Journal* 9:5–13.

Wilson BA, Neldner VJ and Accad A (2002). The extent and status of remnant vegetation in Queensland and its implications for statewide vegetation management and legislation. *Rangeland Journal* 24:6–35.

Woinarski JCZ (1999). Prognosis and framework for the conservation of biodiversity in rangelands: building on the north Australian experience. In: *People and Rangelands — Building the Future*, Proceedings of the VI International Rangelands Congress, Vol 2. 19–23 July 1999, Townsville, Australia, Eldridge D and Freudenberger D (eds), 639–645.

Woinarski J, Fensham R, Whitehead P and Fisher A (2000a). Rangelands monitoring: developing an analytical framework for monitoring biodiversity in Australia's rangelands. Background paper 1. A review of changes in status and threatening processes. Report for National Land & Water Resources Audit, prepared by Tropical Savannas Cooperative Research Centre, Darwin, Australia.

Woinarski J, Fensham R, Whitehead P and Fisher A (2000b). Rangelands monitoring: developing an analytical framework for monitoring biodiversity in Australia's rangelands. A manual for biodiversity monitoring. Report for National Land & Water Resources Audit, prepared by Tropical Savannas Cooperative Research Centre, Darwin, Australia.

Woinarski JCZ, McCosker JC, Gordon G, Lawrie B, James C, Augusteyn J, Slater L and Danvers T (2006). Monitoring change in the vertebrate fauna of central Queensland, Australia, over a period of broad-scale vegetation clearance, 1973–2002. *Wildlife Research* 33:263–274.