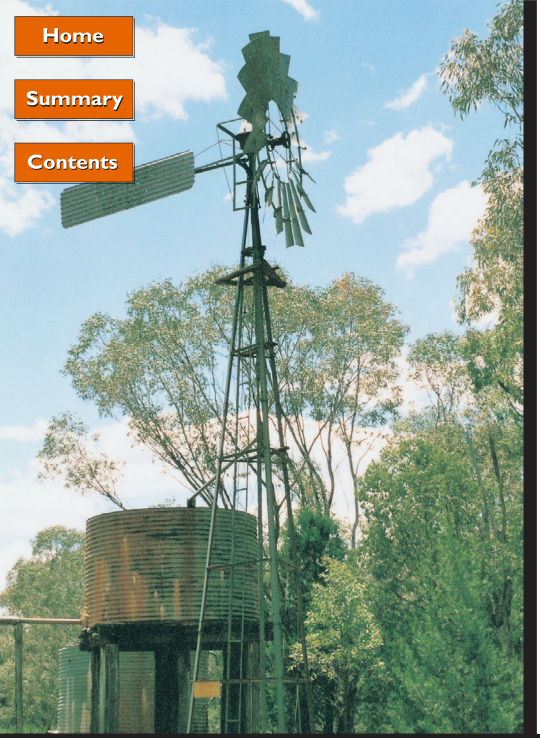

Natural Heritage Trust

Helping Communities Helping Australia

A Commonwealth Government Initiative

RANGELANDS — TRACKING CHANGES

Australian Collaborative Rangeland Information System

National Land and Water Resources Audit

A program of the Natural Heritage Trust

NATIONAL LAND AND WATER RESOURCES AUDIT

Providing Australia-wide assessments

The National Land and Water Resources Audit (Audit) is facilitating improved natural resource management decision making by:

Providing a clear understanding of the status of, and changes in, the nation's land, vegetation and water resources and implications for their sustainable use.

Providing an interpretation of the costs and benefits (economic, environmental and social) of land and water resource change and any remedial actions.

Developing a national information system of compatible and readily accessible land and water data.

Producing national land and water (surface and groundwater) **assessments** as integrated components of the Audit.

Ensuring integration with, **and collaboration** between, other relevant initiatives.

Providing a framework for monitoring Australia's land and water resources in an ongoing and structured way.

In partnership with Commonwealth, and State and Territory agencies, and through its theme activities—Water Availability; Dryland Salinity; Native Vegetation; Rangeland Monitoring; Agricultural Productivity and Sustainability; Australians and Natural Resource Management; Catchments, Rivers and Estuaries Condition; and Information Management—the Audit has prepared:

Assessments of the status of and, where possible, recent changes in the condition of Australia's land, vegetation and water resources to assist decision makers achieve ecological sustainability. These assessments set a baseline or benchmark for monitoring change.

Integrated reports on the economic, environmental and social dimensions of land and water resource management, including recommendations for management activities.

Australian Natural Resources Atlas to provide internet-based access to integrated national, State and regional data and information on key natural resource issues.

Guidelines and protocols for assessing and monitoring the condition and management of Australia's land, vegetation and water resources.

This report concentrates on specifying guidelines for assessing, monitoring and reporting on Australia's rangelands. The report summarises the information on Australia's rangelands available in the Australian Natural Resources Atlas and details the benefits and components of the proposed rangeland monitoring initiative.

Australian Collaborative Rangeland Information System: providing an information base to assist public and private decisions on sustainable land use management in Australia's rangelands.

RANGELANDS — TRACKING CHANGES

Australian Collaborative Rangeland Information System

National Land & Water Resources Audit
A program of the Natural Heritage Trust

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The Hon. Warren Truss MP
Minister for Agriculture, Fisheries and Forestry
Parliament House
Canberra, ACT 2600

Senator, the Hon. Robert Hill
Minister for Environment and Heritage
Parliament House
Canberra, ACT 2600

Dear Ministers,

I have pleasure in presenting to you *Rangelands — Tracking Changes,* a report of the National Land and Water Resources Audit.

Australia's rangelands cover approximately 75% of the continent. They include much of Australia's pastoral and Indigenous land, national parks, and areas where mining and remote ecotourism take place.

The natural, biodiversity, cultural and economic values of Australia's rangelands are well recognised. Outback Australia has particular management needs. Through wise and informed management, we can manage loss of biodiversity, land degradation, and excessive water use, and support development of rural and remote communities. Strategic investment in rangeland monitoring and assessment activities will provide the necessary information to avoid the mistakes (e.g. vegetation loss, dryland salinity) of more developed parts of Australia and ensure maximum return on the substantial investment by government in Australia's rangelands.

The rangelands pose particular institutional challenges since there is no Australia-wide framework for their management; nor are there pressing environmental challenges such as dryland salinity or soil erosion which attract action. Rangeland issues are long term in nature. Arrangements that provide for coordination of protective and long-term natural resource management activities across rangelands are essential. Rural communities are willing to manage these key Australian assets more sustainably. We need to provide leadership and raise awareness of issues through the provision and application of accessible and relevant information at a range of scales from local to regional to national.

This report:

- summarises information collated on Australia's rangelands at national and regional scales;
- details a collaborative plan for monitoring, assessment and reporting that can underpin actions to maintain, protect and develop Australia's rangelands; and
- recognises that investment in information provision will raise awareness, and support and foster community development, sustainable production, nature conservation and Indigenous participation.

Public investment is especially important in outback Australia where there are substantial common property resources. Public investment can catalyse private investment in natural resource and community assets, accruing both private and public benefits. Commonwealth, State and Northern Territory governments already support substantial activities in rangeland management. The Australian Collaborative Rangeland Information System is designed to ensure maximum return on this investment.

This report advocates a partnership of the Commonwealth, States and the Northern Territory to provide rangeland information and foster and promote more effective and efficient management of Australia's rangelands.

The Audit Advisory Council commends this report and *Australian Natural Resources Atlas* to you. Together they provide an information base for improved natural resource management within Australia's rangelands.

I am pleased to present this report to the Natural Heritage Trust Ministerial Board.

Yours sincerely,

Roy Green

Chair
National Land and Water Resources Audit Advisory Council
September 2001

Termites: part of the grazing community

SUMMARY

Australian Collaborative Rangeland Information System—information for sustainable management of Australia's rangelands

More than 75% of Australia is broadly defined as rangelands. This area covers a diverse group of relatively undisturbed ecosystems—tropical savannas, woodlands, shrublands and grasslands.

Each year people in the rangelands generate income from livestock production, tourism and mining. Rangelands are also important in terms of biodiversity, lifestyle, a rich social and cultural heritage, clean air and water, food, and carbon storage.

A relatively small number of people make decisions that influence natural resource management over this large area. Groups include pastoralists, Indigenous land managers, and public land managers and administrators. Tourism operators, mining managers, catchment groups, the Australian Defence Forces and local governments also make decisions that have an impact on natural resources and rangeland people.

Managing Australia's rangelands – the need for strategic investment

Australia's rangelands have special management needs. Through wise and informed management we can manage loss of biodiversity, loss of potential for production, excessive water use and economic decline, and support rural and remote communities. Strategic investment into comprehensive monitoring of rangelands will provide a unique opportunity to help protect and manage the resources while avoiding the mistakes of more developed areas.

Rural communities in rangelands are willing to improve sustainability of management practices but need current information that is relevant in purpose and scale for their decision making.

Monitoring, assessment and reporting will support improved and protective management of Australia's rangelands. Return on investment will far exceed the cost of implementing a comprehensive monitoring system.

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New capabilities in rangeland management

The Audit's Rangeland Monitoring theme was requested to define the elements of a comprehensive monitoring and reporting program to provide regular Australia-wide reports and enable people to make better land use and management decisions. This report presents examples of monitoring products at national and regional scales.

The Audit collated historical and background information to provide context and the ability to identify trends in:

- ecosystem function;
- land tenure and use;
- climate variability; and
- economic, social and institutional factors.

New capabilities and approaches to rangeland monitoring were developed, including:

- a framework for monitoring biodiversity within the context of overall rangeland management;
- an operational system using remote sensing and enabling monitoring across large areas of rangelands in northern Australia; and
- an approach to rangeland management driven by how landscapes function rather than how they are used.

Australian Collaborative Rangeland Information System

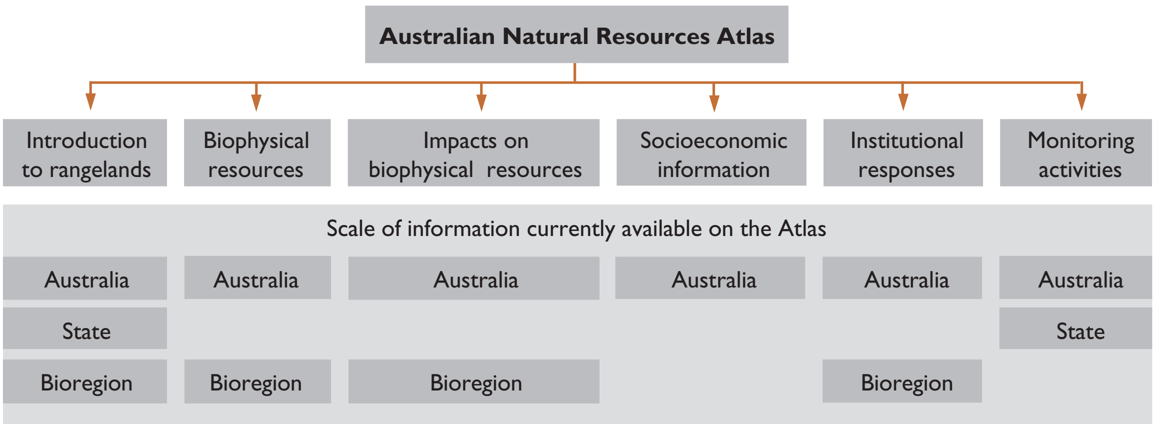
The Australian Collaborative Rangeland Information System is a proposed coordinating mechanism that will bring together and continually update a wide diversity of rangeland information. The system will:

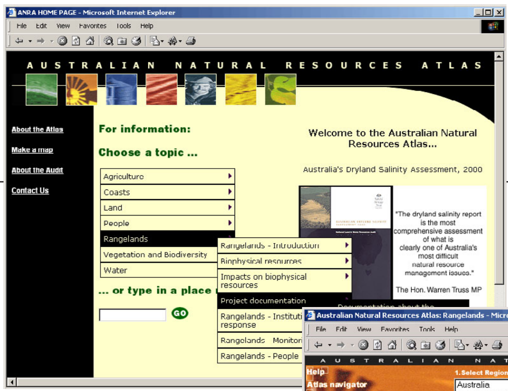
- add value to existing State and Northern Territory monitoring activities;
- report on rangeland condition and change in condition at five-yearly intervals; and
- use the internet-based Australian Natural Resources Atlas to present an analysis of change.

The fundamental activities of data collation and coordination will cost approximately $480 000 each year.

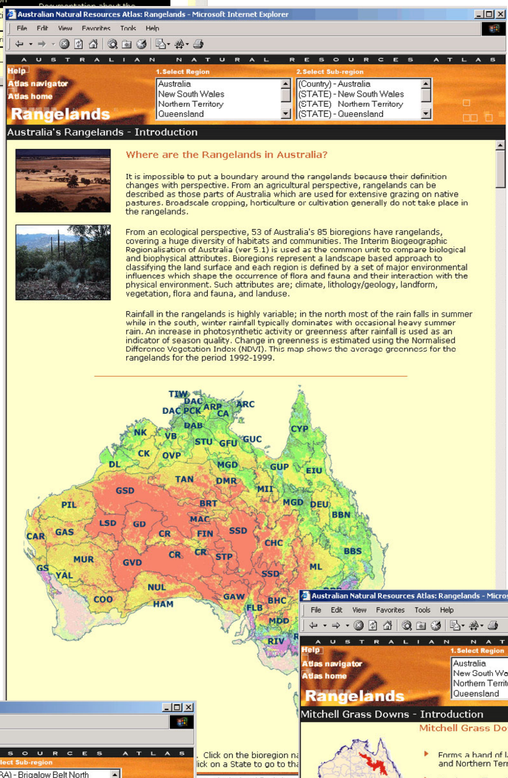
Supplementary activities commissioned and funded by clients to meet their specific needs will be facilitated and coordinated by the Australian Collaborative Rangeland Information System. These may address issues such as:

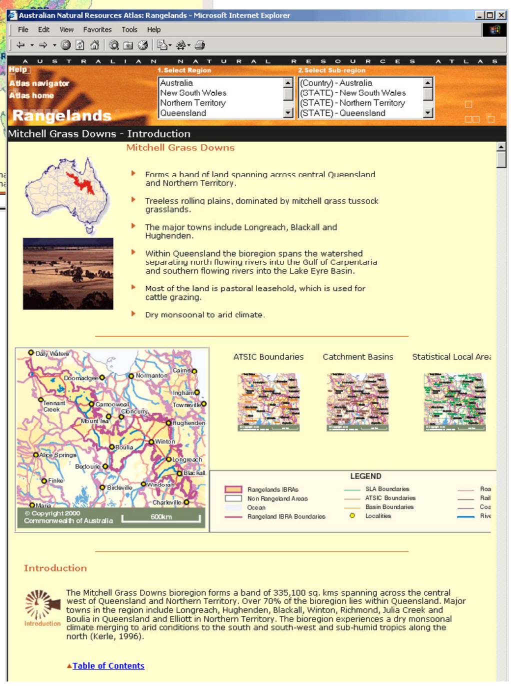
- biodiversity monitoring;
- the expanded application of remote sensing techniques; and
- socioeconomic aspects of rangeland management.



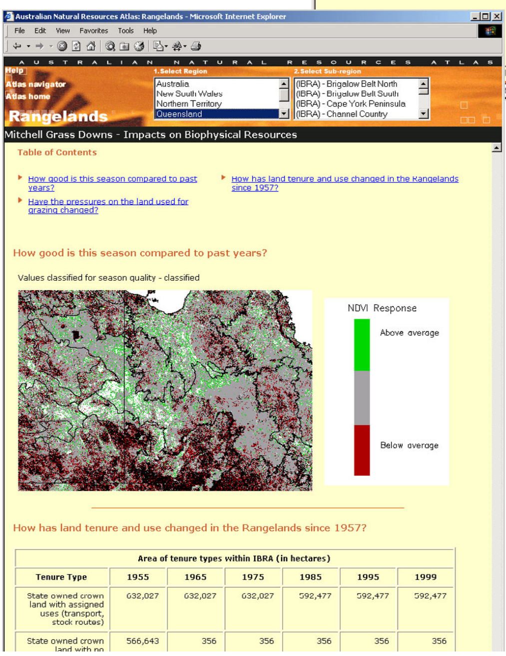


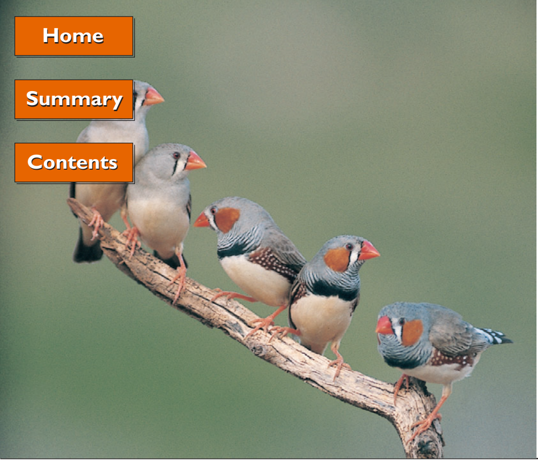
Australia-wide and regional information





Link to monitoring data





Zebra finches (*Taeniopygia guttata*): part of rangeland grassland communities

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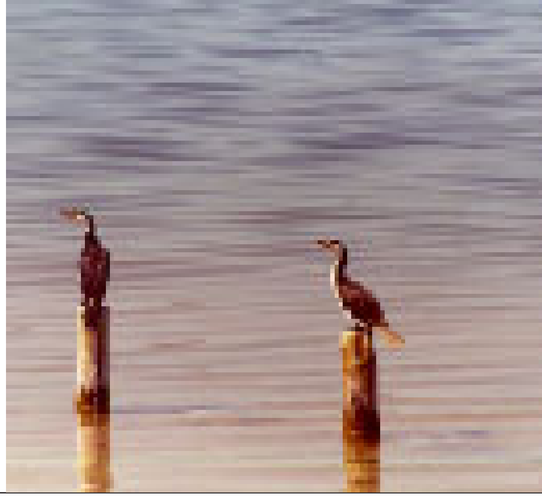

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Cameron Corner where New South Wales, Queensland and South Australia meet

IN PARTNERSHIP

Cooperation and commitment

State, Territory, catchment and biophysical boundaries apply few constraints to rangeland management—already scientists and managers across rangelands work closely with communities to develop monitoring tools and improve management techniques.

The Australian Collaborative Rangeland Information System is founded on an active partnership between agencies, disciplines and groups. It will build on competence and commitment from the States and the Northern Territory through the National Rangeland Monitoring Coordinating Committee that was set up as a part of the Audit's Rangeland Monitoring theme.

National Rangeland Monitoring Coordinating Committee

New South Wales
Daryl Green, Department of Land and Water Conservation

Northern Territory
Rod Applegate, Department of Lands, Planning and Environment (Committee Chair)

Queensland
Eric Anderson, Department of Primary Industries

South Australia
Brendan Lay, Primary Industries and Resources SA

Western Australia and Tropical Savannas Management Cooperative Research Centre
Paul Novelly, Department of Agriculture

Commonwealth
Annemarie Watt, Environment Australia
Lionel Wood, Agriculture, Fisheries and Forestry – Australia
Ken Hodgkinson, CSIRO Sustainable Ecosystems

Indigenous Land Corporation
Paul Jenkins (previously Sally Skyring)

National Farmers' Federation Environment Committee
Sue Walker

National Land and Water Resources Audit
Colin Creighton
Rochelle Lawson

National Coordinator
Ian Watson, Department of Agriculture, Western Australia

RANGELAND MANAGEMENT IN CONTEXT

Wetlands: a vulnerable part of rangeland ecology

Contributing to the National Land and Water Resources Audit

The Rangeland Monitoring theme is one of a series of monitoring, assessment and reporting initiatives fostered under the National Land and Water Resources Audit (Audit). Other issues addressed by the Audit that are relevant to rangeland monitoring include water quantity and quality; dryland salinity; native vegetation; sustainable agriculture; catchment, river and estuary condition; ecosystem health; and social and economic wellbeing.

Water availability limits development opportunities in rangelands. Groundwater is a key resource. Sustainable use is essential to ensure its long-term availability.

- The status of Australia's surface and groundwater resources, including extent, use and sustainability, is detailed within the Audit report *Australian Water Resources Assessment 2000*.

Dryland salinity has had an impact on many agricultural regions of temperate Australia. As rangelands become more developed, good planning and management will ensure that threats from dryland salinity are minimised.

- Assessment of the likely hazard of dryland salinity based on salt stores and an understanding of the water balance is provided in the Audit report *Australian Dryland Salinity Assessment 2000*.

The native vegetation of rangelands is mainly intact. However, it needs to be managed to maintain landscapes and biodiversity. The Audit's activities in developing a readily accessible and standardised database of native vegetation are essential to rangeland management.

- The Audit's National Vegetation Information System provides a hierarchy of vegetation information from overall structure to communities to species. This information provides a context for assessments of vegetation response to climatic variability and other impacts (e.g. fire and grazing) and will be available in the Audit report *Australian Native Vegetation Assessment 2001* (in preparation).

Australia is developing an export and domestic product status that integrates food quality with efficient productivity and sustainable natural resource use. Sustainable agricultural production and the application of best management practice are key priorities for Australian agriculture.

- Information on Australian agriculture, commodities, export earnings, and continuous improvement in practice towards sustainable use of natural resources will be detailed in the Audit report *Australian Agriculture Assessment 2001* (in preparation).

Rangelands cover a wide diversity of habitats and biota and include public assets that have specific management needs (e.g. rivers and estuaries).

- The Audit has assessed the condition of Australian rivers and estuaries and identified management needs, many of which link to issues of grazing land management, especially soil erosion and nutrient enrichment. River and estuary condition and management needs will be detailed in *Catchments, Rivers, and Estuaries Assessment 2001* (in preparation).
- The Audit is assessing biodiversity and building on the information already collated for Australia's rangelands and native vegetation assessment. This will be detailed in *Australian Biodiversity Assessment* (to be published in 2002) and will suggest conservation and management priorities at a range of scales from national to regional.

Natural resource management requires multidisciplinary endeavours and takes account of biophysical conditions, and social and economic constraints and opportunities. Rangelands occupy the more remote parts of Australia, are often sparsely settled and experience more limited access to services and facilities.

- The Audit is collating resource accounting information on rural land use, the benefits of agricultural production to the Australian economy, the costs resulting from land degradation and the opportunities that arise from understanding the characteristics of our communities. This analysis will be presented in the Audit's *Australians and Natural Resource Management 2001* report (in preparation).

For a wide range of other issues, Australia needs to adopt comparable approaches to natural resource assessment, link the results of monitoring with land use practices and progressively upgrade and make accessible management-orientated natural resource information.

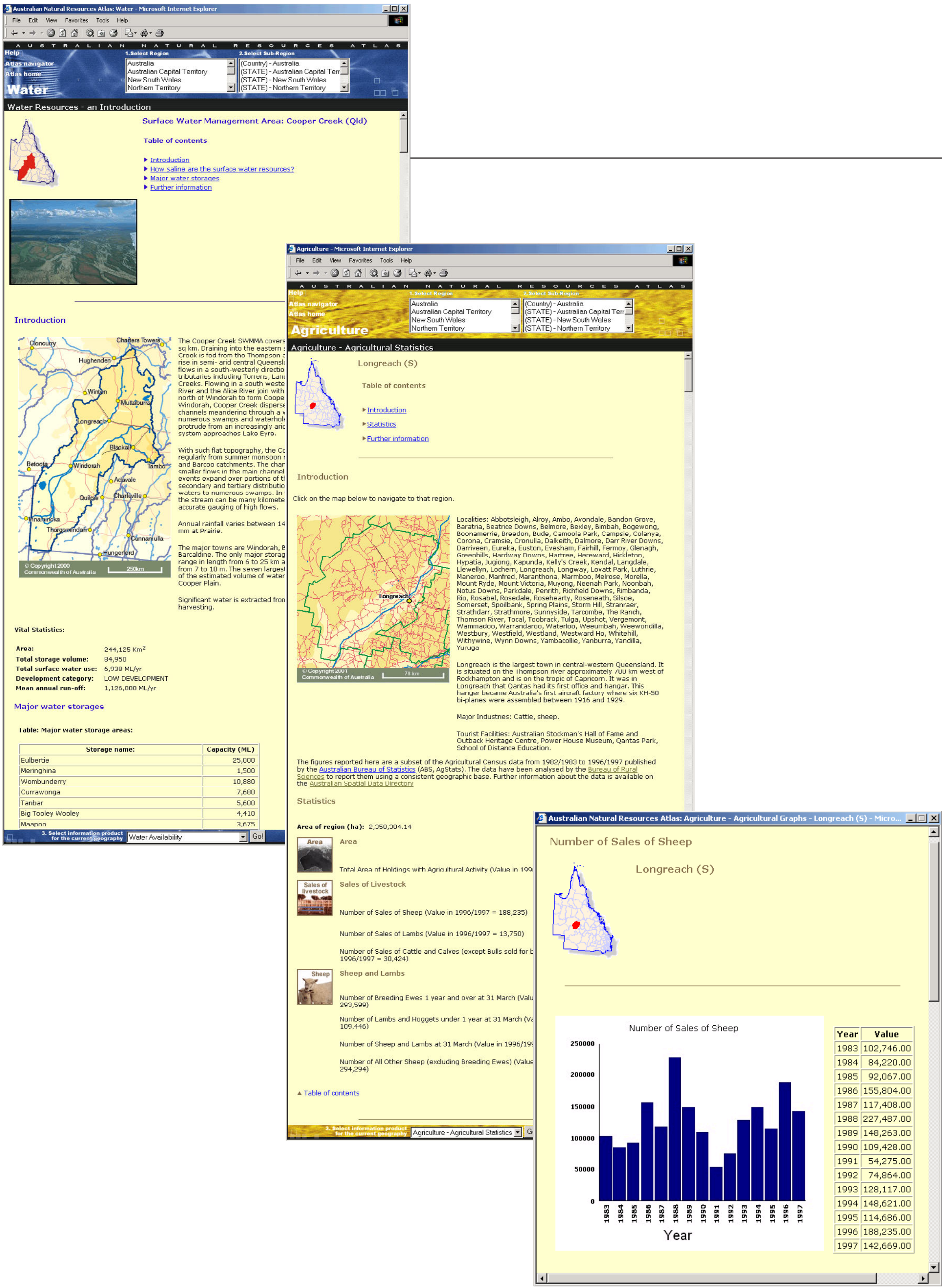
- Overall natural resource database maintenance and information provision will be reported as part of the *Australian Natural Resources Information 2001* report (in preparation).

Integration through the Atlas

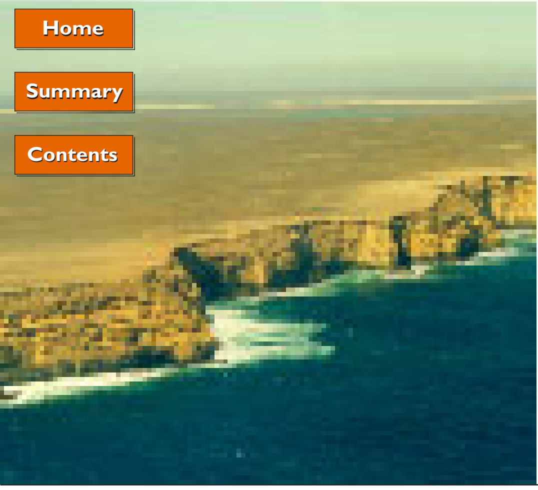
Access to information on natural resources provides opportunities for increased awareness, informed debate and improved management. This access has been improved through internet and database technology. The interactive web-based Australian Natural Resources Atlas (Atlas) will present Audit products at a range of scales (from local to regional to Australia-wide) and a range of boundaries (from ecological to administrative).

The Atlas provides information to aid decision making across all aspects of natural resource management. It covers the broad categories of water, land, agriculture, people and ecosystems. It is organised by geographic region (national, State/Territory, ecological) and information topic. A data library supports the Atlas with links to Commonwealth, State and Northern Territory data sets.

The rangelands section of the Atlas is a monitoring and reporting system providing summary information that is intended to be updated at appropriate intervals: shorter (e.g. each fortnight for vegetation response to rainfall) and longer (e.g. annually or every few years for census and farm survey data).



Australian Natural Resources Atlas: www.nlwra.gov.au/atlas



West Australian coast: western edge of Australia's rangelands

MEETING AUDIT OBJECTIVES

The Rangeland Monitoring theme has made progress in meeting Audit objectives as stated in the *Strategic Plan 1998–2001* by compiling context information and defining a comprehensive framework for monitoring and assessing Australia's rangelands.

Audit objective 1. Providing a clear understanding of the status of, and changes in, the nation's land, vegetation and water resources and implications for their sustainable use

Through this report the Audit has:

- compiled historical data on changes in tenure, stocking rates, some native and feral grazing animals and their impact on biodiversity in rangelands.

Audit objective 3. Developing a national information system of compatible and readily accessible resource data

The Audit has:

- gained commitment from State and Northern Territory agencies to compile rangeland monitoring data into consistent and compatible information products;
- gained Australia-wide agreement on data collation systems that make disparate data sets (both attributes and scale) compatible;
- gained Australia-wide agreement to make rangeland monitoring data readily accessible to the broader community;
- made rangeland information available to community and government through the Atlas.

This report compiles sample information products that cover biophysical resources, impacts on those resources and socioeconomic factors.

Audit objective 5: Ensuring integration with, and collaboration between, other relevant initiatives

The Audit has:

- collaborated with the States, Northern Territory, Commonwealth and key client groups in collating rangeland information and defining processes for continuing data collection and management;
- defined the institutional arrangements and resources necessary for continued activity in rangeland monitoring and assessment;
- provided information on Australia's rangelands for inclusion in State of Environment reporting; and
- met the requirements for the Audit specified in the *National Principles and Guidelines for Rangeland Management* (ANZECC/ARMCANZ 1999) to define a rangeland monitoring program.

Audit objective 6: Providing a framework for monitoring Australia's land and water resources in an ongoing and structured way

Through this report the Audit has defined:

- the components of a comprehensive Australia-wide rangeland monitoring system—the Australian Collaborative Rangeland Information System; and
- the steps towards implementing that system.

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PURPOSE AND STRUCTURE OF THIS REPORT

The development of an Australia-wide rangeland monitoring system that can meet the needs of rangeland managers at a wide range of scales and for a variety of objectives is recognised as a key national challenge.

The Rangeland Monitoring activity was designed to meet the requirements of the *National Principles and Guidelines for Rangeland Management* (ANZECC/ARMCANZ 1999). The guidelines specified a series of projects to be undertaken by the Audit to develop a rangeland monitoring system.

This report defines elements of a comprehensive monitoring and reporting program that can provide regular Australia-wide reports and allow for better decisions to be made affecting land use and management within Australia's rangelands.

The Audit also collated available information for rangelands as context for this monitoring system.

The structure of the report is as follows.

Introduction

- Describing Australia's rangelands: their extent, use and role.
- Defining challenges to rangeland management.

Development of rangeland monitoring

- Tracing development of a national rangeland monitoring system in Australia.
- Summarising Audit Rangeland Monitoring theme projects, including explanations of new capabilities that have been developed as a result of this work.

Tracking changes

Examples of information available to date, presented as assessments of:

- changes to biophysical resources;
- impacts on biophysical resources;
- socioeconomic information; and
- institutional responses.

Australian Collaborative Rangeland Information System

- Outlining the activities, scope and structural arrangements for a proposed Australia-wide rangeland monitoring collative mechanism.

This report does not provide a complete status report on the condition of Australia's rangelands. It provides much of the information and system for this to occur and recommends that a full assessment of Australia's rangelands, based on the Audit's monitoring system and data now collated, be undertaken in the next five years. The report does not fully address the information and skill requirements of Indigenous rangeland managers, or the implications for land management of Indigenous land ownership. This is currently being addressed through a separate Audit project.

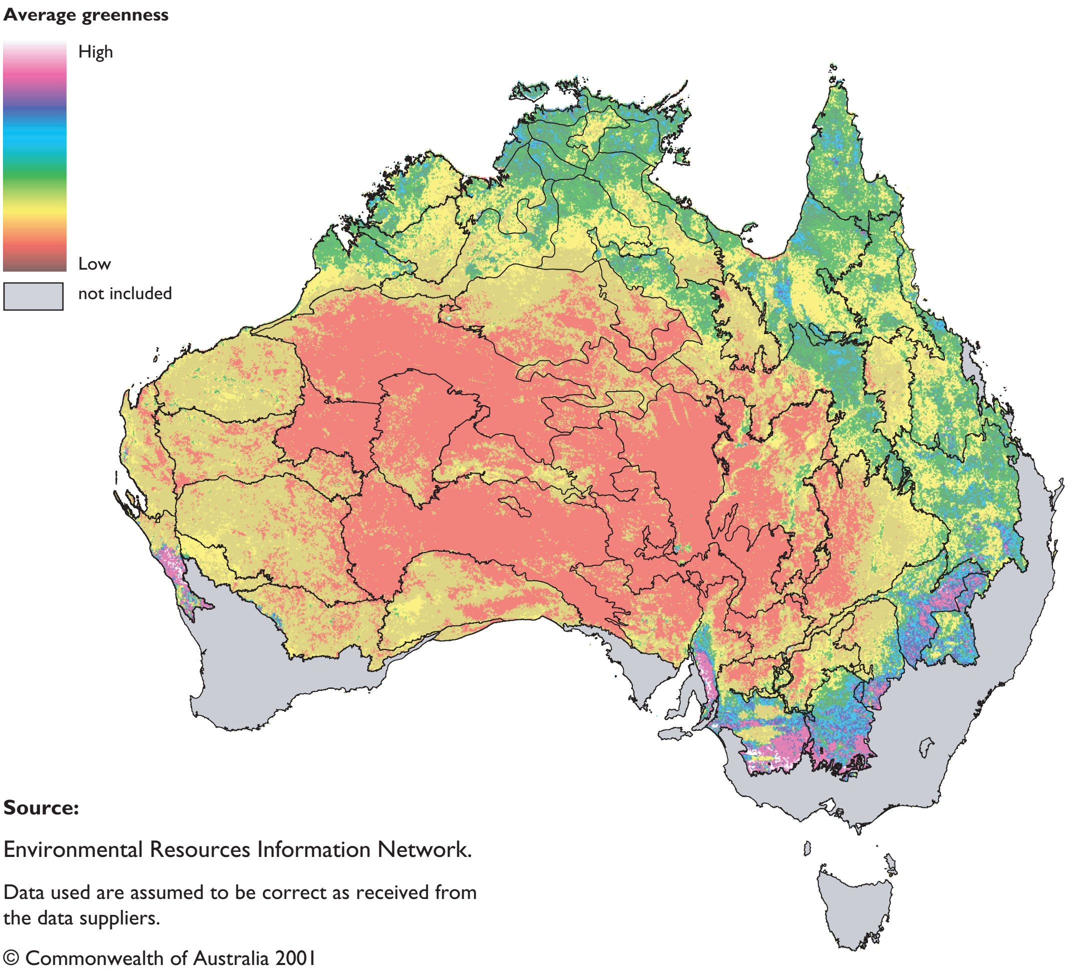
Tropical savannas are an integral part of Australia's northern rangelands

INTRODUCTION

Identifying the challenge

More than 75% of Australia is broadly defined as rangelands (Harrington et al. 1984). This includes a diverse group of relatively undisturbed ecosystems—tropical savannas, woodlands, shrublands and grasslands. Rangelands extend across low rainfall areas, including arid and semi-arid, and some seasonally high rainfall areas (Figure 1). Extensive grazing on native pastures occurs across much of the rangelands; broadscale cropping and cultivation generally do not take place.

Figure 1. The rangelands: yearly change in photosynthetic activity (or greenness) averaged over 1992 to 1999, as estimated by the Normalised Difference Vegetation Index from satellite data. The arid interior (red area), where rainfall is less frequent than in the tropical savannas (green and yellow), shows a lower average annual response to rainfall. Pink and blue indicate that the annual greenness response is the highest on average and these areas are generally not considered rangelands. Interim Biogeographic Regionalisation of Australia (Version 5.1) is used as an approximate boundary for rangelands.



Source:

Environmental Resources Information Network.

Data used are assumed to be correct as received from the data suppliers.

Sturt's desert pea (*Swainsona formosa*): the floral emblem of South Australia that occurs in arid woodlands and open plains

Approximately 2.3 million people (13% of Australia's total population) live in rangelands. They use and manage the land for a variety of purposes and have different information needs.

People managing and using rangelands make decisions that can affect large tracts of country:

- land administrators—dealing with changes in pasture condition, revising tenure arrangements and addressing conservation needs on public lands, making land management policy, ensuring that the public good is protected;
- public land managers—making access and use decisions in road, railway, defence, park and conservation reserve development and operation;
- pastoralists—choosing grazing, burning, weed control and watering regimes;
- Indigenous land managers—providing a place to live and retaining a basis for their cultural identity, using the land for pastoral purposes and for traditional hunting, gathering and cultural activities;
- mining managers—exploring for and extracting minerals, building infrastructure, and rehabilitating mine sites; and
- township communities—deciding about infrastructure and use of the surrounding landscape.

These decisions are not made in isolation and are often influenced by external pressures:

- government policy and its implementation;
- advice from government and commercial organisations;
- economic opportunities and constraints;
- results of scientific research; and
- community expectations and values.

Increasing global pressures—including international conventions on biodiversity, greenhouse gas emissions, desertification, use of wetlands together with international market fluctuations on rangeland products—influence rangeland management.

International conventions

Convention on Biological Diversity: Concerned with conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilisation of genetic resources.

Framework Convention on Climate Change: Concerned with the stabilisation of greenhouse gas concentrations in the atmosphere to prevent climate change.

Convention to Combat Desertification: Long-term integrated strategies that focus on areas affected by desertification; improved productivity; and rehabilitation, conservation and sustainable management of land and water resources.

Ramsar Convention on Wise Use of Wetlands: Nominates wetlands of international importance as a focus for demonstrating best practice management. Guidelines are developed for the use and management of wetlands.

Urban dwellers and government policy makers outside rangelands are seeking more information about what is happening in the rangelands. They have an increasing awareness of and interest in:

- the environment, including biodiversity conservation;
- the quality and supply of water;
- the well-being of rangeland people and communities; and
- investment opportunities specific to rangelands.

Value of rangelands

Biodiversity

Australia's rangelands are made up of a variety of habitats supporting high levels of species diversity. They represent the largest group of Australia's ecosystems remaining in a relatively natural condition.

Income

Much of Australia's mineral wealth (approximately $12 billion each year) is derived from rangelands. In addition cattle and calf production generates $4.4 billion each year; sheep, lamb and wool production generates approximately $1 billion each year; and tourism generates approximately $2 billion each year.

Social and cultural heritage

Rangeland landscape is an intrinsic element of the social and cultural heritage of its towns and communities. Rangelands provide a sense of place for many Indigenous Australians who continue traditional hunting and gathering and whose everyday life is underlain by traditional cultural heritage.

Sub-artesian water sources and major river systems

Rangelands are spread over large artesian and sub-artesian water sources (including the Great Artesian Basin, one of the world's largest underground water sources) and major river systems (e.g. the Gascoyne in Western Australia, the Victoria River in the Northern Territory, the Lake Eyre Basin across several States and the Darling River in New South Wales).

Clean and green food and fibre production

Rangelands present opportunities for 'clean and green' food and fibre, and for harvesting wild animal and plant products.

Carbon storage

Rangelands contribute to Australia's carbon account. Work is under way through the Australian Greenhouse Office to define carbon sources, sinks, fluxes and losses.

Australia's rangelands are used for multiple purposes

Many areas of Australia's rangelands are used for multiple purposes.

This Landsat satellite image shows the area around the town of Carnarvon at the mouth of the Gascoyne River on the west coast of Western Australia. The Gascoyne River flows above ground only intermittently and underground water is used to irrigate an area of tropical agriculture east of the town (bright green areas). This water comes from rainfall in the Gascoyne catchment, falling up to 650 km away on land mostly used for pastoralism and nature conservation.

The most extensive land use around Carnarvon is pastoralism. Individual stations may occupy more than 100 000 ha (marked by straight green lines).

Salt mining (bright blue areas in the north-west corner of the image) is a major contributor to the region's economy.

Many people are attracted to the area to experience the outback and enjoy coastal pursuits (e.g. fishing, surfing, snorkelling and whale watching).

Carnarvon provides services to these industries and is an important land manager and user in its own right, with extensive commons to the north and south of the town.

Rangeland information—the challenges

Australia's rangelands are in relatively good condition. Nevertheless loss of biodiversity and productive potential, excessive water loss and rapidly changing rural communities require early attention and protective management. Investment in protective management through monitoring is far more cost-effective than funding rehabilitation of degraded areas.

1. Multiple user needs

Rangelands have many users, each with the potential to impact on the land. Users have stewardship obligations and a duty of care that recognises landscape values (including landscape integrity, and social and cultural requirements). Rangeland natural resource management information will be used differently depending on land use, scale of management, cultural background, values and expectations.

- *Multiple rangeland uses must be recognised. Factual information that can be analysed and interpreted by managers with different interests, perspectives and values and by the wider community must be provided.*

2. Providing information and policy support at a range of scales

Rangeland management issues are complex and information requirements vary.

- *Information needs to be able to support both short-term management and long-term policy development.*
- *Information needs to be readily accessible, interpretable and applicable at a range of scales and perspectives, including international, national, State, regional and local.*

3. Evaluating sustainability

Rangeland managers make decisions affecting large tracts of land. Their experience in achieving sustainability is valuable and should be documented (Heywood et al. 2000).

- *Information that provides options and evaluates strategies for sustainable management must be presented.*

4. Regular assessment to evaluate ecological, economic and social changes

Regular and repeatable assessment of rangelands is necessary to evaluate the effectiveness of management decisions and will facilitate analysis of economic, social and environmental consequences resulting from different management strategies. It will provide a framework to select and evaluate various investment options for both government and community.

- *Monitoring must be multidisciplinary and account collectively for ecological, economic and social aspects of management and policy.*

5. Identifying long-term change

Changes in rangelands occur in both the long and short term. Monitoring enables early detection of change, ways to interpret it, and provides an objective and repeatable process for future reference. Integrating the spatial capacity of remote sensing and detailed field measurements provides the basis for determining trends in long-term change.

- *Monitoring must track change consistently over the long term and provide an analysis that is capable of separating changes due to land use impacts from changes that are part of the inherent variability of Australia's climate and ecosystems.*

Long-term change

The effect of fire, grazing and variable rainfall confounds monitoring of landscape change and condition in rangelands. Consistent patterns of change over the longer term (several years or decades) are more indicative of the true condition of the landscape than observing patterns over the shorter term (days to months).

Many monitoring systems need to use indicators (e.g. soil surface features and the dynamics of perennial vegetation) that show long-term rather than short-term change.

In 1984 rainfall at this site in Western Australia was very high and over one tonne per hectare of biomass from annual species (herbage) was produced. In 1987, a year of very low rainfall, herbage was almost absent. By 1988, average rainfall had produced an average herbage response.

While herbage fluctuated widely during this period, the shrub population and size of individual shrubs showed little change. This indicated that the land management in place maintained basic function of the landscape over the four-year period, despite the major differences in seasonal herbage response due to rainfall.

1984

1987

1988

6. Seeking opportunities for early response

Time scales and investment required to reverse changes to and rehabilitate rangelands are huge. Often full recovery is not possible either ecologically or economically.

- *Changes in condition must be tracked and opportunities for early response intervention identified if degradation is occurring.*

7. Understanding biodiversity—status, condition and trends

Rangeland environments provide diverse habitats for flora and fauna—an important ecological asset. An increase in ecotourism has meant that biodiversity is also an important economic asset.

- *Information on the status and trends in Australia's flora and fauna is critical to providing a sound basis for effective and protective management activities.*

8. Managing a complex ecology

Rangeland ecology is complex. Many rangeland ecosystems are vulnerable to vegetation loss, soil erosion and the introduction of exotic species; rainfall is highly variable and unpredictable. There is limited knowledge on ecological change, the time scales involved and the ultimate impacts of land uses.

- *The complex ecology of rangelands must be recognised and trend information provided to separate natural variability from land use induced change.*

9. Providing information on key ecological drivers such as fire

Fire is a key natural driver of rangeland ecosystem processes, both in northern Australia where fire is frequent and in southern Australia where fire is infrequent but the effect is significant (Bradstock et al., in press). Fire is used to 'control' weeds, produce 'green pick', reduce fire hazard and manage wildlife habitat.

Too many or too few fires at the wrong time can lead to major flora and fauna changes. Inappropriate use of fire can result in damage to and loss of feed, infrastructure and fire-sensitive vegetation.

- *Information on key ecological drivers of change such as fire must be recognised and provided.*

10. Changes in and diversity of tenure

There is a wide range of tenure types and variety of ownership patterns. This includes Indigenous freehold ownership (11.7%), leasehold interest (about 7%) and Native Title interests through interest in crown land and pastoral leases.

Change in tenure often reflects change in land use. It is a key driver of change in condition in rangelands. Almost all of the commercially used rangelands outside Queensland are public land held under leasehold tenures administered by State and Territory governments. In Queensland, commercial land is either leasehold or freehold. Key land managers include pastoralists and Indigenous people, while land administrators such as pastoral lands boards (Northern Territory, Western Australia, South Australia) play a major role in ensuring sustainable management. Most non-commercial rangelands are managed either through agencies responsible for national parks and unassigned land, or by Indigenous groups.

- *Land administrators must be provided with up-to-date summaries of changes in tenure and land use.*

11. Reducing the barriers of distance

Rangeland managers need access to good quality information that will assist cooperative management and stewardship in remote Australia. The development of infrastructure to deliver this information is a national obligation and requires both Commonwealth commitment and cooperation across State and Territory borders.

- *Information must be provided to reduce barriers of distance in the transfer of ideas, technologies and management options and to provide an Australia-wide approach to rangeland management.*

12. Facilitating adoption

Before managers can adopt improved techniques, they need to understand the complexities of rangelands. Education and training should be based on scientifically sound knowledge building on the existing knowledge and skills of managers and continuously improving through feedback and partnership.

- *Information provided must be consistent, easily available, readily understood, build on existing knowledge and provide the basis for practical management decisions.*

13. International reporting

Australia has obligations under international conventions (e.g. in biological diversity, climate change, desertification and wetlands).

- *Information on rangeland condition and management must be provided at local scales to meet local needs. It should also be able to be consistently aggregated to a national scale to demonstrate how Australia complies with international obligations.*

14. Support for marketing exports

Most of Australia's rangeland production is based on natural inputs. Limited use of agricultural chemicals in rangelands provides a market edge for products.

- *A documentary base is required to support marketing of exports from 'clean and green' grazing systems.*

The vast area of the continent referred to as rangelands is important to Australians who derive their living and identity from it. Collecting and providing information to decision makers presents many challenges—mainly as a result of differing needs, time frames and scales for different uses. The common goal is sustainable resource management. As an Australia-wide monitoring system is developed and put in place to track changes, the complexities of rangeland ecology and processes will become better understood and management more effective.

Ground surveys: part of an integrated monitoring system

DEVELOPMENT OF RANGELAND MONITORING

Towards better decisions

In the middle 1990s those of us who had to make recommendations to the federal government about 'exceptional circumstances' really struggled with that concept in the rangelands. We worried about our judgements because of scant short term figures. And I am sure we made mistakes ... 'On the ground' data recorded over a long period would have made us more confident in our reports to the Minister of the day.

Neil Inall
Chairman
Rural Adjustment Scheme Advisory Council
1993–1998

Regular observations, or monitoring, are an integral part of management. Information about how rangelands respond to the pressures placed on them is required to make informed management decisions. Monitoring information is also needed to analyse previous decisions and outcomes.

Many people have polarised but relatively uninformed views on land use impacts. Decisions may be based on memory and perceptions of how previous management decisions affected the resource, or on the managers' own experiences and training. Individual decision makers may not always take account of the multiple values of rangelands relating to production, biodiversity, society, economics and culture.

Monitoring systems have been developed to assess the impacts of management across Australia but these have been deficient in a number of areas.

Existing rangeland monitoring systems

All rangeland States and the Northern Territory have rangeland monitoring and condition assessment programs. Examples of these activities are presented in Appendix 1. More detail is available in Gould et al. (2001), Green et al. (2001), Karfs et al. (2001), Anderson et al. (in press) and Watson et al. (2001).

Rangeland monitoring systems established in Australia over the last 30 years generally involved ground-based data collection on the pastoral estate, focusing on pasture response under grazing of domestic stock. Such systems did not extend across State and Northern Territory borders, and were limited to individual jurisdictions in which varying methodologies and rationales were developed. The information generated did not always reflect the needs of decision makers, or the scales and time frames within which decisions needed to be made. Decisions about rangelands continued to be made using only limited objective information on how pasture responds to impacts from land use, climate, weeds and grazing by native and feral animals.

Some elements of biodiversity inventory (determining presence or absence of species) have been included in rangeland monitoring and research. However, biodiversity monitoring (determining how biodiversity is changing) has not been included to date.

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Progress in the development of an Australia-wide rangeland monitoring system

early 1990s

Request by the Technical Committee on Soil Conservation of the Sustainable Land and Water Resources Management Committee to develop a Rangelands Monitoring Program recognising that all States and the Northern Territory were developing monitoring systems, and that efficiencies and effectiveness would result from cooperative effort. Efforts were mostly focused on pastoral lands with judgements about change in condition made from a pastoral perspective.

1997

Joint submission from the States and Northern Territory to the Sustainable Land and Water Resources Management Committee calling for Commonwealth coordination of the collation and assessment of pasture monitoring data. The Commonwealth was not able to support the proposal as developed.

after 1997

The *National Principles and Guidelines for Rangeland Management* (ANZECC/ARMCANZ 1999) (Guideline 16.1) stated:

The opportunity created by the National Land and Water Resources Audit must be used to establish a national rangelands monitoring program to determine trends in the long term health of Australia's rangelands at a regional, land type and property level.

The guidelines called for a broad coverage of Australia's rangelands, encompassing … *indicators of production, biodiversity, water resource condition, climate and socioeconomic factors on a regional and bio-physical unit basis.*

1998

The *Rangeland Monitoring Work Plan* was designed to meet requirements of the *National Principles and Guidelines for Rangeland Management* that specified a series of projects to be undertaken by the Audit to work towards developing an enduring rangeland monitoring system rather than simply producing a one-off condition assessment.

2000–01

The Audit developed a proposal for a comprehensive rangeland monitoring system that strengthens commitment across agencies. This proposal recognises the multidisciplinary nature of information needs for rangeland management. It is working towards gaining Commonwealth support for Australia-wide coordinated rangeland monitoring, assessment and reporting.

Water resources monitoring

Social and economic data regularly collected by the Australian Bureau of Statistics and the Australian Bureau of Agricultural and Resource Economics has not been interpreted with relevance to rangeland natural resource management.

Rangeland management from an Indigenous perspective is quite different to the European perspective and values. Building an understanding of Indigenous needs and information requirements is essential and recognises the increasing Indigenous role in rangeland natural resource management.

It has not been possible to successfully develop a broadly accepted comprehensive national rangeland strategy because of a lack of:

- agreed monitoring techniques; and
- objective information on status and long-term trends in natural resource condition.

Until such information is readily available and applied as a basis on which to develop strategies, decisions on rangeland management will continue to be flawed.

The Audit approach to rangeland monitoring

The needs of a wide range of potential users of Audit monitoring products were identified through a series of workshops held across Australia (Hassall & Associates 1998). This review indicated that State and Northern Territory agencies recognised that existing information and monitoring systems did not comprehensively reflect the condition of Australia's rangelands. They also strongly supported developing an integrated proposal for rangeland monitoring. Direction was provided by the *National Principles and Guidelines for Rangeland Management* (ANZECC/ ARMCANZ 1999) and the Audit *Rangeland Monitoring Work Plan* (as developed by the National Rangeland Monitoring Coordinating Committee with input from the community).

Rangeland Monitoring theme projects

Rangeland Monitoring theme projects as specified in the work plan had two broad objectives:

- to collate background information that provides context and an increased ability to identify trends; and
- to develop new methods to cost-effectively collect data and meet information needs.

Five main projects and individual contracts contributed to each objective. Some summary outputs of Audit projects are presented in this report; full reports are available in the Atlas.

1. An assessment of change in ecosystem function, trends in intensity of use and history of climate and fire that impact on the ecosystem

1.1 Landscape function analysis of rangeland monitoring data (see p. 34)

- Provided methods of interpreting State and Territory site data in a landscape function context

Marble gum (*Eucalyptus gongylocarpa*) on low sandy dunes in the Great Victoria Desert

- Summarised landscape function data on a regional scale

1.2 Indices of change in landscape function for northern South Australia using Landsat Thematic Mapper satellite data (see p. 40)

- Demonstrated remote sensing methods to identify critical thresholds in vegetation cover for areas used for extensive cattle grazing

1.3 Indices of change in landscape function at the national scale using Advanced High Resolution Radiometer Normalised Difference Vegetation Index data (see p. 64)

- Provided continental images comparing recent and past seasonal Normalised Difference Vegetation Index values
- Highlighted areas of possible change in landscape function

1.4 Incidence of extreme climatic events using Advanced High Resolution Radiometer Normalised Difference Vegetation Index data

- Provided continental images showing variation in seasons and comparative analyses across years

1.5 Intensity of land use (see p. 68)

- Developed a national database of total grazing density (dry sheep equivalent per square kilometre) within local government areas from 1956 to 1999

1.6 Regional land condition and trend assessment in tropical savannas (see p. 41)

- Provided landscape change, condition and trend summaries at a range of scales and methods for interpreting satellite data sequences

2. Determining trends in economic, social and institutional factors that influence land use and management in rangelands

2.1 Indicators within a decision framework (see p. 99)

- Identified social, economic and institutional indicators of individual and community capacity to adopt sustainable resource management

2.2 Change in land tenure/land use (see p. 83)

- Developed a database of changes in land tenure and land use since 1956

2.3 Compiling a database of socioeconomic indicators for rangelands (see p. 99)

- Compiled a database of indicators derived from existing census and survey databases

3. Developing an adaptive framework for monitoring biodiversity in rangelands

- Developed a monitoring framework that uses a minimum set of nine indicators for monitoring biodiversity and threatening processes

4. Developing information and decision aids to help decision makers reach their management decisions

4.1 Collation of State and Northern Territory monitoring activities

- Identified and documented existing State and Northern Territory rangeland monitoring systems and how they will contribute to Australia-wide reporting (see Appendix 1 for summary)

4.2 National reporting framework

- Integrated existing State and Northern Territory activities, products and project techniques into an Australia-wide framework (documented as the *Operational Manual* [Holm 2000])

4.3 Plain English summaries of regional information

- Prepared web-ready summaries by bioregion that provide information about the natural environment, land tenure and use, landscape condition, social and economic aspects and key references

4.4 Web reporting system

- Developed the rangeland component of the Atlas

5. Coordination and reporting

- Oversaw the interests of the National Rangeland Monitoring Coordinating Committee
- Liaised between the Audit, project contractors and the National Rangeland Monitoring Coordinating Committee
- Oversaw implementation of all contracts to ensure project objectives were met in the context of the entire work plan

Key achievements of the Audit Rangeland Monitoring theme

- Framework for monitoring biodiversity within the context of overall rangeland management.
- Operational system using remote sensed and ground-based data that enables monitoring across large areas of rangelands.
- Approach to rangeland monitoring driven by landscape and ecosystem function rather than use.
- Data sets of historical and contextual information.

These achievements have led to the development of a comprehensive Australia-wide monitoring system that is based on:

- the understanding that rangeland change is driven by climate, land use and tenure;
- recognition of the dynamic and multidisciplinary nature of rangeland management; and
- recognition that people and communities are part of the rangeland environment and that socioeconomic profiles and changes are as important to rangeland management as biophysical changes.

Potential benefits from regular collection of information have been established through three case studies. These case studies show the value of using monitoring to track changes in rangelands over time.

CASE STUDY 1

Australia-wide program implementation: exceptional circumstances decisions

Pressure is often placed on the Commonwealth, State and Northern Territory governments to provide support to landholders suffering from variable and exceptional climatic events. These requests are assessed under the Exceptional Circumstances Provision of the Agriculture Advancing Australia program.

Exceptional circumstances are assessed by the National Rural Advisory Council. The Council's ability to improve support and achieve increased sustainability are restricted due to lack of:

- baseline data to provide points of comparison;
- a coordinated approach to providing information (information collection to assess claims is ad hoc, costly and time consuming); and
- continued monitoring (returns on investment are not able to be quantified or output based).

These deficiencies would be overcome if data on changes in rangelands over time were available. Data would include:

- *stocking rates* compared to historic levels;
- *vegetation cover* compared to previous seasons and adjoining areas, from both ground-based and satellite measurements;
- *rainfall effectiveness* at local and regional scales, within a long-term historical context;
- *economic trends* and the capacity of landholders to respond to exceptional climatic events;
- *social issues* affecting the region; and
- *evaluation of the impacts of decisions* to provide support for exceptional circumstances.

A comprehensive monitoring system would provide this information for rangelands and secure a more rational, cost-effective and partnership-based approach between the Commonwealth, States and the Northern Territory in implementing exceptional circumstances activities.

Felled mulga (*Acacia aneura*) for drought feeding sheep near Charleville in Queensland

CASE STUDY 2

Regional program support: WEST 2000/WEST 2000 Plus restructuring strategy, New South Wales

The projection of 'regional futures' is becoming a key requirement for policy development. Regional scale management strategies are currently in place for the South West and the Desert Uplands of Queensland, the Gascoyne–Murchison Region of Western Australia and the Western Division of New South Wales.

WEST 2000 was developed in response to pressures from the regional community for action on the biological, social and economic state of the Western Division of New South Wales following the collapse of the wool market in the early 1990s. WEST 2000 Plus is a successor program.

Information on the biological, social and economic status of the region was needed in order to make decisions on issues to be addressed under both WEST 2000 and WEST 2000 Plus. Information was gathered from disparate and often unsubstantiated sources and was variable in coverage, and its reliability was not always known.

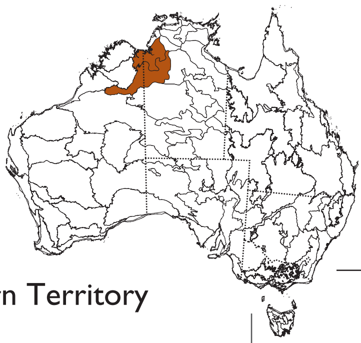
Information is needed on:

- *natural resource sustainability*: information on vegetation, grazing pressure and water availability would allow land managers to manage land in more economically and ecologically sustainable ways;
- *rural restructuring*: showing the relationship between property size and sustainable management (e.g. small property sizes can limit flexibility of stocking rates);
- *training and skills development*: in particular the need for and access to education and training on sustainable management practices; and
- *alternative industries*: to assess the impact of alternative industries in the Western Division.

An Australia-wide comprehensive monitoring system will:

- provide accessible, credible and coordinated information.
- provide the framework, assessment tools and data management system required to evaluate the response of biological, social and economic resources to regional decision making.

Regular analysis and reporting will ensure the implications of the information are understood and the community is actively involved in scenario development.



CASE STUDY 3

Property management support: Victoria River District, Northern Territory

Uniformity of heavy grazing over large areas is one of the greatest threats to rangeland biodiversity. This is because it encourages conditions that may favour grazing-resilient species and disadvantages more sensitive species. Satellite information can be used to identify environments in which species have been shown to be more sensitive to grazing and to develop more environmentally appropriate grazing regimes.

Regular reporting of satellite-based monitoring would assist managers by providing information on:

- *Pasture management.* Satellite monitoring can be used to identify under- or over-utilised pasture. It provides a basis for manipulating stocking rates to maintain productivity and protect sensitive or degraded areas.
- *Fencing and watering points.* Time-series satellite images have helped to determine the best design for additional watering points and fencing of large paddocks to change grazing density.
- *Stocking rates.* Stratification of paddocks into land types is important to assess the area available for grazing. Stocking rate regimes can be modified and linked to land capability through the application of spatial land type and condition information.
- *Seasonal response to rainfall.* Climate models and seasonality indices derived from satellite data help predict the quality of the previous growing season (potential feed available) and determine appropriate stocking.
- *Early warning.* Remote sensed and ground-based monitoring data combined with climate forecasts can predict feed alerts. Destocking can occur before permanent degradation of pasture occurs.

A comprehensive monitoring system would provide information to support investment and management decisions for larger rangeland grazing properties. A major pastoral company in the Northern Territory is already using products developed through the application of satellite-based monitoring over large areas of the Victoria River District to guide investment and property management. These techniques were demonstrated at an operational scale through the Audit's project in the tropical savannas.

REPORTING BY BIOREGIONS

One of the major challenges in the development of a comprehensive monitoring system is the provision of information that is relevant at a range of scales from regional to national. Bio-geographic regions (bioregions) have been used in this report as a consistent unit for comparing information.

The **Interim Biogeographic Regionalisation of Australia** provides a framework that describes the dominant landscape scale attributes of climate, lithology, geology, landforms and vegetation of interacting similar ecosystems. Fifty-three bioregions cover the rangelands. Bioregions have been further subdivided and some maps use these subregions (Morgan 2001).

1 Arnhem Coast
2 Arnhem Plateau
3 Brigalow Belt North
4 Brigalow Belt South
5 Broken Hill Complex
6 Burt Plain
7 Cape York Peninsula
8 Carnarvon
9 Central Arnhem
10 Central Kimberley
11 Central Ranges
12 Channel Country
13 Cobar Peneplain
14 Coolgardie
15 Daly Basin
16 Dampierland
17 Darling Riverine Plains
18 Darwin Coastal
19 Davenport Murchison Range
20 Desert Uplands
21 Einasleigh Uplands
22 Finke
23 Flinders Lofty Block
24 Gascoyne
25 Gawler
26 Geraldton Sandplains
27 Gibson Desert
28 Great Sandy Desert
29 Great Victoria Desert
30 Gulf Coastal
31 Gulf Fall and Uplands
32 Gulf Plains
33 Hampton
34 Little Sandy Desert
35 MacDonnell Ranges
36 Mitchell Grass Downs
37 Mount Isa Inlier
38 Mulga Lands
39 Murchison
40 Murray Darling Depression
41 Northern Kimberley
42 Nullarbor
43 Ord Victoria Plain
44 Pilbara
45 Pine Creek
46 Riverina
47 Simpson Strzelecki Dunefields
48 Stony Plains
49 Sturt Plateau
50 Tanami
51 Tiwi Cobourg
52 Victoria Bonaparte
53 Yalgoo

Source: Thackway & Cresswell 1995.

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TRACKING CHANGES

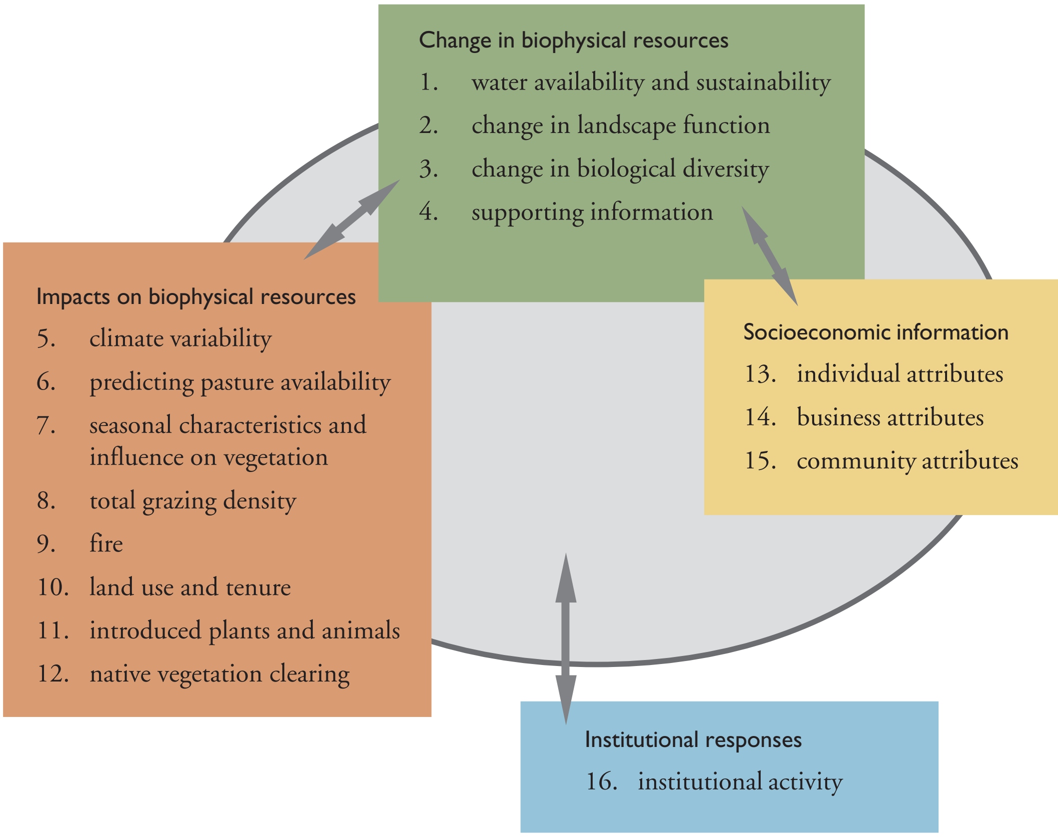
Information products for informed decisions

Decision making requires information on:

- the status of rangelands (an inventory of current condition);
- variations in condition and the cause of these variations; and
- some indications of trend (the direction of change in condition) where change is occurring.

One output of the Rangeland Monitoring theme is a system for assessing relative condition and trend that could form the basis for a system of inventory and monitoring tools collectively entitled the Australian Collaborative Rangeland Information System. Sixteen 'information products' are identified as integral to a comprehensive monitoring system (Figure 2) and are organised under four components. Some of the products have already been developed and operationalised by one or more jurisdictions; others require further development.

Figure 2. Components of a comprehensive rangeland monitoring system and associated information products.



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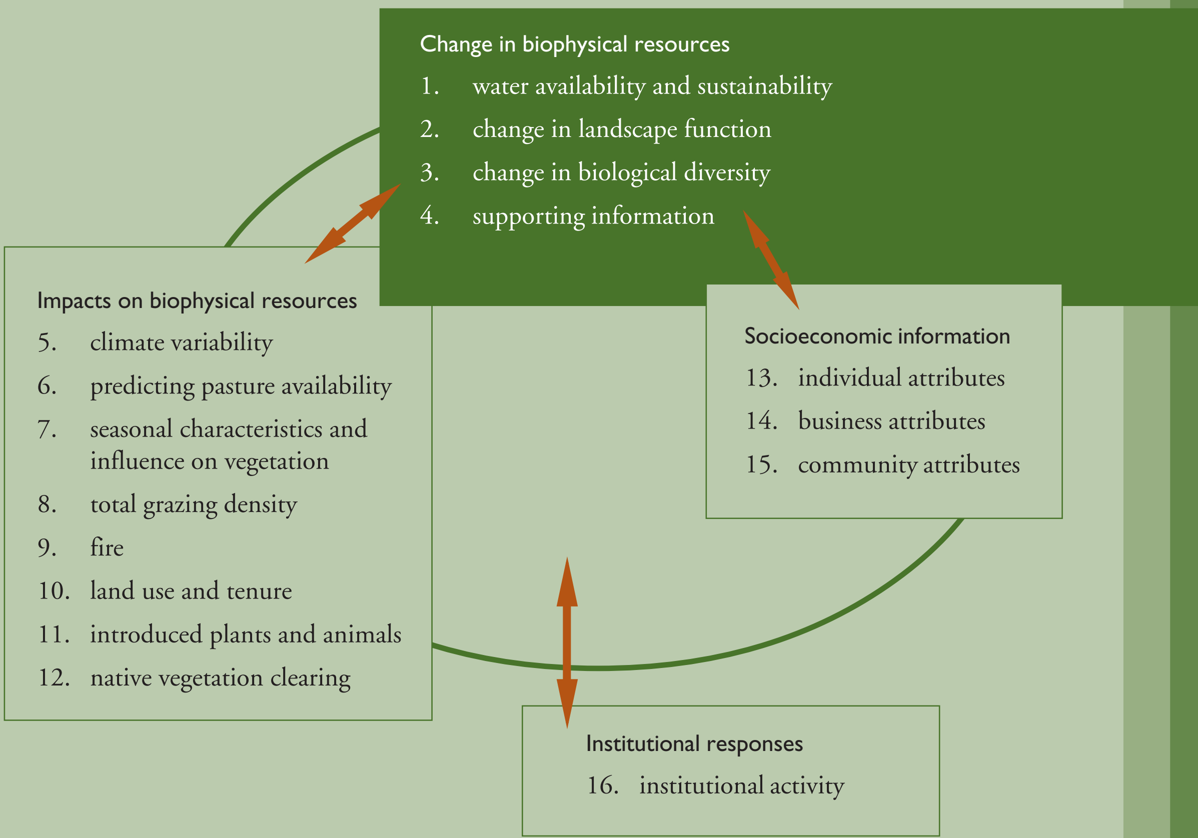
Change in biophysical resources

Biophysical resources are soil, nutrients, water, plants and animals. Information on these resources can be used to assess how well landscapes conserve soil and recycle plant nutrients and how landscape condition is changing.

Change in biophysical resources influences:

- productive potential of economic opportunities (e.g. wool or meat products);
- ecosystem services (e.g. clean water, carbon);
- loss of biodiversity; and
- traditional land uses (e.g. gathering of bush tucker).

Information products under this component are summarised in Table 1.



Brigalow (*Acacia harpophylla*): often cleared for grazing in Queensland

Table 1. Information products for change in biophysical resources.

Key attributes	Description and current status	Rationale for inclusion
Product 1. Water availability and sustainability		
Definition of surface and groundwater resources; their availability and quality Assessment of surface and groundwater sustainable yield	Water resource characterisation and assessments of use against sustainability criteria are undertaken at irregular intervals, with the last assessment being *Australian Water Resources Assessment 2000* (National Land and Water Resources Audit 2001a).	Water resources are a key limiting factor to development, including agricultural enterprise, urban and mining activities. Water use needs to be managed in the context of sustainability—flow regimes for surface water and yield for groundwater.
Product 2. Change in landscape function		
Change in vegetation cover from Landsat satellite data	The Tropical Savannas project and a companion project in South Australia have defined, applied and demonstrated methods for applying Landsat data at an operational level.	This product will provide information at various scales. Data archiving will allow for time sequences and tracking change. Ground monitoring data provide direct estimates of factors affecting landscape processes and are used to validate remotely sensed methods.
Change in landscape function from monitoring site data	Data variables include vegetation patchiness, woody plant density, frequency of perennial grasses and soil surface condition.	
Changes in landscape function using NOAA satellite data, including continued refinement of methods (product in development)	Change in minimum cover of perennial vegetation and change in rainfall use efficiency (as assessed by NOAA) are roughly related to change in landscape function. These products are readily available at continental and regional scales, but are yet to be proven.	

Table 1. continued on next page

Table 1. continued

Key attributes	Description and current status	Rationale for inclusion
Product 3. Change in biological diversity		
Change in composition of perennial plant species and abundance of specified invasive, fire sensitive, threatened and grazing-sensitive species	Biodiversity monitoring activities are ready to implement and could use existing ground-based sites for vegetation monitoring. Additional sites will be needed to collect information on non-pastoral areas.	This product provides direct estimates of biodiversity and assists validation of the links between remotely sensed and ground-based assessments.
Changes in the composition of ant communities	Ant monitoring is done through projects such as WEST 2000 and the Great Artesian Bore Recapping project.	Changes in the composition of ant communities are used to reflect local changes in biodiversity integrity.
Change in distribution and abundance of threatened vertebrates (mammals and birds) from repeat surveys of wildlife	There is little institutional vertebrate monitoring at regional scales. The only Australia-wide vertebrate collection is the Bird Atlas.	Periodic re-sampling of a set of benchmark wildlife surveys will provide spatial context to the site-based information.
Product 4. Supporting information		
Long-term photographic records of landscape change Regional resource condition assessments and other regional/ local information collection	Long-term photographic sequences of representative sites and landscapes around Australia provide rangeland condition context information within defined land systems (e.g. see Cunningham 2000a, b). Resource inventory surveys, pastoral lease inspections and other activities provide further context and issue specific information.	This product provides context to help interpret changes in biophysical resources.

Capping of leaking bores: an imperative for groundwater management

Product 1. Water availability and sustainability

Most rivers in Australia's rangelands are ephemeral and so water used is mainly derived from local run-off or groundwater. Pastoral rangelands use natural and artificial watering points that are typically less than 10 km apart. These provide water for not only domesticated stock but also for native and feral grazing animals. This can lead to intensive grazing near watering points and potential threats to biodiversity (Landsberg et al. 1997).

Definition of surface and groundwater resources available and their quality

Australian Water Resources Assessment 2000 (National Land and Water Resources Audit 2001a) assessed the quantity, quality, use, allocation and management of surface water and groundwater resources. There were 325 surface water management areas and 535 groundwater management units defined as a basis for management and reporting. For the first time, Australia has a spatially defined set of groundwater management units, an important basis for improved groundwater management. Sixty-one broadly defined groundwater provinces (defined by the former Australian Water Resources Council) have been used as an aggregation unit for map representations of groundwater management data because groundwater management units can overlie each other and therefore cannot be easily represented as a single map.

Groundwater resources

- 161 (30%) of Australia's 535 groundwater management units are either close to or are overused when compared with their estimated sustainable yield.
- In terms of licences for abstraction, 168 groundwater management units are either fully allocated or over-allocated when compared with estimated sustainable yield.

Substantially increased effort by Australia's water resource managers is required to precisely define sustainable yield and improve management of Australia's groundwater management units. Priority must continue to be given to the highly- and over-committed groundwater management units.

Water resource development

- 241 surface water management areas and 265 groundwater management units are at low to medium levels of development. Many of these have limited capability for significant development—particularly the more arid basins of Australia.

Development opportunities vary across Australia: in tropical Australia opportunities based on water capture (e.g. dams, bore fields, harvesting of overland flows) are still to be fully assessed and realised; in southern Australia development is approaching its extraction limits and caps on further allocation are being introduced.

Understanding water use

- Water use across Australia has increased to 24 000 gigalitres (GL) (19 000 GL from surface water; 5000 GL from groundwater) in 1996/97 from 14 600 GL in 1983/84.

The greatest increases by volume in water use are in New South Wales (3600 GL) and Queensland (2300 GL)—accounting for 25% of total annual water use. Water use and delivery efficiency, recycling, trading and pricing are increasingly becoming priorities and provide opportunities for development.

The results of the assessment of surface and groundwater are available in the Atlas at national, State, groundwater management unit and surface water management area levels.

Information available in the Atlas for each groundwater management unit

Water availability

- Developed yield (average annual volume that can be abstracted for use by existing infrastructure measured in megalitres per year [ML/yr])
- Abstraction (average annual volume currently extracted for use measured in megalitres per year [ML/yr])

Aquifer characteristics

- Depth (average depth to aquifer)
- Thickness (thickness of strata)
- Salinity (salt concentration as measured by electrical conductivity in microSiemens per centimetre [µS/cm)
- Bore levels (monthly hydrographs)

Assessment of sustainable groundwater yield

Sustainable groundwater yield is the level of extraction that should not be exceeded over a specified planning time frame to protect the higher value—social, environmental and economic—uses associated with the aquifer.

Key considerations are:

- *Maintenance of water level and/or pressure.* Short-term declines of water level and pressure occur with any groundwater development. Ensuring that long-term or unplanned decline does not occur is a key issue in sustainable groundwater management.
- *Maintenance of water quality.* Water quality can be degraded by excessive abstraction flows or intrusions from adjoining aquifers containing saline water, or from land uses that result in contamination.
- *Determination of environmental water provisions and setting sustainable limits.* Sustainable yield needs to be assessed and agreed as a basis for managing the sharing of the resource between consumptive and in situ uses such as mound springs.

Assessment of groundwater systems against sustainable yield is difficult. Assessment must consider use, allocation and environmental water requirements in the context of resource characterisation. Not much is known about groundwater-dependent ecosystems. A precise assessment cannot be made for many of the groundwater systems in Australia as characterisation data for groundwater management units are either partially or completely lacking.

THE GREAT ARTESIAN BASIN

The Great Artesian Basin is one of the world's largest aquifer systems. It covers an estimated 1.7 million km^2 and stores 8 700 000 GL. Each year the Great Artesian Basin supplies 570 GL of water for a variety of uses—mainly grazing and mining.

Management of the groundwater resource of the Great Artesian Basin is shared between Queensland, New South Wales, South Australia and the Northern Territory. The *Strategic Management Plan* (Great Artesian Basin Consultative Committee 2000) provides for its management as a single resource, including continued bore rehabilitation and piping of bore drains (costed at approximately $220 m) to minimise waste from previously free-flowing bores in the Great Artesian Basin. Further work required includes:

- recovering artesian pressure to achieve pastoral and biodiversity outcomes;
- making water available for new users; and
- reducing adverse impacts of water distribution on natural resources and biodiversity.

Water use in the Great Artesian Basin exceeds State and Territory sustainable estimates (Figure 3).

Estimates of sustainability

A four-class classification system was developed to provide a simple method to communicate the status of the use and allocation of Australia's water resources.

Category	Extraction* %	Development status
1	<30	Low development
2	30–70	Moderate development
3	70–100	Highly developed
4	>100	Overdeveloped

* Water extraction as a percentage of sustainable yield

Category 1 systems have zero to low levels of resource use: direct management intervention and information requirement are low.

Category 2 systems are moderately developed: management intervention and resource information requirement is moderate.

Category 3 systems are close to, or at, their extraction limit and require a high level of management inputs. Resource information and monitoring are vital for these systems.

Category 4 systems are over-committed in water allocation and/or use: insufficient provision has been made for environmental and non-consumptive uses, management intervention and information requirements are substantial.

Estimates of sustainability—Great Artesian Basin use profile—indicating priority areas for investment in bore rehabilitation and piping of bore drains.

Category	Number of groundwater management units in category
1	4
2	0
3	6
4	24

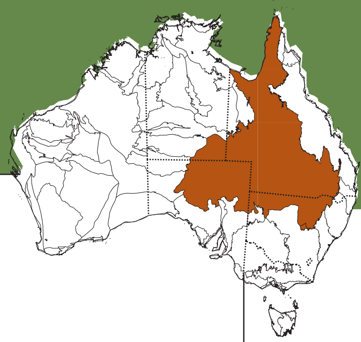
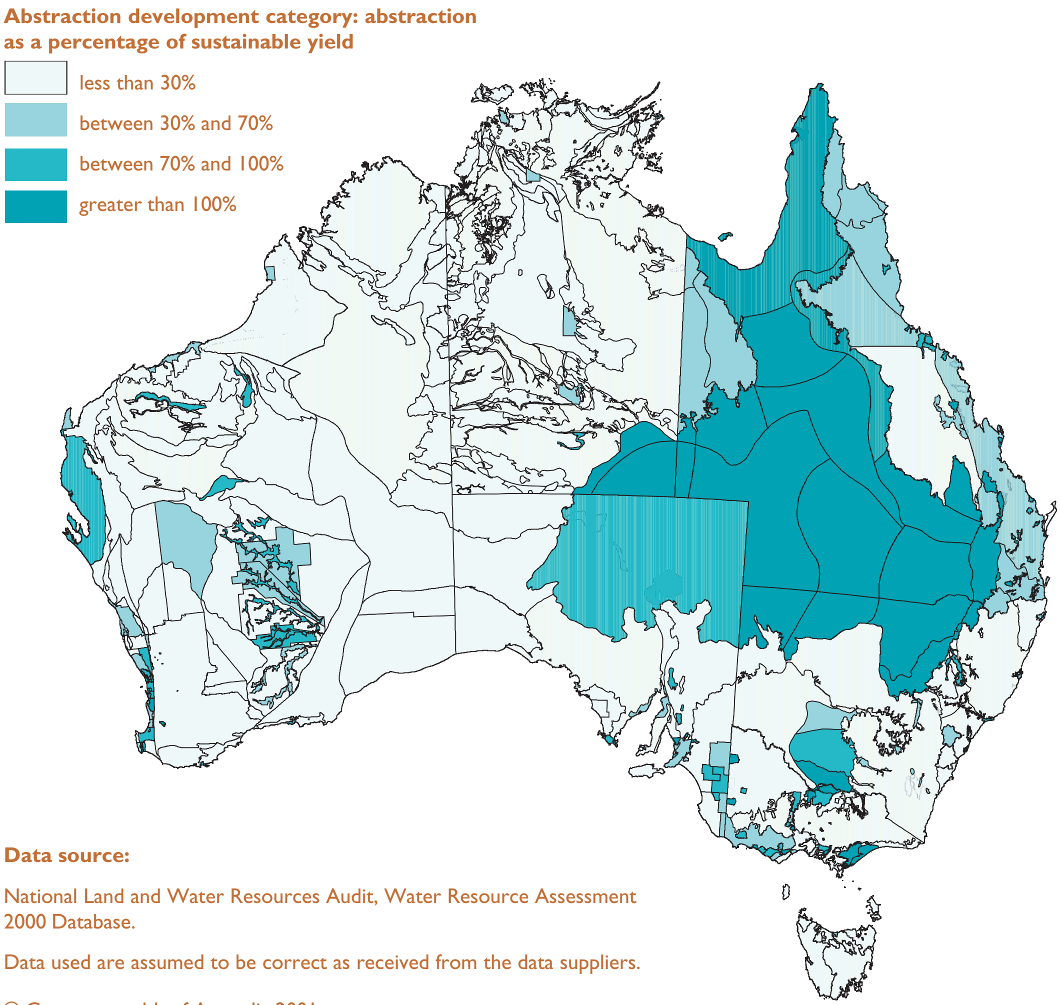


Figure 3. Groundwater management units in each abstraction development category (2000).



Data source:

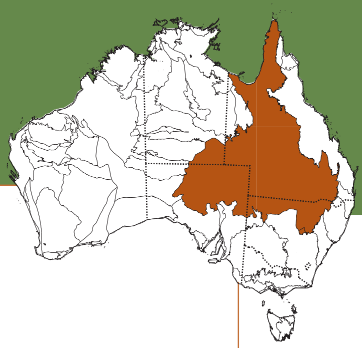
National Land and Water Resources Audit, Water Resource Assessment 2000 Database.

Data used are assumed to be correct as received from the data suppliers.

Excerpt from Australian Water Resources Assessment 2000 (National Land and Water Resources Audit 2001a)

Great Artesian Basin groundwater province summary data

Groundwater management unit	Sustainable yield (ML)	Groundwater use: Total abstraction (ML)	Groundwater use: Development category	Groundwater allocation: Total allocation (ML)	Groundwater allocation: Development category	Sustainable yield assessment reliability
55S Great Artesian Groundwater Province						
New South Wales						
Great Artesian Basin – Central – New South Wales	5 750	6 580	4	6 580	4	D
Great Artesian Basin – Southern Recharge	10 100	11 580	4	36 490	4	D
Great Artesian Basin – Surat	53 640	70 780	4	70 780	4	D
Great Artesian Basin – Warrego	38 770	44 390	4	44 390	4	D
Lower Gwydir alluvium	35 000	40 762	4	99 032	4	C
Lower Namoi alluvium	95 000	43 849	3	213 264	4	A
Queensland						
Condamine – Condamine Groundwater Management Unit Sub-area 1	1 440	2 157	4	3 560	4	A
Condamine – Condamine Groundwater Management Unit Sub-area 2	2 490	4 252	4	10 723	4	A
Condamine – Condamine Groundwater Management Unit Sub-Area 3	14 810	19 179	4	49 562	4	A
Condamine – Condamine Groundwater Management Area Sub-area 5	1 500	154	1	1 126	3	A
Condamine River (down-river of Condamine Groundwater Management Area)	3 500	1 800	3	1 898	2	C
Great Artesian Basin – Barcaldine – Queensland	36 310	44 170	4	44 170	4	D
Great Artesian Basin – Central – Queensland	16 680	28 000	4	28 000	4	D
Great Artesian Basin – Eastern Recharge A – Queensland	1 400	1 600	4	1 600	4	D
Great Artesian Basin – Eastern Recharge B – Queensland	32 450	37 140	4	37 140	4	D
Great Artesian Basin – Eastern Recharge C – Queensland	15 690	17 950	4	17 950	4	D
Great Artesian Basin – Flinders – Queensland	39 270	48 710	4	48 710	4	D
Great Artesian Basin – Gulf – Queensland	18 570	21 260	4	21 260	4	D
Great Artesian Basin – Mimosa – Queensland	13 970	15 990	4	15 990	4	D



Groundwater management unit	Sustainable yield (ML)	Groundwater use: Total abstraction (ML)	Groundwater use: Development category	Groundwater allocation: Total allocation (ML)	Groundwater allocation: Development category	Sustainable yield assessment reliability
55S Great Artesian Groundwater Province						
Great Artesian Basin – Northwest – Queensland	10 680	12 230	4	12 230	4	D
Great Artesian Basin – Surat – Queensland	71 960	96 720	4	96 720	4	D
Great Artesian Basin – Warrego – Queensland	48 960	59 400	4	59 400	4	D
Great Artesian Basin – Western – Queensland	80	90	4	90	4	D
Great Artesian Basin – Western Recharge – Queensland	80	90	4	90	4	D
St George alluvium	18 000	2 000	1	6 340	2	C
Weipa	64 000	63 000	3	210	1	D
Winton/Mackunda Formations	24 000	n/a	4	n/a	1	D
South Australia						
Curdimurka (Wellfield A)	n/a	2 000	3	15 000	3	n/a
Total Great Artesian Basin – South Australia	60 000	54 800	3	63 800	3	D
Muloorina (Wellfield B)	n/a	5 500	3	–	3	n/a
Unincorporated area – Hamilton	n/a	n/a	1	n/a	n/a	D
Unincorporated area – Peake Denison	n/a	n/a	1	n/a	n/a	n/a
NorthernTerritory						
Great Artesian Basin – Western – Northern Territory	490	570	4	570	4	D
Great Artesian Basin – Western Recharge – Northern Territory	330	380	4	380	4	D

Estimates of data reliability

Class	Groundwater quantity
A	Based on reliable recorded and surveyed data that have required little or no extrapolation or interpolation. Estimated accuracy: ±10%.
B	Based on approximate analysis and limited surveys. Some measured data and some interpolation/extrapolation to derive the dataset. Estimated accuracy: ±10% to 25%.
C	Little measured data, based on reconnaissance data. Estimated accuracy: ±25% to 50%.
D	Derived without investigation data. Figures estimated from data in nearby catchments, or extrapolated/interpolated from any available data. Estimated accuracy: ±50%.

Product 2.
Change in landscape function

The landscape function framework focuses on understanding how well a landscape is working as a system by studying the regulation of nutrients and water across the landscape (Ludwig et al. 1997). It is a spatial and dynamic concept focusing on landscape processes (e.g. nutrient cycling) rather than outputs (e.g. the particular species composition of vegetation). It is free of value judgements, and its information can be used and interpreted within a range of value systems. Broad indicators of landscape function include condition and trend of perennial vegetation, and a range of soil surface attributes.

Abundance of perennial grasses endemic to an area is an indication that the landscape is functioning well.

- Functional landscapes are likely to recover quickly from disturbance (e.g. grazing or fire), and to maintain a consistent vegetation cover through variable seasonal conditions. They are able to adequately regulate water and nutrients (e.g. slowing runoff to maximise infiltration is important where lack of water limits plant growth).
- Dysfunctional landscapes may not recover or take longer to recover.

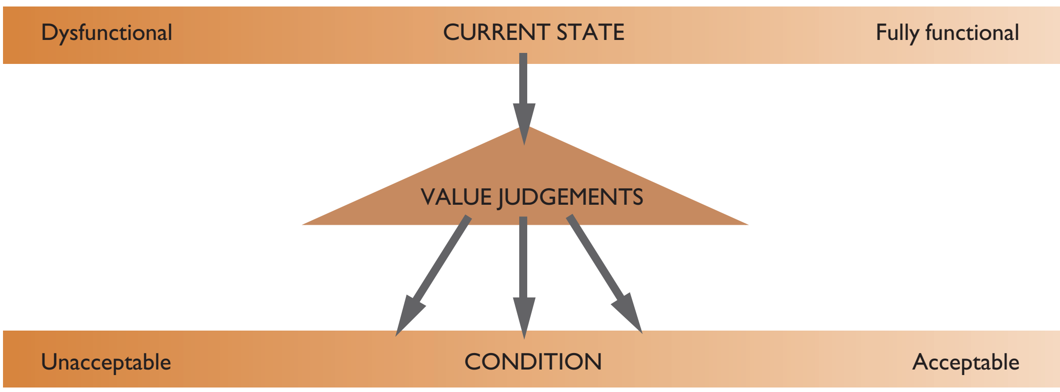
Landscape function versus condition

Landscape *function* and *land condition* are separate measures.

- Landscape function is characterised by the interrelationships of landscape components in relation to changes in energy and materials in space and time. Assessment of landscape function is a necessary precursor to a judgement of condition.
- Condition of a landscape is a value judgement and is related to its worth for a particular land use. It can be influenced by preconceptions, and cultural and social views (Figure 4).

Monitoring for landscape function analysis is more cost-effective than for other types of analysis as less emphasis is placed on a complete inventory of species at a site. The key attributes for assessing landscape function are change in vegetation cover and species monitored through a combination of methods from remote-sensed imagery and ground-based data collection.

Figure 4. Continuum of landscape function. **Adopted from:** Ludwig at al. 1997.



Hummock grassland of hard spinifex (*Triodia basedowii*) on sandy plains in the Great Victoria Desert

Rangeland vegetation

Most rangeland vegetation is dominated by native species.

In northern and eastern Australia the dominant vegetation types are eucalypt woodland with a grassy understorey, eucalypt forest and acacia woodland with a grassy understorey, and open grasslands. The distribution of forest and woodland is determined by rainfall effectiveness and soil type—little water, higher evaporation rates and low fertility limit the height and density of trees.

In central and central-western Australia the dominant vegetation type is shrubland where acacias, eucalypts and casuarina species make up the tree layer with a grassy or shrubby understorey. Common plants are the mallee (multi-stemmed eucalypts) and mulga (e.g. *Acacia aneura*).

Chenopod species (including bluebush and saltbush) are widespread, particularly across the southern half of the rangelands. The chenopods form communities that are drought- and salt-tolerant and of reasonable palatability to stock. Grasslands are also widely distributed with tussock grasses such as Mitchell grass (common in the central east). Hummock or spinifex grasslands cover large areas of inland Australia and are a dominant understorey layer across vast areas of north-western Australia where acacias and eucalypts form the dominant overstorey.

The National Vegetation Information System is being developed as part of the Audit's *Australian Native Vegetation Assessment 2001*. It contains information on the type and extent of Australia's native vegetation both now and before European settlement. It provides a classification framework that is comparable across administrative boundaries. The scale, spatial coverage and level of classification of the information varies depending on mapping activities and data that has been collated into the National Vegetation Information System (Figures 5, 6 & 7). Estimates of pre-European vegetation give us a benchmark to assess vegetation change relative to European disturbance, and an indication of change in composition, that can be used for conservation planning and revegetation strategies.

Figure 5. Major vegetation groups: Australia.

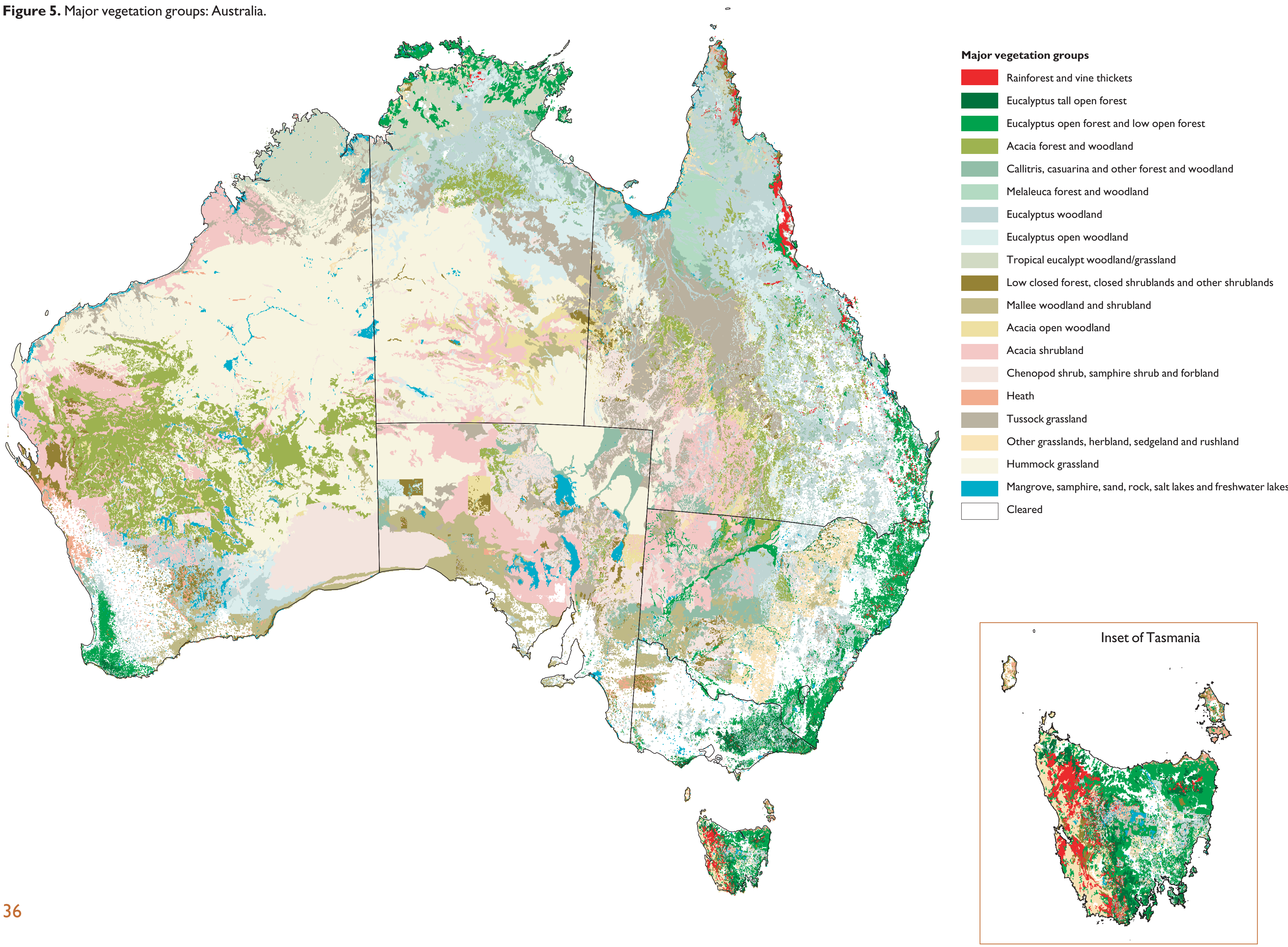
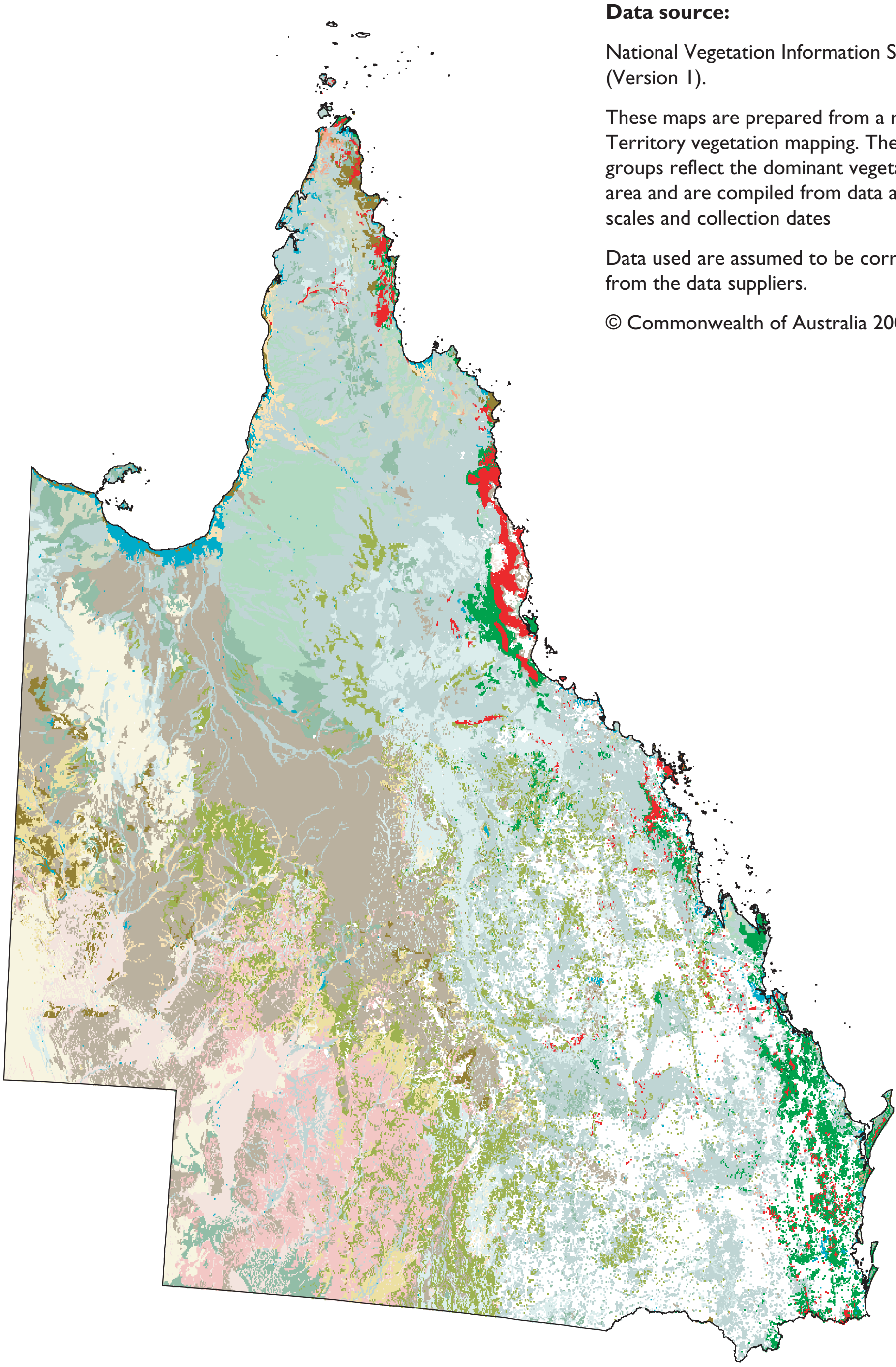


Figure 6. Major vegetation groups: Queensland.



Data source:

National Vegetation Information System 2001 (Version 1).

These maps are prepared from a range of State and Territory vegetation mapping. The major vegetation groups reflect the dominant vegetation type over an area and are compiled from data across a range of scales and collection dates

Data used are assumed to be correct as received from the data suppliers.

Figure 7. Major vegetation groups: Desert Uplands bioregion.

Eucalyptus open forest

- Eucalyptus mallee woodland/spinifex woodland

Eucalyptus woodland

- Eucalyptus low woodland/spinifex woodland
- Eucalyptus woodland
- Eucalyptus woodland/acacia woodland/ grassy low sparse tussock grassland
- Eucalyptus woodland/chenopod sparse shrubland/grassy open tussock grassland
- Eucalyptus woodland/grassy low sparse tussock grassland
- Eucalyptus woodland/grassy open tussock grassland
- Eucalyptus woodland/grassy sparse tussock grassland
- Eucalyptus woodland/mixed low sparse hummock grassland
- Eucalyptus woodland/mixed low tussock grassland
- Eucalyptus woodland/mixed tall open shrubland/grassy open tussock grassland
- Eucalyptus woodland/mixed tall open shrubland/mixed sparse tussock grassland
- Eucalyptus woodland/spinifex low sparse hummock grassland
- Mixed woodland
- Unknown

Acacia forest and woodland

- Acacia low woodland/chenopod isolated shrubs/grassy open tussock grassland
- Acacia low woodland/chenopod sparse shrubland/grassy sparse tussock grassland
- Acacia low woodland/grassy low sparse tussock grassland
- Acacia low woodland/mixed low sparse shrubland/mixed sparse forbland
- Acacia low woodland/mixed sparse shrubland/grassy sparse tussock grassland
- Acacia low woodland/mixed tall open shrubland/grassy open tussock grassland
- Acacia open forest/mixed open shrubland
- Acacia open forest/mixed tall open shrubland/grassy isolated tussock grasses
- Acacia open forest/mixed tall open shrubland/grassy sparse tussock grassland
- Acacia woodland
- Acacia woodland/acacia tall sparse shrubland/grassy sparse tussock grassland
- Acacia woodland/grassy low open tussock grassland
- Acacia woodland/grassy low sparse tussock grassland
- Acacia woodland/spinifex open tussock grassland
- Mixed low woodland
- Mixed open woodland

Callitris forest and woodland

- Coniferous woodland/coniferous isolated shrubs/grassy tussock grassland

Casuarina forest and woodland

- Casuarina open forest/mixed tall shrubland/grassy open tussock grassland

Melaleuca forest and woodland

- Melaleuca low woodland/grassy low sparse tussock grassland
- Melaleuca low woodland/spinifex low sparse hummock grassland
- Melaleuca woodland/grassy low sparse tussock grassland

Other forests and woodlands

- Mixed low open woodland
- Mixed low open woodland/grassy low sparse tussock grassland
- Mixed low open woodland/grassy low tussock grassland
- Mixed low open woodland/mixed tall sparse shrubland/spinifex low sparse hummock grassland
- Mixed low open woodland/spinifex low sparse hummock grassland
- Unknown

Eucalyptus open woodland

- Eucalyptus low open woodland
- Eucalyptus low open woodland/grassy low open tussock grassland
- Eucalyptus low open woodland/grassy low sparse hummock grassland
- Eucalyptus low open woodland/grassy low sparse tussock grassland
- Eucalyptus low open woodland/mixed low sparse hummock grassland
- Eucalyptus low open woodland/spinifex low sparse hummock grassland
- Eucalyptus open mallee woodland/spinifex low sparse hummock grassland
- Eucalyptus open woodland
- Eucalyptus open woodland/acacia open shrubland/grassy open tussock grassland
- Eucalyptus open woodland/acacia sparse shrubland/spinifex low sparse hummock grassland
- Eucalyptus open woodland/grassy low open tussock grassland
- Eucalyptus open woodland/grassy low sparse tussock grassland
- Eucalyptus open woodland/mixed low isolated shrubs/grassy open tussock grassland
- Eucalyptus open woodland/mixed low sparse xanthorrhoealand/spinifex low sparse hummock grassland
- Eucalyptus open woodland/mixed open shrubland
- Eucalyptus open woodland/mixed sparse shrubland/spinifex sparse tussock grassland
- Eucalyptus open woodland/mixed sparse tussock grassland
- Eucalyptus open woodland/mixed tall isolated shrubs/dichanthium open tussock grassland
- Eucalyptus open woodland/spinifex low hummock grassland
- Eucalyptus open woodland/spinifex low open hummock grassland
- Eucalyptus open woodland/spinifex low sparse hummock grassland
- Mixed open woodland
- Mixed open woodland/grassy low sparse tussock grassland

Acacia open woodland

- Acacia low open woodland
- Acacia low open woodland/grassy low sparse hummock grassland
- Acacia low open woodland/mixed isolated shrubs/astrebla and iseilema open tussock grassland
- Acacia low open woodland/mixed low isolated shrubs/grassy low open tussock grassland
- Acacia low open woodland/mixed open tussock grassland
- Acacia low open woodland/myoporum sparse shrubland/grassy open tussock grassland
- Acacia low open woodland/spinifex low sparse hummock grassland
- Acacia low open woodland/spinifex open hummock grassland
- Acacia open woodland/astrebla and iseilema sparse tussock grassland

Acacia shrubland

- Acacia open shrubland
- Acacia sparse shrubland/chenopod isolated shrubs/mixed open forbland
- Acacia sparse shrubland/mixed isolated shrubs/grassy open tussock grassland
- Acacia sparse shrubland/mixed sparse shrubland/grassy low open tussock grassland

Other shrublands

- Melaleuca low open shrubland/spinifex low sparse hummock grassland
- Mixed sparse shrubland/acacia isolated shrubs/astrebla and iseilema tussock grassland

Tussock grassland

- Acacia isolated shrubs/astrebla and iseilema low tussock grassland
- Acacia isolated shrubs/astrebla and iseilema open tussock grassland
- Acacia low isolated trees/astrebla and iseilema open tussock grassland
- Acacia low open woodland/acacia isolated shrubs/astrebla and iseilema tussock grassland
- Acacia low open woodland/astrebla and iseilema tussock grassland
- Astrebla and iseilema tussock grassland
- Grassy low open tussock grassland
- Mixed low open tussock grassland
- Mixed low open woodland/astrebla and iseilema tussock grassland
- Mixed low open woodland/grassy open tussock grassland
- Mixed sparse shrubland/acacia isolated shrubs/mixed open tussock grassland

Hummock grassland

- Spinifex low open hummock grassland
- Spinifex low sparse hummock grassland

Other grasslands, herblands, sedgelands and rushlands

- Chenopod low isolated chenopod shrubs/ cyperaceae low open sedgeland
- Cyperaceae low open sedgeland
- Cyperaceae low sedgeland

Chenopod shrub, samphire shrub and forbland

- Acacia isolated shrubs/casuarina isolated shrubs/mixed open forbland
- Asteraceae low forbland
- Halosarcia low sparse samphire shrubland

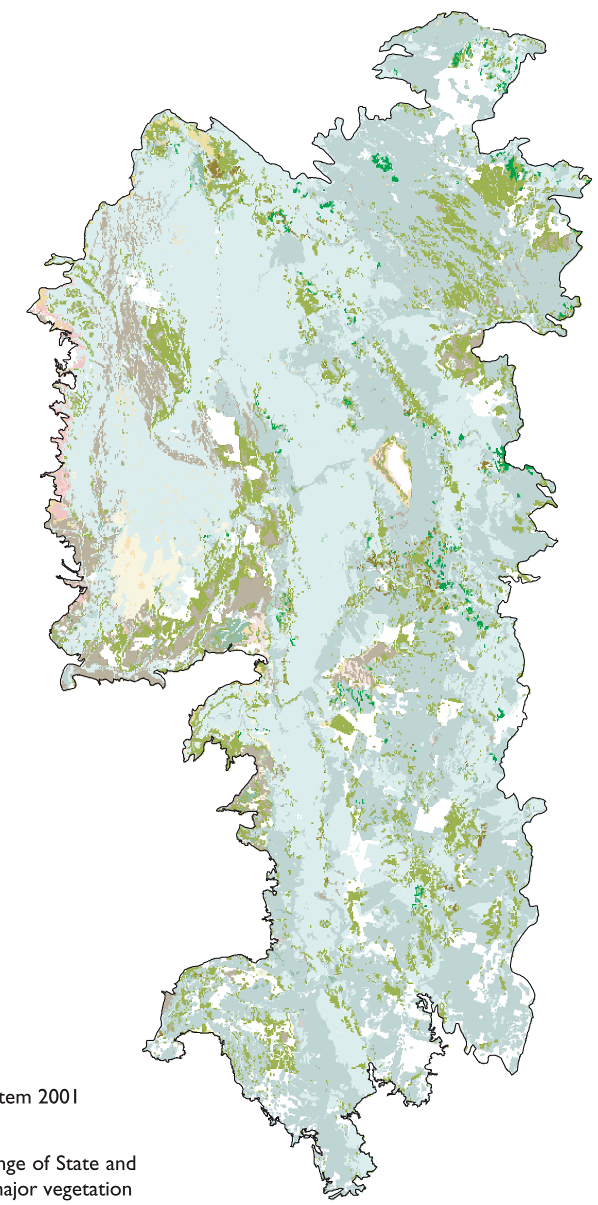
Cleared

Data source:

National Vegetation Information System 2001 (Version 1).

These maps are prepared from a range of State and Territory vegetation mapping. The major vegetation groups reflect the dominant vegetation type over an area and are compiled from data across a range of scales and collection dates

Data used are assumed to be correct as received from the data suppliers.



Hor Sumr Contents

Shrubland: the dominant vegetation type in central Australia

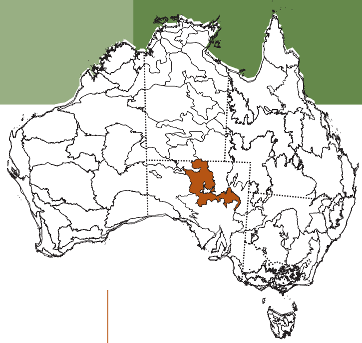
Change in vegetation cover from Landsat satellite data

Landsat satellite imagery provides information on vegetation response to rainfall and allows an assessment of landscape function. Australia-wide coverage and regular updating and archiving mean that images can be chosen by season and climate history. The images can be used to provide a measure of vegetation cover and change over time. Field verification and the collection of data at permanent monitoring sites refine satellite-based interpretations and improve understanding of complex landscape processes.

Remote sensing is a good monitoring tool because:

- image databases are made up of objective, consistently processed data;
- it allows monitoring at a range of scales and across environments;
- it can be integrated with ground data to detect change and identify function in rangelands (Figures 8, 9 & 10); and
- it is cost-effective, providing an ability to regularly monitor large areas and store a large amount of information on Australian landscapes.

Relationships between ground monitoring and remote sensing techniques are important. They enable an understanding of how landscapes respond to disturbance and variable seasons over a long period, and allow comparison between functional and dysfunctional landscapes.



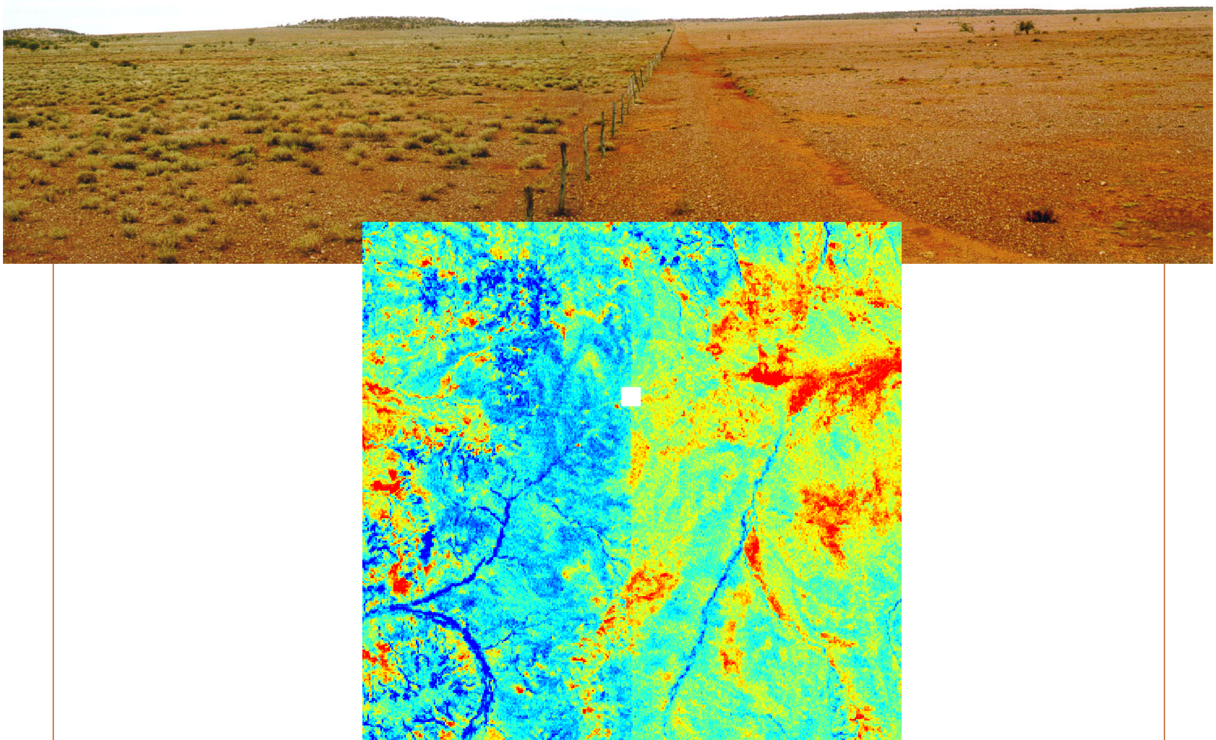


Figure 8. Landsat-derived vegetation cover map at the paddock scale in the Stony Plains bioregion (March 1988).

The cover index is calculated from the visible reflectance bands of the Landsat image. Vegetation levels are represented by red (lowest cover) through to orange, yellow, green, light blue and dark blue (highest cover).

The location of the photograph is marked by the white square on the image.

A uniform cover of bladder saltbush (*Atriplex vesicaria*) and scattered dead finish (*Acacia tetragonophylla*) occurs on the Gibber plain on the left hand side of the fence, with barley Mitchell grass (*Atrebla pectinata*), feathertop wiregrass (*Aristida latifolia*) and common bottlewashers (*Enneapogon avenaceus*) on the more heavily grazed right hand side of the fence. Grazing by cattle only occurs in this area for short periods when surface water is available.

To the right side of the fence, the bladder saltbush has been substantially reduced by intense grazing from sheep and cattle over several decades. The image indicates cover differences. Interpretation of causes and effects on plant communities is provided by integrating remote-sourced data with ground data.

Source: Brook et al. 2001.

Figure 9. Integrated ground- and satellite-based monitoring system. Landsat sequences (1983 to 1997) from the Victoria Bonaparte and Ord Victoria Plains bioregions have been processed and combined with landscape function data from ground sites and ancillary data to provide summaries and interpretation of changes in the region.

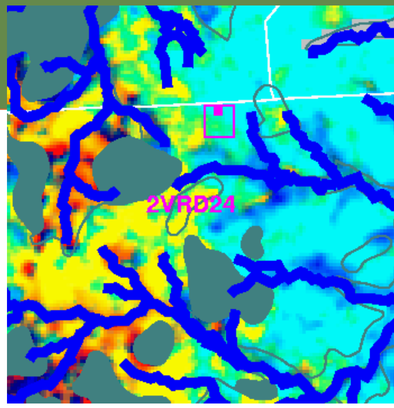
Summaries of the intensity and trend of Landsat cover indices (mean and slope) are displayed as map products over discrete image sequences (A).

By examining the brightness and variation in cover indices over time, in relation to distance from water and the location of fences, roads and land resources, a first indication of vegetation composition and landscape function can be interpreted. On the image, light blue and green represent high cover indices over a 1 ha monitoring site (2VRD24) represented by a solid red square and surrounds (hollowed square) from 1994–97. Within this 20 km^2 image, landscapes with low cover indices (red and dark blue) and decreasing trend (yellow) are also identified; riparian and rugged landscapes are masked and fence lines are represented as white lines.

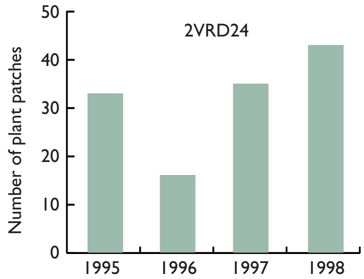
Ground monitoring data provide information on a site's functionality (B) with which to evaluate variations over time from 1983 to 1997 (C).

Based on the four years of Landscape Function Analysis data, using only 'number of plant patches' in this example, it is apparent that this site is functioning well and able to recover from disturbance (i.e. heavy grazing in 1996). From the time-trace (C), we can interpret that the vegetative cover documented at the site (D) was generally higher than in the poor to average seasons from 1988 to 1992. However in these poorer years, cover at the site was still significantly higher compared with the regional average.

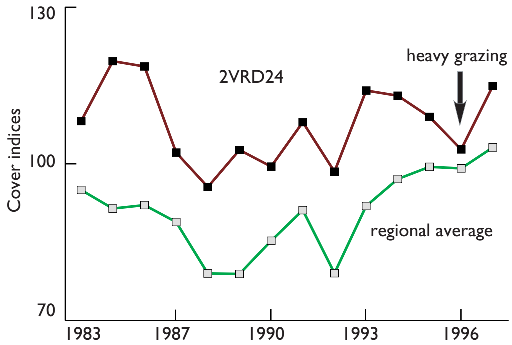
A



B

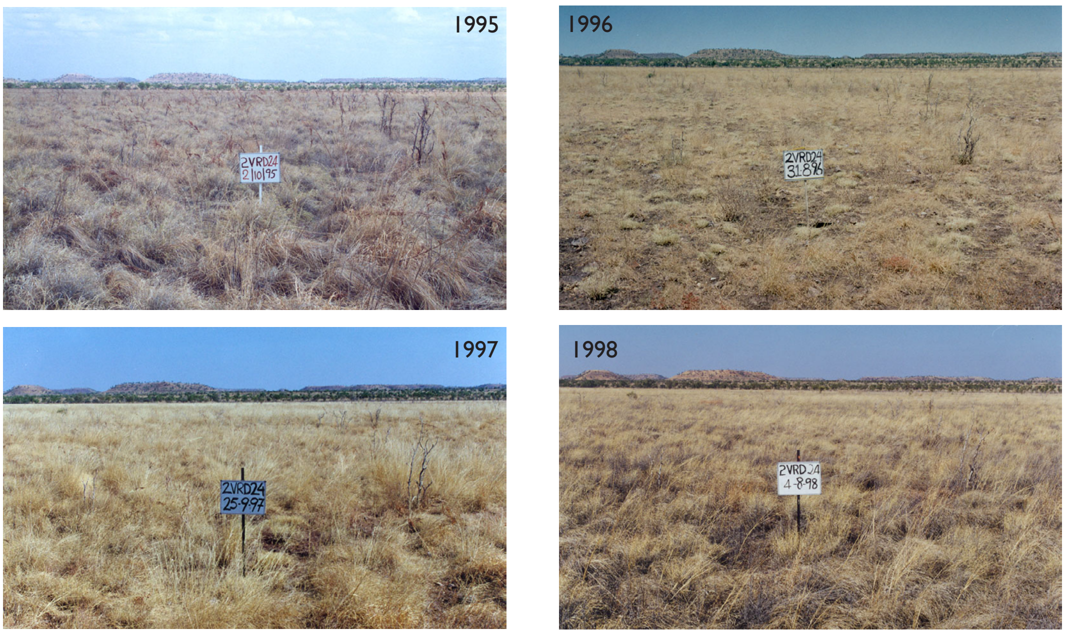


C



D

Source: Karfs et al. 2000.



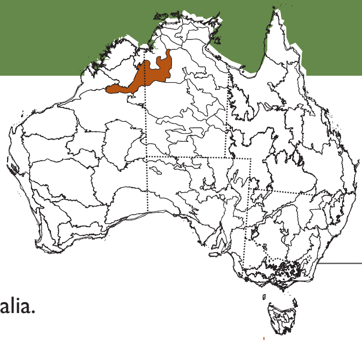


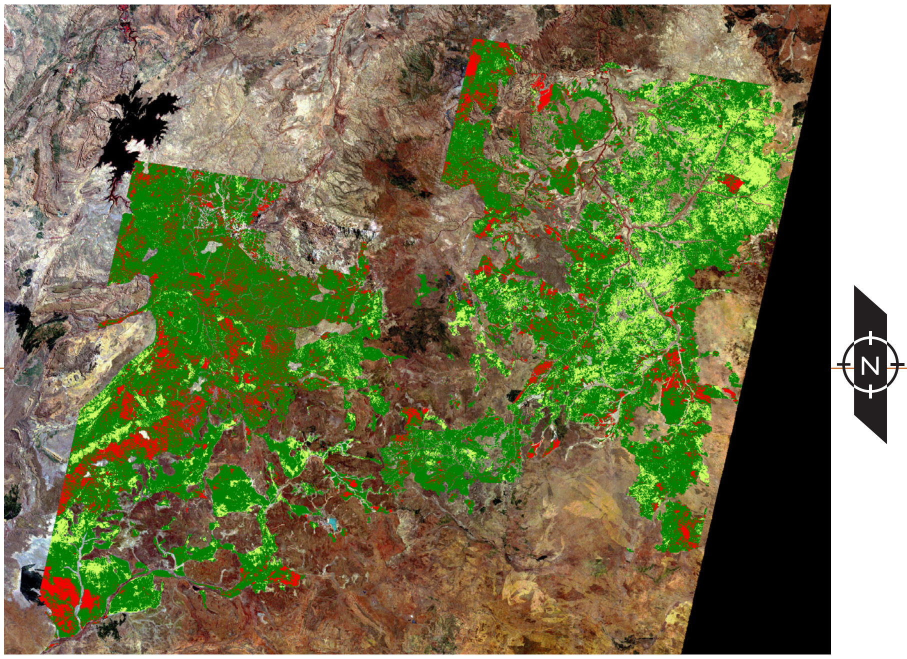
Figure 10. Regional trend for the Ord Victoria Plains bioregion in north-west Australia.

Analysing three land types separately and then combining them into a contiguous coverage creates a regional trend product from 1992 to 1997. The area analysed covers 66 550 km^2 within four mosaic Landsat scenes.

Light green represents areas where cover increased; dark green represents areas with stable cover; red represents areas where cover decreased. In this example, fire scars have not been removed and much of the red is attributed to burnt country. Fire history maps overlain on this image would aid in interpreting landscape condition.

These data show that cover has increased over much of the region. This trend can be attributed to a run of good seasons from 1993 to 1997. This is also consistent with the interpretation of ground data collected at monitoring sites over the same period.

Source: Karfs et al. 2000.



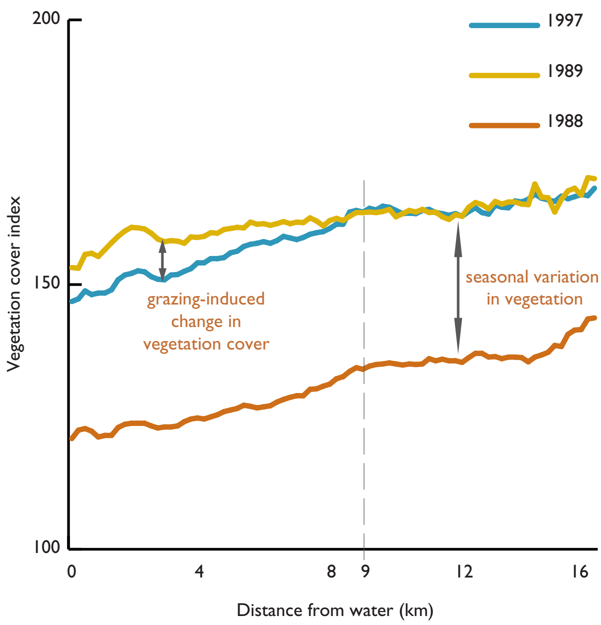
Grazing gradients: careful management of watering points is essential

The location of watering points often determines the distribution of stock in areas of low or variable rainfall. The reducing intensity of grazing on the landscape at increasing distance from water is called a 'grazing gradient'. If vegetation cover close to water is fully restored after significant rainfall then the grazing gradient is temporary, showing that grazing has not had a long-term effect. If the gradient persists after significant rainfall, then grazing has had a long-term impact on pasture productivity (Figure 11). Grazing effects can be separated from seasonal effects by using remote sensing imagery over a range of time periods.

Figure 11. Grazing gradient, Stony Plains bioregion in South Australia.

The graph shows how grazing effects can be separated from seasonal variation.

- 1988 was a dry period
- 1989 and 1997 were wet periods
- The difference between the top lines and the bottom line reflects the seasonal variation in vegetation cover.
- The difference between the top lines shows a reduction in landscape function up to 9 km from water because the vegetation cover in 1997 has not recovered to the 1989 levels.



Source: Brook et al. 2001.

Spinifex: grasslands are an important part of rangeland ecosystems

Change in landscape function from monitoring site data

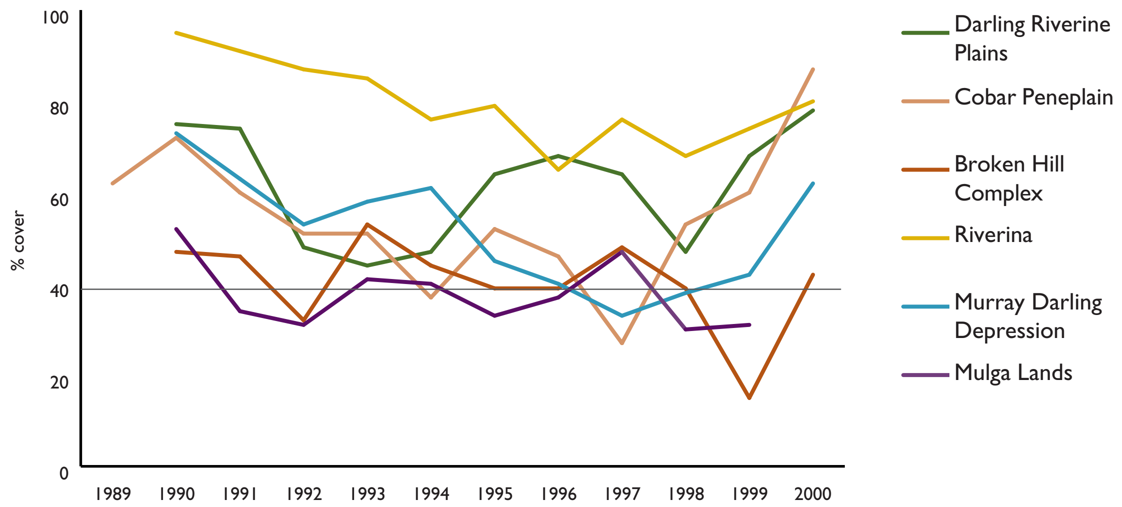
At the site scale, landscape function can be directly assessed using the Landscape Function Analysis approach. A range of attributes can be used to provide an indication of landscape function. One example is that the frequency and change in frequency of perennial species can be used to provide a broad estimate of the ability of the landscape to regulate nutrients and water (Table 2); soil or vegetation cover could also be used in this example (Figure 12). The specific attribute used will depend on the objective of the analysis.

Table 2. Changes in Kimberley grasslands, Western Australia. Average change in perennial grass frequency and average crown cover estimates (%) for all woody species taller than 1 m, by vegetation group. Data came from monitoring sites assessed between 1994 and 1996 and reassessed between 1997 and 1999. The frequency of perennial grasses can be used as a broad indicator of landscape function.

Vegetation group	No. of sites	Mean frequency 1994–1996	Mean frequency 1997–1999	Significant change
Average change in perennial grass frequency (%)				
Black soil plains	113	74.4	80.7	*
Curly spinifex	69	83.7	85.7	
Coastal vegetation	12	86.2	89.2	
Frontage grass	13	70.0	75.4	
Limestone grass	14	39.9	47.1	
Northern ribbon grass	32	88.5	85.7	
Southern ribbon grass	64	75.0	76.6	
Soft spinifex	23	84.9	86.5	
Average crown cover (5)				
Black soil plains	113	1.8	1.4	*
Curly spinifex	69	13.2	13.8	
Coastal vegetation	12	1.0	0.5	
Frontage grass	13	7.9	9.3	
Limestone grass	14	6.7	4.8	*
Northern ribbon grass	32	12.5	12.5	
Southern ribbon grass	64	6.1	5.6	
Soft spinifex	23	5.0	7.7	

Significance was tested using the two-tailed paired t-test. Not significant = P>0.05

Figure 12. Soil surface vegetative cover from 1989 to 2000 for selected bioregions in western New South Wales. Soil surface vegetative cover levels for all bioregions except the Riverina remained between 30% and 70%. The Broken Hill Complex bioregion experienced significant decrease in vegetative cover in 1999. The number of sites in each bioregion varies (see Table A1). At each site, data is collected within 4 x 300 m transects and 4 x14 quadrats.



Data source: NSW Department of Land and Water Conservation Rangeland Assessment Program.

Acacia peuce: a rare tree restricted to three locations in Queensland and the Northern Territory

Product 3. Change in biological diversity

> *During the years since you last saw it, there have been many changes in this country. The rabbits have supplanted the marsupials and the indigenous plants are gradually giving way to inferior kinds of herbage.*
>
> P.M. Byrne describing Charlotte Waters 1921, (quoted in Calaby 1996)

Native vegetation

The benefits of tracking changes in Australia's native vegetation are far from well documented. However the link between vegetation and animal biodiversity is well recognised (e.g. in the southern arid zone there is a direct link between vegetation and animal biodiversity):

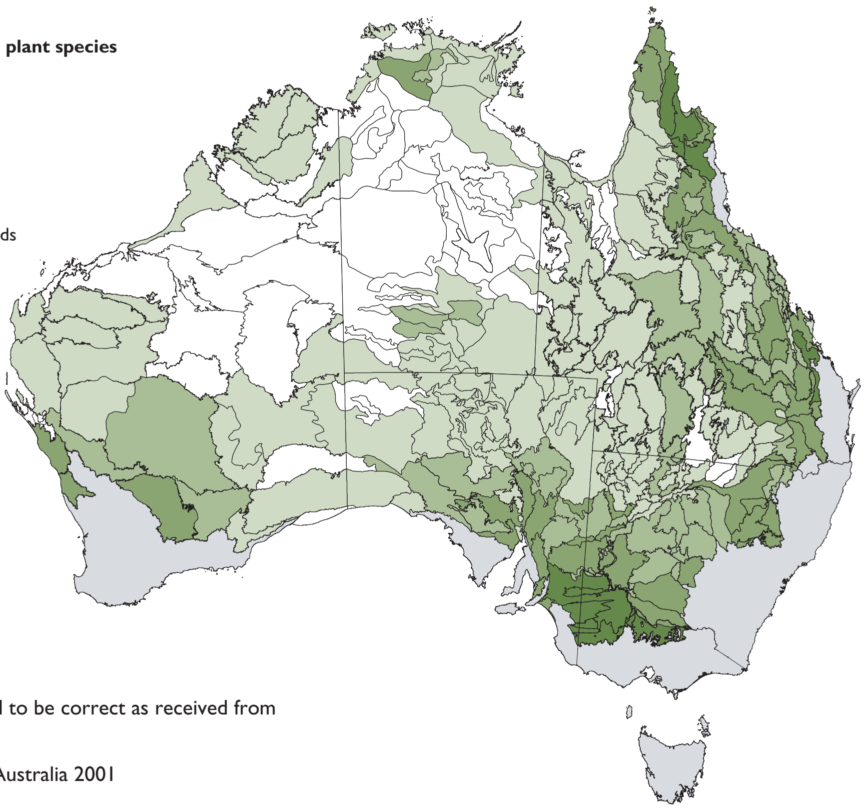
> *… the lack of effective regeneration of perennial shrubs and trees … is like a time bomb quietly ticking away; as this aging generation of chenopods, mulga, western myall and native pines thins and dies out, we will witness unprecedented changes in bird community composition …*
>
> Reid & Fleming 1992

The major threats to native vegetation are grazing by stock and feral animals, and change in fire frequency (Figure 13).

Figure 13. Known and predicted occurrence of threatened plants by subregion. Species are considered threatened if they are listed under the *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth). Threatened species may be listed as extinct, endangered, vulnerable or conservation dependent.

Number of threatened plant species

- > 49
- 30 – 49
- 10 – 29
- 5 – 9
- < 5
- no known records
- not included



Data source:

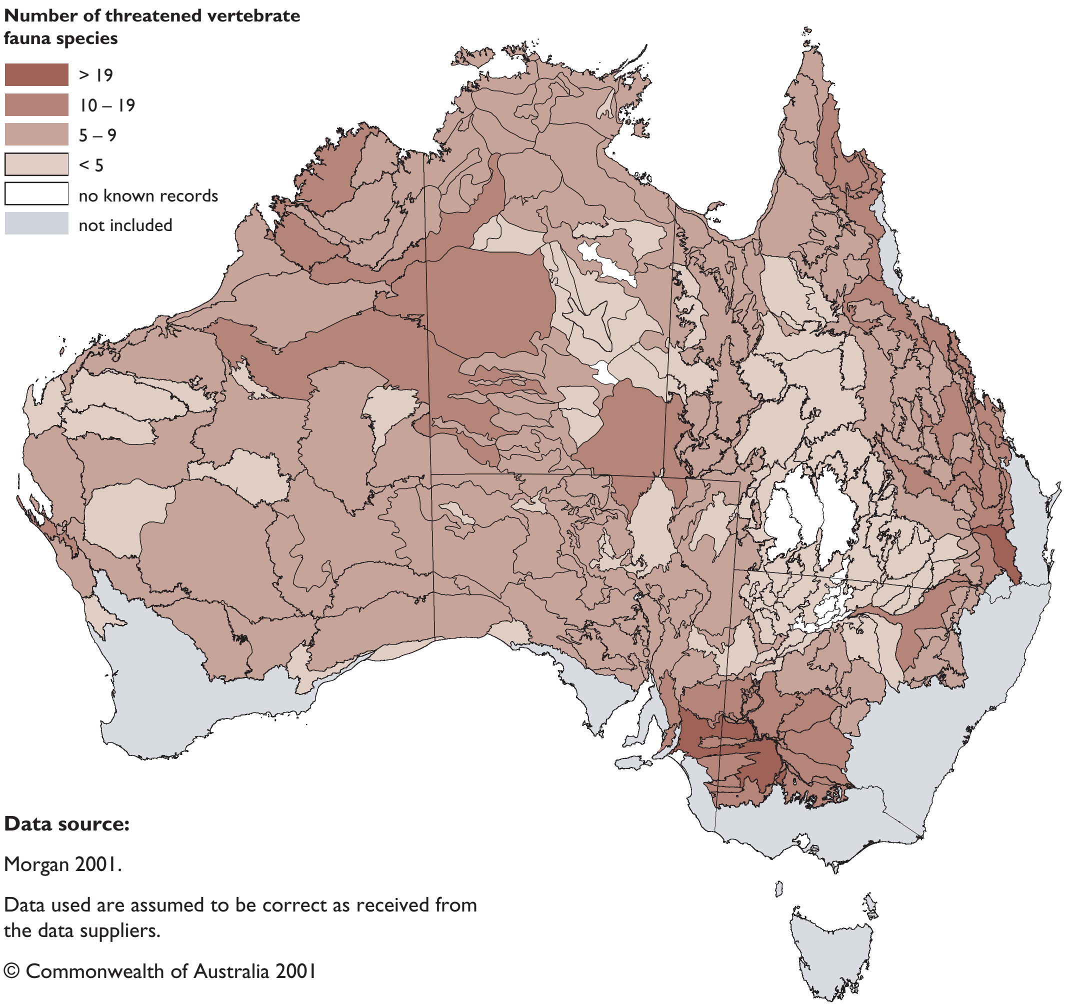
Morgan 2001.

Data used are assumed to be correct as received from the data suppliers.

Native fauna

Major threats to vertebrate fauna are grazing by domestic stock and feral animals, habitat change, and predation by feral animals such as cats and foxes (Figure 14 & 15). Native mammals lost from the rangelands over the last 200 years form one of the largest known extinction records in the world (Childs et al. 2001) (Figure 16). Bird populations have also been declining rapidly since European settlement. Although the extent of change in bird populations has not yet matched that of mammals, this may be due to a time lag and extinctions may become increasingly evident over the next few decades.

Figure 14. Known and predicted occurrence of threatened vertebrate fauna by subregion. Continued management is essential to minimise further extinctions.



Data source:

Morgan 2001.

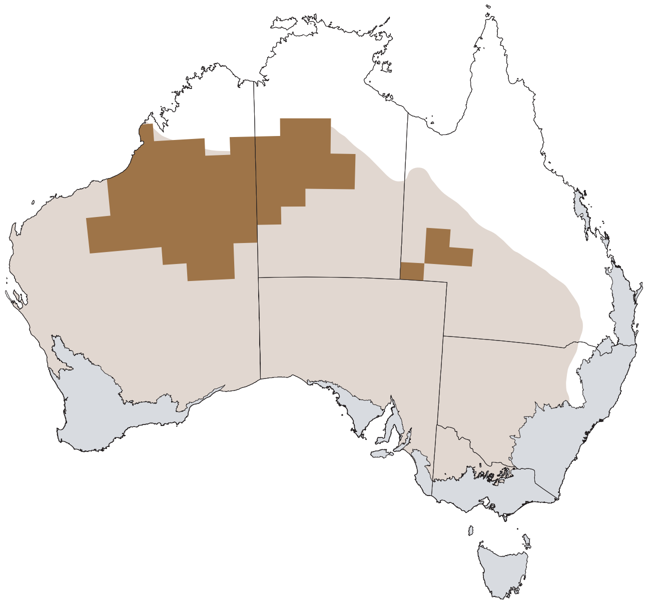
Data used are assumed to be correct as received from the data suppliers.

Figure 15. Distribution of greater bilby in Australia.

The greater bilby (*Macrotis lagotis*) is a ground-dwelling marsupial that was once common in many parts of the dry interior and temperate coastal regions. Loss of habitat and competition with introduced animals mean that it now occurs only in fragmented populations in mulga shrublands and spinifex grasslands. Wild populations are being monitored and captive breeding programs aim to retain their genetic diversity.

Number of extinct mammals

- current distribution
- historic distribution
- not included
- no bilbies in this area



Data Source:

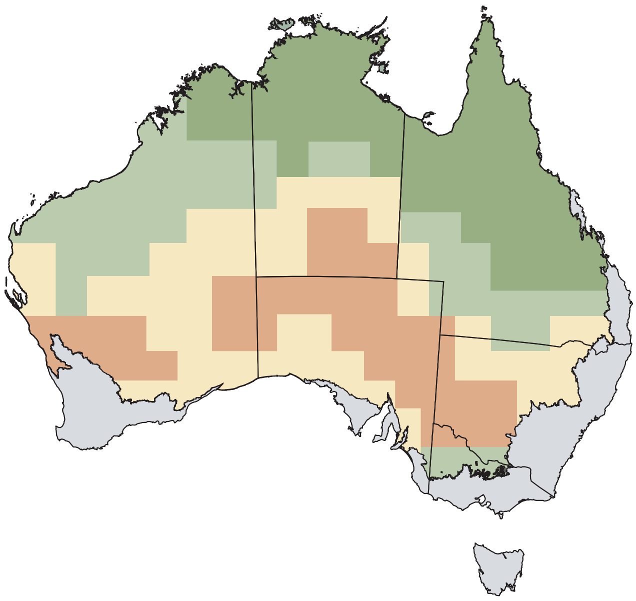
Maxwell et al. 1996.

Data used are assumed to be correct as received from the data suppliers.

Figure 16. Loss of terrestrial mammal species across Australia's rangelands (calculated as the number of species assumed to be present in 1788 minus the current number). The figure probably under-represents the loss of species across tropical savannas.

Number of extinct mammals

- > 9
- 6 – 9
- 2 – 5
- 0 – 1
- not included



Adapted from: Childs et al. 2001.

FLINDERS LOFTY BLOCK

Changing biodiversity and threatening processes within a bioregion

Major land uses

Extensive grazing by sheep is the dominant land use and has been since the 1840s. Agriculture (mainly wheat) and mining (including coal and copper) have historically been important. Tourism is now a major industry.

Conservation areas

Although 10% of the bioregion is protected in conservation areas, these include only 14 of the 49 recognised environmental subregions.

Condition and threats

Overgrazing by sheep, rabbits and goats has led to degradation, including lack of regeneration for a range of woody plant species.

Eight exotic animal species (rabbit, fox, cat, goat, black rat, house mouse, donkey and brown hare) are established in the bioregion. Rabbits (arriving in approximately 1880) and foxes (1900) have been extremely common until release of the calicivirus.

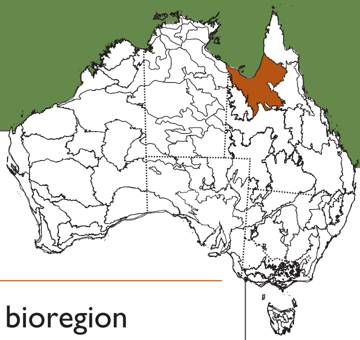
The understorey of many vegetation associations (e.g. white cypress pine *Callitris glaucophylla* woodland and tussock grasslands) is now mostly made up of exotic plant species, especially where stock have grazed heavily. One hundred and twenty-three exotic plants have been recorded in the greater Flinders Ranges area including rosy dock (*Acetosa vesicaria*), Salvation Jane or Patterson's curse (*Echium plantagineum*), red brome (*Bromus rubens*), ward's weed (*Carrichtera annua*), *Maltese cockspur Centaurea melitensis*, common storksbill (*Erodium cicutarium*), spiked malvastrum (*Malvastrum americanum*), *Schismus barbatus*, smooth mustard (*Sisymbrium erysimoides*), common sow thistle (*Sonchus oleraceus*), onion weed (*Asphodelus fistulosus*), horehound (*Marrubium vulgare*) and woolly burr-medic (*Medicago minima*).

Yellow-footed rock wallaby (*Petrogale xanthopus*): winning the conservation battle

Changes in biodiversity

Mammal fauna has suffered major losses, mainly in the regional extinction of 24 out of the 50 mammal species. These include small macropods, bandicoots, dasyurids, bats and rodents. Until recent control of rabbits, foxes and goats, the yellow-footed rock wallaby (*Petrogale xanthopus*) was continuing to decline.

Three plant species are believed to have become extinct in the Flinders Ranges: reed bent-grass (*Deyeuxia quadriseta*), blunt pondweed (*Potamogeton ochreatus*), and *Pilularia novae-hollandia*.



GULF PLAINS

Changing biodiversity and threatening processes within a bioregion

Major land uses

The dominant land use is cattle grazing on native pastures, dating back to the 1860s. Mining continues to be a significant industry.

Conservation areas

Two point five percent of the Queensland part of the bioregion is in conservation reserves. None of the Northern Territory portion is reserved.

Golden-shouldered parrots (*Psephotus chrysopterygius*) are confined to Cape York Peninsula where just a few thousand remain

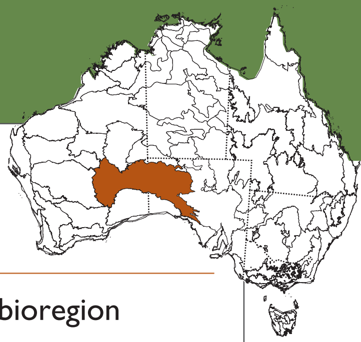
Condition and threats

Of the 83 regional ecosystems defined for the Queensland part of this bioregion, three are considered endangered and 26 are considered of concern. Most (72%) of those that are endangered and of concern are associated with watercourses and flood plains.

> *… the three major processes that pose a threat to biodiversity in the Gulf Plains are unsustainable grazing pressures, weed infestation and the development of ponded pastures. High total grazing pressure is causing increasing land degradation through changes in the density of ground cover and in species composition … This is having a particular effect on riverine areas and on wetlands. Changes in stock and pasture management are leading to a reduction in seasonal burning, and a consequent increase in the density of the woody stratum … The major weed threatening biodiversity is rubber vine (*Cryptostegia grandiflora*), that now infests most major river systems … Potential or local problem weed species include parkinsonia (*Parkinsonia aculeata*) and prickly acacia (*Acacia nilotica*). Salvinia (*Salvinia molesta*), water hyacinth (*Eichhornia crassipes*), calotrope (*Calotropis procera*), and noogoora burr (*Xanthium pungens*) are also locally significant … Ponded pastures pose a threat … to wetlands … [through] the introduction of ponded pasture species to natural wetlands, where they displace most native wetland plants and animals. A secondary concern is the impact of retaining walls on floodplain hydrology … Clearing of gidgee (*Acacia cambagei*) communities is occurring.*
>
> Sattler & Williams 1999

Changes in biodiversity

Major declines and local extinctions of the golden-shouldered parrot (*Psephotus chrysopterygius*) have occurred across the Gulf of Carpentaria part of its range. This decline has been attributed to habitat change (principally invasion of grassland areas by melaleucas) caused by altered fire regimes over the last century. No plant species are known to have become extinct in this bioregion.



GREAT VICTORIA DESERT

Changing biodiversity and threatening processes within a bioregion

Major land uses

The Great Victoria Desert is sparsely inhabited. Most of the area is Indigenous land—in some cases tenured as conservation reserve. A network of exploration lines was surveyed and cleared across large areas during the late 1960s and early 1970s. Mineral exploration continues. Parts of the bioregion were used as restricted area for the Woomera Rocket Range, for nuclear testing and as storage for spent atomic fuels. Pastoral leases exist in the less arid margins.

Conservation areas

The 'Unnamed Conservation Park' in the South Australian portion of the bioregion is one of Australia's largest (21 327 km^2) conservation reserves. More than 10% of the South Australian and 5–10% of the Western Australian parts of the bioregion are in conservation reserves.

Condition and threats

The impacts of rabbits and pastoralism on land condition resulted in fewer perennial species and lower plant density especially for the most susceptible vegetation type—chenopod shrublands.

> *… the introduction of several exotic mammals, most notably the rabbit, has undoubtedly been responsible for the decline in some mammals but for reptiles the full impact is possibly yet to come. Rabbits are present throughout much of the eastern Great Victoria Desert and continue to severely modify the environment. By eating all young seedlings, rabbits have for the past 100 years effectively prevented regeneration of many of the palatable, slow-growing, perennial tree and shrub species over much of the area. As this process continues, the whole character of the eastern Great Victoria Desert is likely to change dramatically as species like mulga die out over large areas. With them will go the characteristic assemblages of species they support … Fires which have killed most mature mulgas over large areas of far eastern sections of the Great Victoria Desert are hastening this process.'*
>
> Greenslade et al. 1986

Changes in biodiversity.

Reptiles are a feature of this bioregion with relatively intact populations. Two snake species (the desert death adder [*Acanthophis pyrrhus*] and western black-naped snake [*Neelaps bimaculatus*]) have not been observed in the South Australian part of the bioregion for about 60 years—a possible decline that may be of concern.

One-third of mammal species have become extinct in this bioregion during the last 40 years including the numbat (*Myrmecobius fasciatus*), bilby (*Macrotis lagotis*), burrowing bettong (*Bettongia lesueur*) and stick-nest rats (*Leporillus* spp.).

Some bird species are declining, including mallee fowl (*Leipoa ocellata*) and scarlet-chested parrot (*Neophema splendida*). Comparison of recent bird records with those reported between 1873 and 1945 suggest that Australian bustard (*Ardeotis australis*), bush stone-curlew (*Burhinus grallarius*) and spinifex pigeon (*Geophaps plumifera*) have declined.

Desert death adder (*Acanthophis pyrrhus*): one of the deadliest snakes of central Australia

The decline in species is occurring in both non-pastoral and conservation areas. This highlights the need to reduce feral animal populations as part of protective management activities across all tenures.

Product 4.
Supporting information

Long-term photographic records

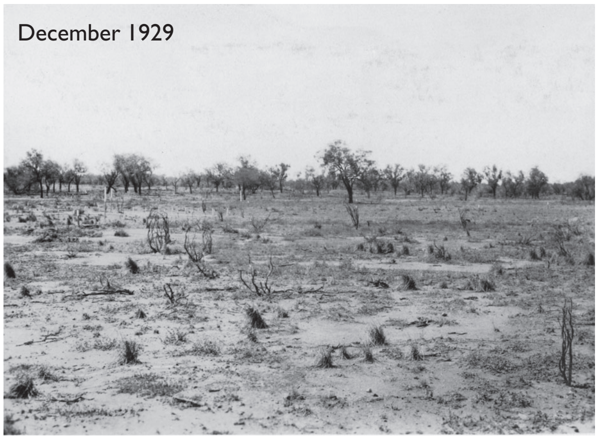
Photo sequences provide a local record of change and are particularly useful as tools for raising awareness (Figure 17). They show types and extent of change that have occurred over time and provide context and assist in interpreting broader-scale changes collated through remote sensing and plot monitoring.

The Audit in cooperation with State and Northern Territory agencies has compiled sets of photographic sequences for some bioregions. These can be accessed on the Rangelands Monitoring part of the Atlas.

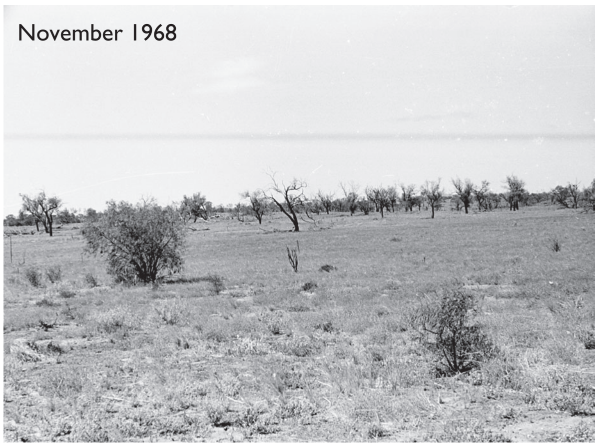
Figure 17. Photo sequence at one point (1928 to 2000) Koonamore Vegetation Reserve, South Australia.

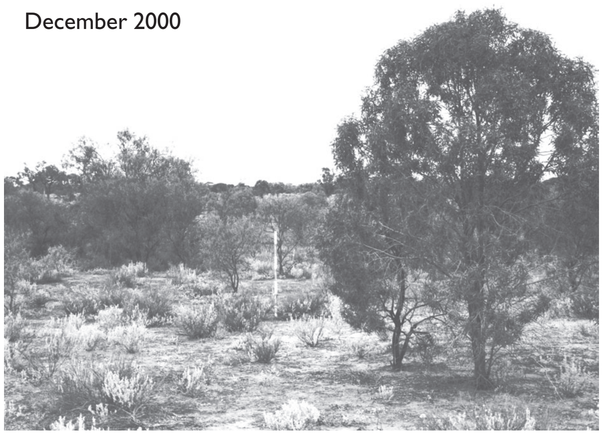
December 1928

December 1929



November 1968



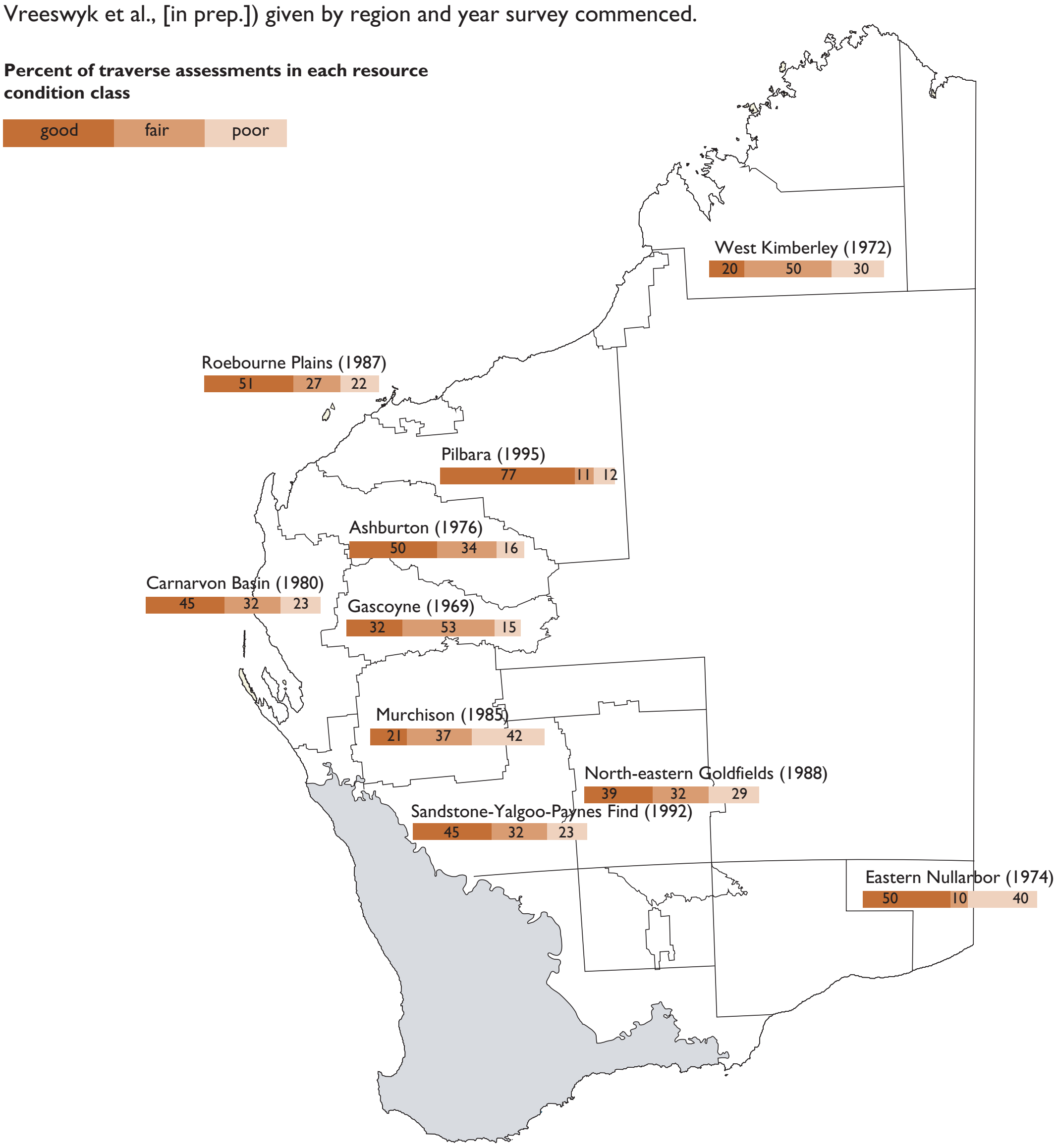


Source: University of Adelaide.

Regional resource assessments

Much of Australia's rangelands has been mapped into land systems or land units using consistent resource inventory techniques. Many of these surveys and accompanying pastoral lease inspections include estimates of resource condition based on field traverse by combining estimates of soil erosion and vegetation state. Although the surveys were not designed to be repeated, they provide baselines with which to compare recent change, and highlight areas where condition is poor (Figure 18).

Figure 18. Resource condition summaries for regional rangeland surveys within Western Australia (Van Vreeswyk et al., [in prep.]) given by region and year survey commenced.



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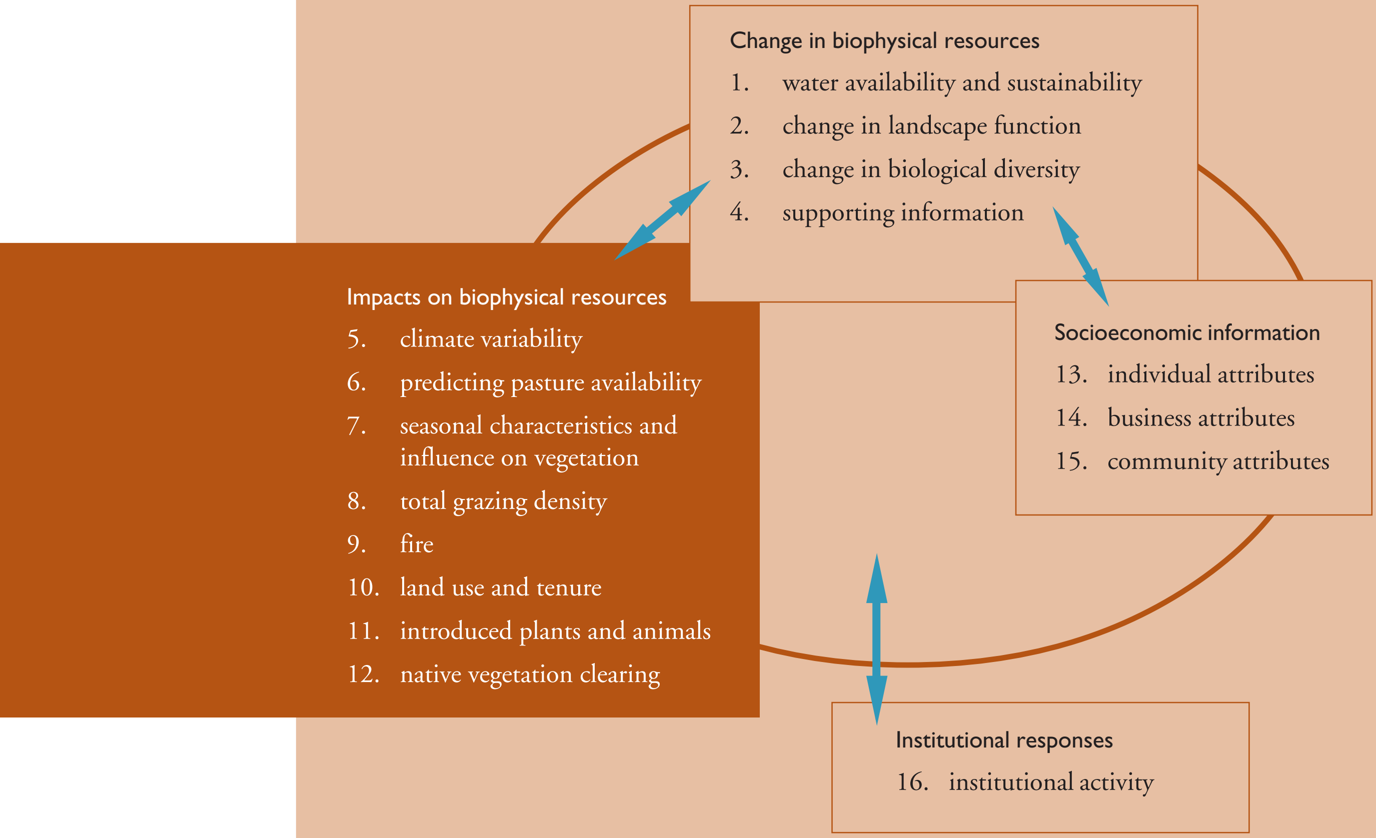
The dingo-proof fence: the longest fence in the world

Impacts on biophysical resources

Both human activity and natural events have an impact on the biophysical resources of Australia's rangelands. These activities and events include:

- land clearing;
- grazing by domestic, feral and native animals;
- introduction of exotic plants and animals;
- use of fire and wildfires; and
- seasonality and variability in climate.

Information products under this component are summarised in Table 3.



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Loss of cover leads to erosion

Table 3. Information products for impacts on biophysical resources.

Key attributes	Description and current status	Rationale for inclusion
Product 5. Climate variability		
Seasonal climate outlooks	Seasonal climate outlooks are routinely provided by the Bureau of Meteorology and Queensland Government for rainfall and temperature.	Rainfall in Australia's rangelands varies substantially from year to year and from place to place. Understanding this variability and predicting the probability of rainfall is an essential forward looking component of rangeland management.
Product 6. Predicting pasture availability		
Pasture growth and cover predictions	The *Aussie GRASS* model developed by the Queensland Department of Natural Resources and Mines simulates plant production and provides forecasting of pasture growth, cover and land condition risk. *Aussie GRASS* is being undertaken through partnership arrangements across rangeland States.	When animal numbers and climate forecasts are combined, projected grazing pressure can be calculated and risks of degradation and loss of productivity assessed.
Product 7. Seasonal characteristics and influence on vegetation		
Seasonal characteristics and extent and duration of exceptionally dry and wet seasons	The increase in greenness as measured by the Normalised Difference Vegetation Index is an indicator of the effectiveness of the current season in terms of rainfall converted to biomass compared with past seasons. Information on past season quality gives a context.	Changes in rangelands need to be interpreted within a seasonal context.
Product 8. Total grazing density		
Trends in total grazing density	This product consists of estimates of annual grazing density by stock and native large herbivores.	This product provides context to interpret outputs from other products.

Table 3. continued on next page

Table 3. continued

Key attributes	Description and current status	Rationale for inclusion
Product 9. Fire		
Extent, timing and frequency of fire	Remote sensing provides information on occurrence of fire annually, and frequency and timing of fire. Fire frequency monitoring is being undertaken as a partnership across participating States and the Northern Territory.	Fire is a major natural driver as well as a management tool across Australia's rangelands. Fire is the ultimate grazer, converting available biomass to carbon and nutrients.
Product 10. Land tenure and use		
Change in land tenure	Tenure classes for each decade from the 1950s include freehold, leasehold, Indigenous-held land, conservation reserve and unassigned Crown lands. Tenure changes are routinely updated by State and Northern Territory agencies and, once collated, provide a surrogate for land use.	Land tenure and land use influence land condition through the intensity of use applied to the holdings to achieve economic returns and the impact on land stewardship activities.
Product 11. Introduced plants and animals		
Distribution and abundance of selected environmental weeds Distribution and abundance of feral animals	Information is available through the National Weeds Strategy and State and Northern Territory programs. Australia-wide maps of introduced species that may impact on biodiversity or availability of forage have been collated using expert opinion.	Weeds have an impact on biodiversity and productivity. Feral animals such as foxes and cats have a major impact on native bird, reptile and small mammal populations. Feral animals such as goats and rabbits have a significant impact on availability of feed and add to the grazing pressure.
Product 12. Native vegetation clearing		
Extent of clearing	This product consists of information from various State and Northern Territory initiatives that collect data on extent of change in vegetation.	Clearing of native vegetation is a surrogate for loss of biodiversity and may lead to potential impacts on land condition, soil erosion and salinisation.

Floods are a part of Australia's climate variability

Product 5. Climate variability

Rainfall and its effectiveness are major drivers of processes and functions in rangelands (e.g. drought can lead to wind erosion and requires change in animal populations and land management decisions).

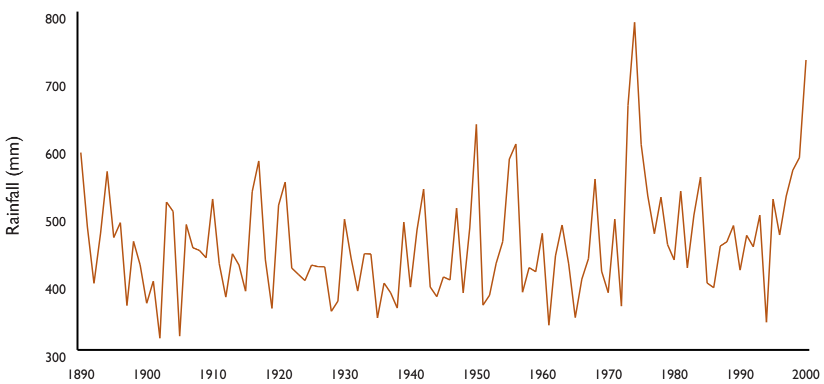
Rainfall in Australia's rangelands varies from one year to the next (Figure 19), from season to season and spatially (Figure 20). Climate variability can lead to degradation:

- Years with above average rainfall may support increased stock numbers. Retention of high stocking rates in subsequent 'normal' or drought periods may lead to degradation.
- Years with below-average or little effective rainfall may lead to grazing pressures that degrade the rangeland resource.
- Years with above average rainfall may lead to changed rangeland condition (regeneration of desirable vegetation, opportunities for burning) and rangeland management problems (woody weed infestation, increases in feral and native herbivores).

Climate science has documented historical climate variability associated with global fluctuations of sea surface temperatures and atmospheric variables. The time-scales of these fluctuations range from annual to about every ten years (e.g. in rangelands of eastern Australia extreme droughts and floods have been associated with the interaction of the El Niño-Southern Oscillation phenomenon [Figure 21] and the Inter-decadal Pacific Oscillation). Oscillations in sea surface temperatures of which these are examples also provide some explanation of the likely causes of historical sequences of dry or wet years. This new understanding of the influence of climate in rangelands is leading to the development of improved climate forecasting systems and monitoring. Information provision will ensure better management decisions.

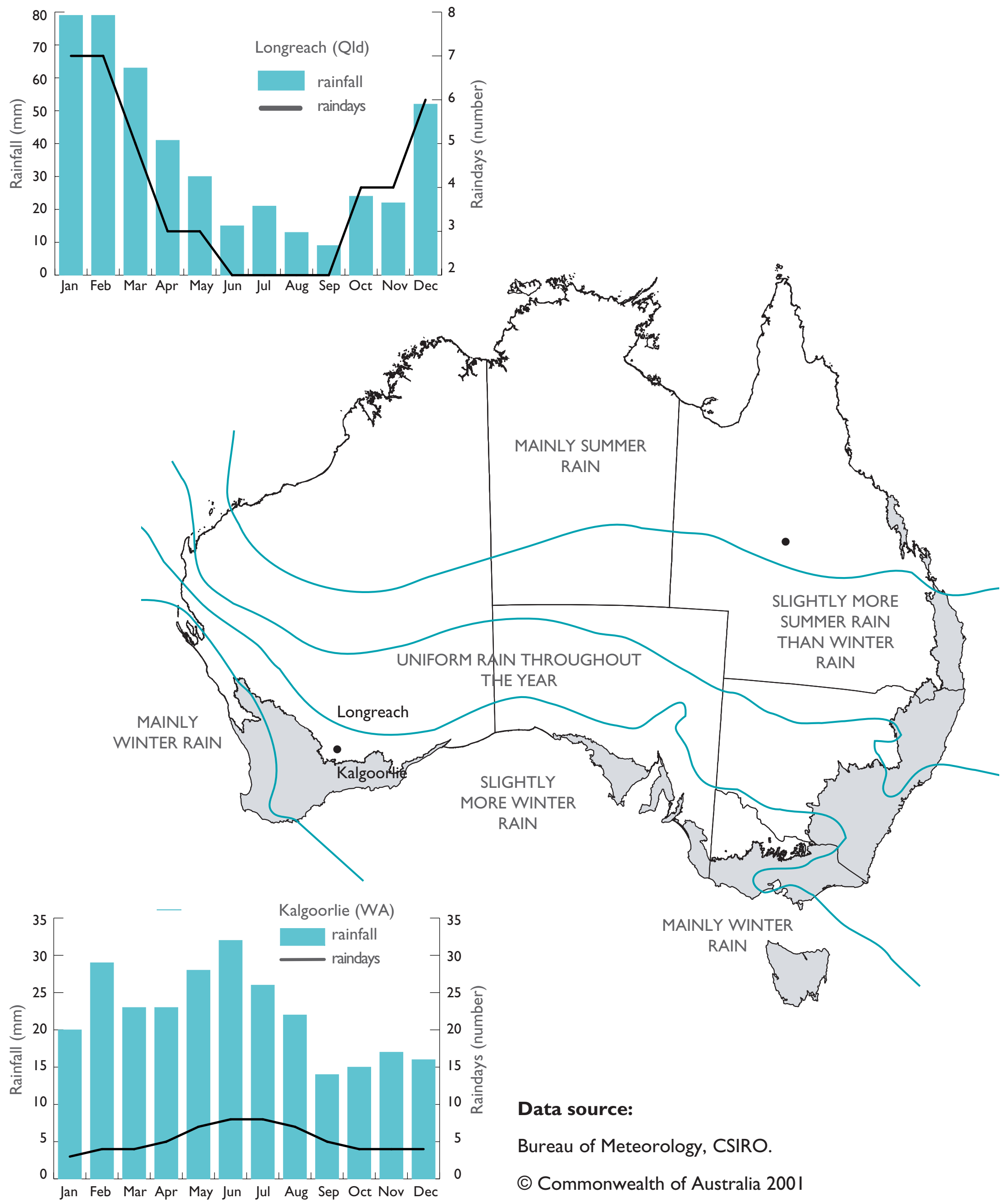
The Bureau of Meteorology routinely provides seasonal climate forecasts for both rainfall and temperature (Figure 22). Climate forecasting work is also under way in Queensland and Western Australian agencies, and will take much of the guess work out of assessments for exceptional circumstances.

Figure 19. Annual rainfall using all available rainfall recording stations across Australia. A Barnes interpolation method was used in regions without data (e.g. central Western Australia) and to calculate the area weighted average for a 0.25 x 0.25 degree grid.



Data source: Bureau of Meteorology.

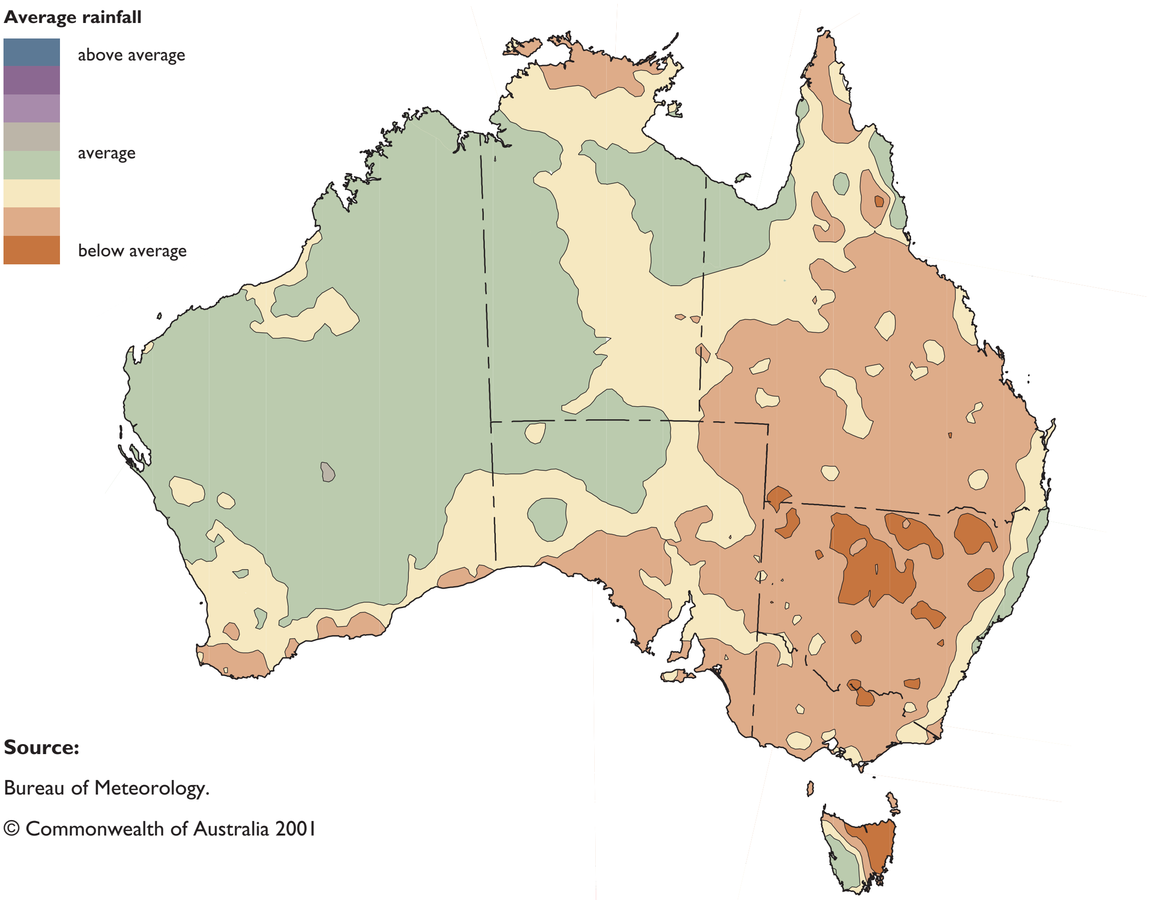
Figure 20. Seasonal and spatial rainfall variability. Rainfall in rangelands is highly variable; in the north rainfall is in summer while in the south, winter rainfall typically dominates with occasional heavy summer rain.



Data source:

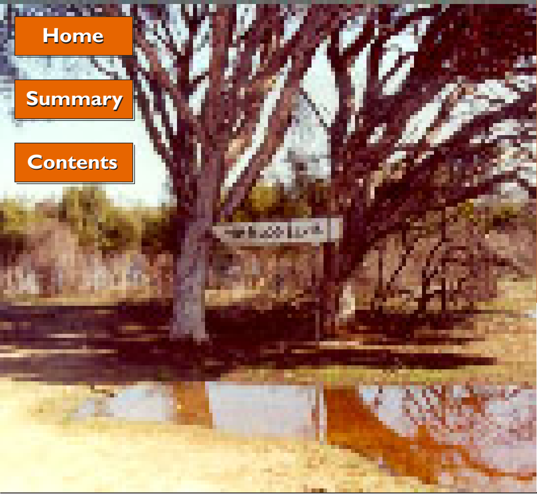
Bureau of Meteorology, CSIRO.

Figure 21. Rainfall in El Niño years. The El Niño phase of the El Niño-Southern Oscillation cycle is associated with dry conditions. The brown regions have generally experienced below average rainfall during the winter–spring period of the El Niño years in the past 100 years. There are no areas of above-average rainfall.



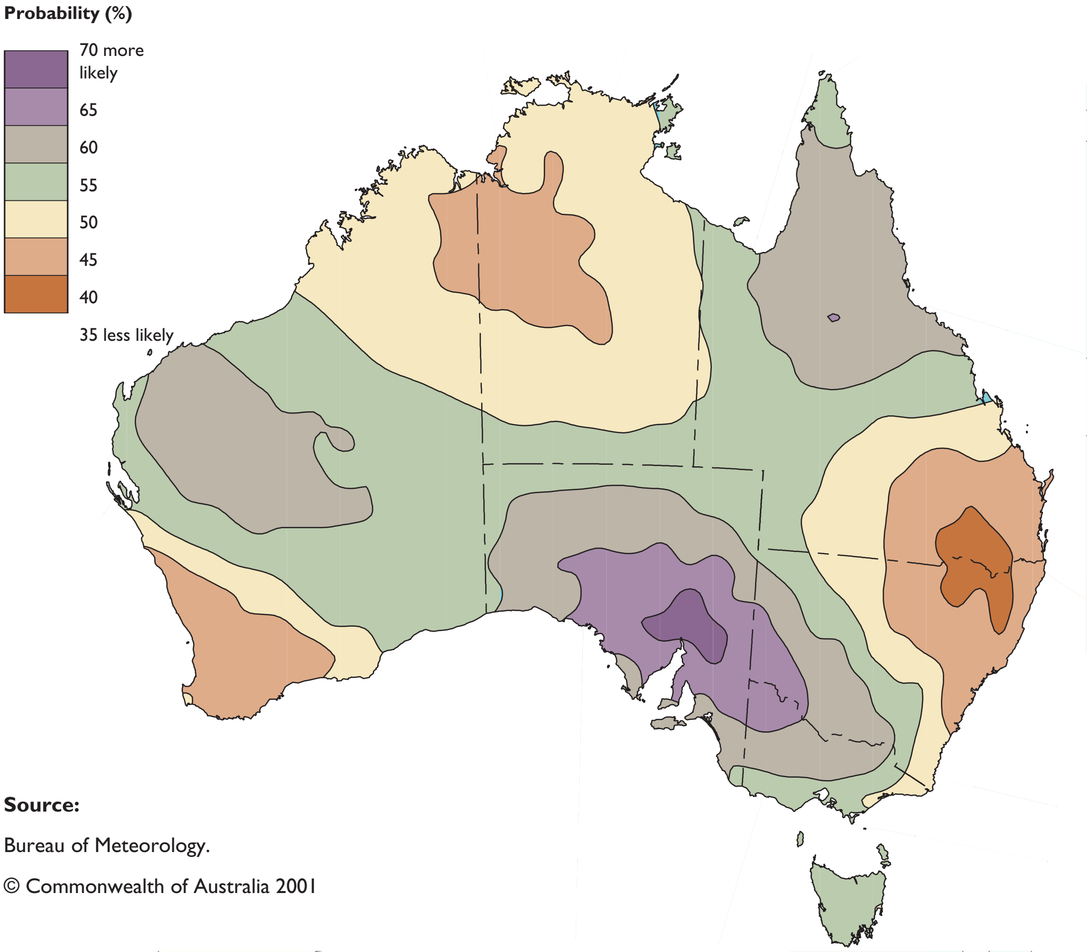
Source:

Bureau of Meteorology.



Climate forecasts are described as chances and probabilities because the chaotic nature of the climate system means that precise predictions are not possible. Rainfall and other climate-based forecasts can be used in rangeland management as direct tools in forward planning and as inputs to models of pasture availability (e.g. *Aussie GRASS*). Longer-term forecast information is becoming available from coupled atmosphere–ocean (and other) models (e.g. see www.bom.gov.au/climate, www.bom.gov.au/silo and www.dnr.qld.gov.au/longpdk/). Information products displaying and modelling climatic variability are routinely collated and made available by the Bureau of Meteorology.

Figure 22. The probability (%) of receiving the long-term median rainfall between April and June 2001. We know that sea surface temperatures affect Australia's climate. The strength of the relationship between the sea surface temperatures in the Pacific and Indian Oceans and Australia's rainfall and temperature in the previous two months are used to predict rainfall patterns for the coming three months.



Source:

Bureau of Meteorology.

Understanding pasture dynamics: a key part of property management

Product 6.
Predicting pasture availability

Aussie GRASS is a simulation model incorporating the complex interaction of climate, soils, vegetation, fire, animal numbers and management responses and is used to:

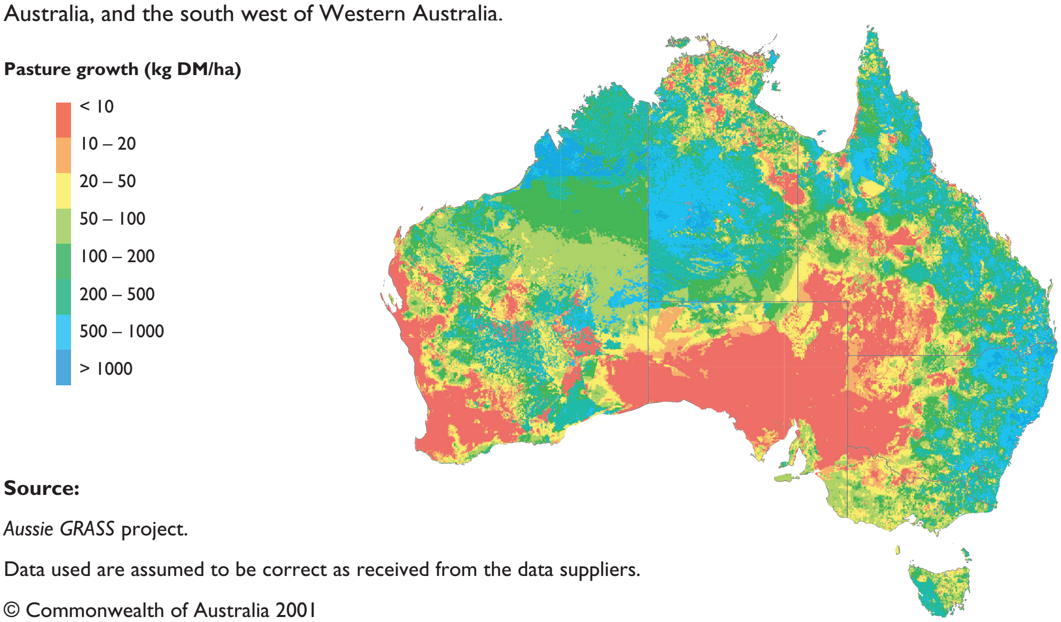
- simulate grass production;
- provide both monitoring and forecasts of potential grass growth and cover;
- estimate historical and projected grazing pressure;
- assess risks of degradation; and
- compare current conditions and opportunities for improved stock management with past situations.

Aussie GRASS information products display and model availability of herbage biomass (Figures 23 & 24). They are routinely collated and made publicly available by the Queensland Department of Natural Resources and Mines on behalf of a partnership across State and Territory agencies.

Integration of *Aussie GRASS* with information on vegetation condition from remote sensed and ground monitoring sites and stocking rate data will allow sustainability of grazing activity to be assessed. Key applications for this integrated information include:

- providing an information base for assessment of exceptional circumstances;
- predicting likely trends in feed production so that pastoralists can strategically manage stocking rates; and
- detailing change in pasture availability as a key input to rangeland condition assessment.

Figure 23. Simulated total pasture growth (kg dry matter/ha) for Australia (March 2001). The model predicted minimal growth in large areas of south west Queensland, western New South Wales, South Australia, and the south west of Western Australia.

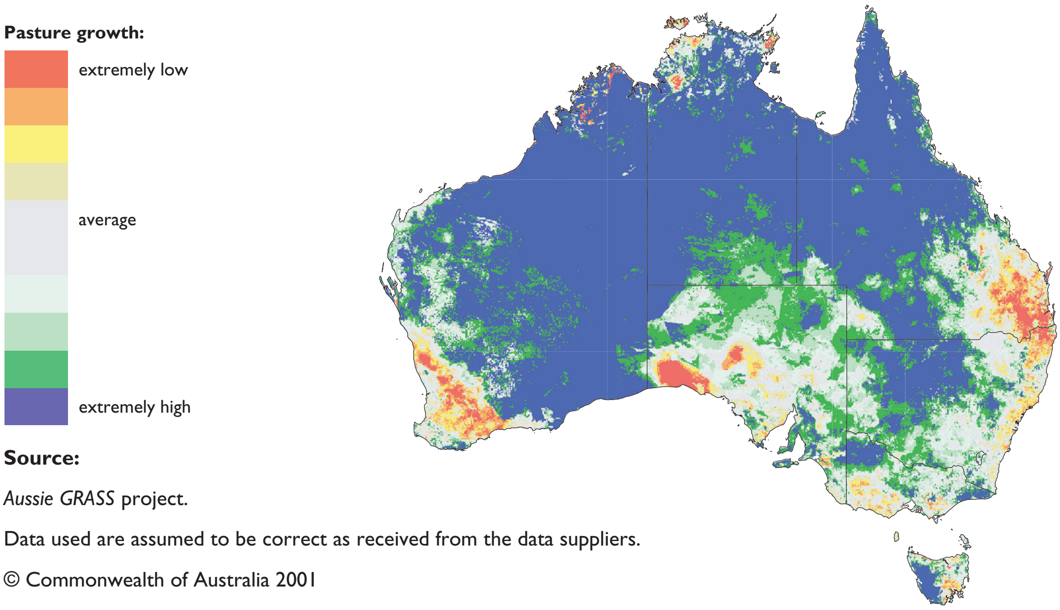


Source:

Aussie GRASS project.

Data used are assumed to be correct as received from the data suppliers.

Figure 24. Simulated total pasture growth for the 12-month period (February 2000 to January 2001) relative to the same period from 1957 to 2001. This map allows seasonal conditions to be ranked relative to the historical record on a regional basis. Most of Australia experienced good seasonal conditions over this period apart from areas in the south-west of Western Australia, central and south-west South Australia and south-east Queensland. These areas experienced relatively poor seasonal conditions.



Source:

Aussie GRASS project.

Data used are assumed to be correct as received from the data suppliers.

Eucalyptus populnea: part of Queensland's woodlands

Product 7. Seasonal characteristics and influence on vegetation

Rangeland condition needs to be interpreted in a seasonal context. An increase in photosynthetic activity or greenness after rainfall is an indicator of season quality. Change in greenness is estimated using the Normalised Difference Vegetation Index. An increase in Normalised Difference Vegetation Index in response to vegetation growth will depend on the amount, structure and composition of vegetation present in an area. Comparing each area to itself over time gives a good indication of relative changes in herbage. A relative rating of season quality can be mapped by comparing a particular year with all years recorded (data starts in 1991/92). This provides a context for the interpretation of finer scale Landsat-derived assessments and interpolation of data collected from ground monitoring plots. It also provides information on the scale and extent of wet or dry periods. Advantages of Normalised Difference Vegetation Index data over rainfall data include the ability to:

- provide estimates on 1 km^2 areas, rather than interpolated rainfall data from a limited number of stations, and;
- estimate the response of vegetation to climate including rainfall and evaporation rates, rather than simply estimating the rainfall amount.

The Normalised Difference Vegetation Index provides an estimate of maximum and minimum greenness in any given year (Figures 25a & 25b). The difference between maximum and minimum in any given year is called the flush (Figure 25c).

Figure 25a. Maximum greenness (January 2000 to December 2000) as estimated by the Normalised Difference Vegetation Index.

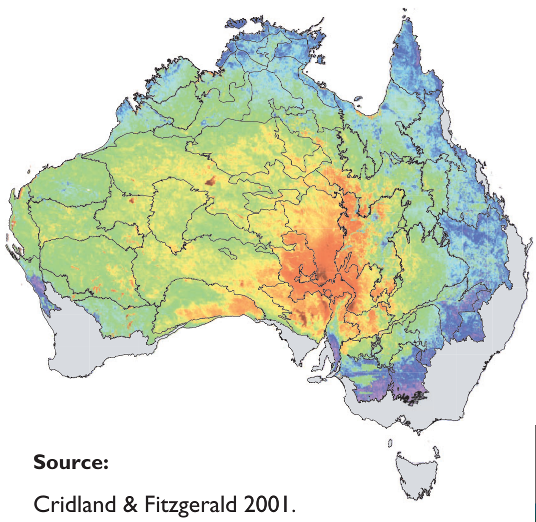
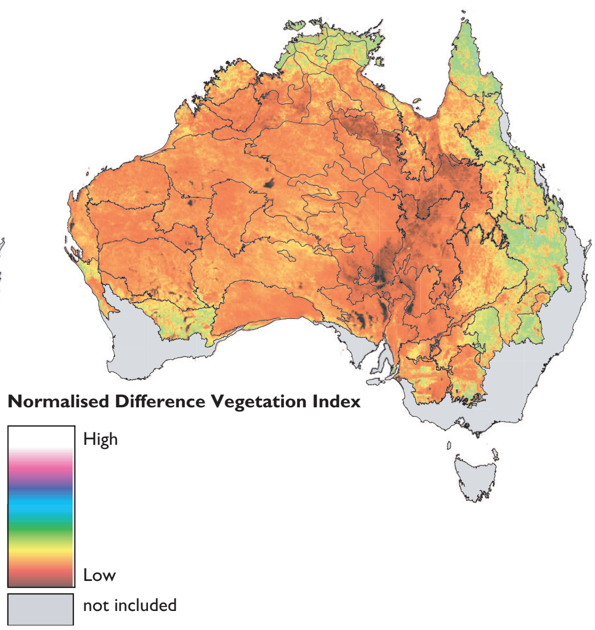


Figure 25b. Minimum greenness (June 1999 to July 2000) as estimated by the Normalised Difference Vegetation Index.

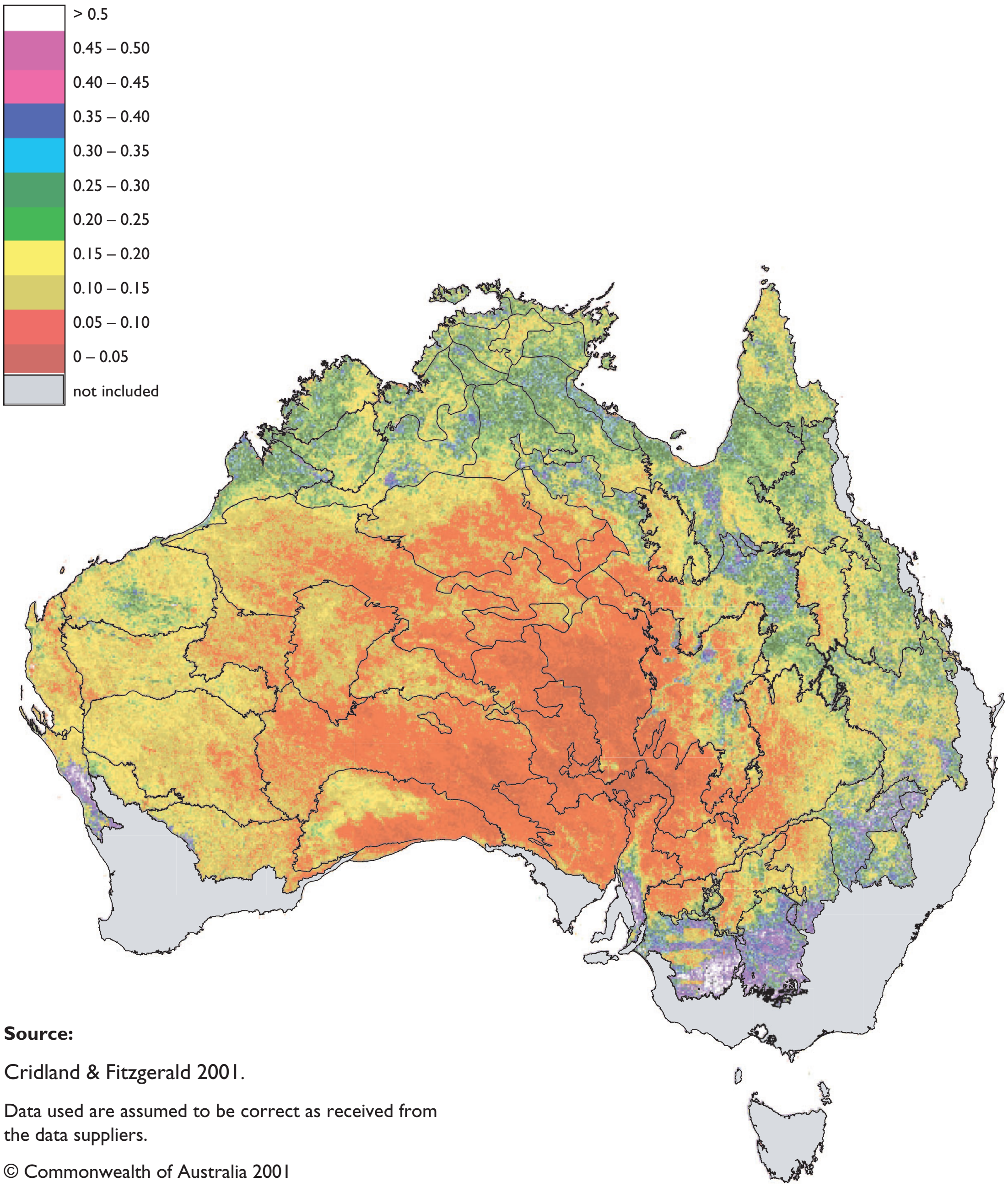


Source:

Cridland & Fitzgerald 2001.

Data used are assumed to be correct as received from the data suppliers.

Figure 25c. Flush for the year 2000. The difference between maximum (Figure 25a) and minimum (Figure 25b) Normalised Difference Vegetation Index within any year.



Source:

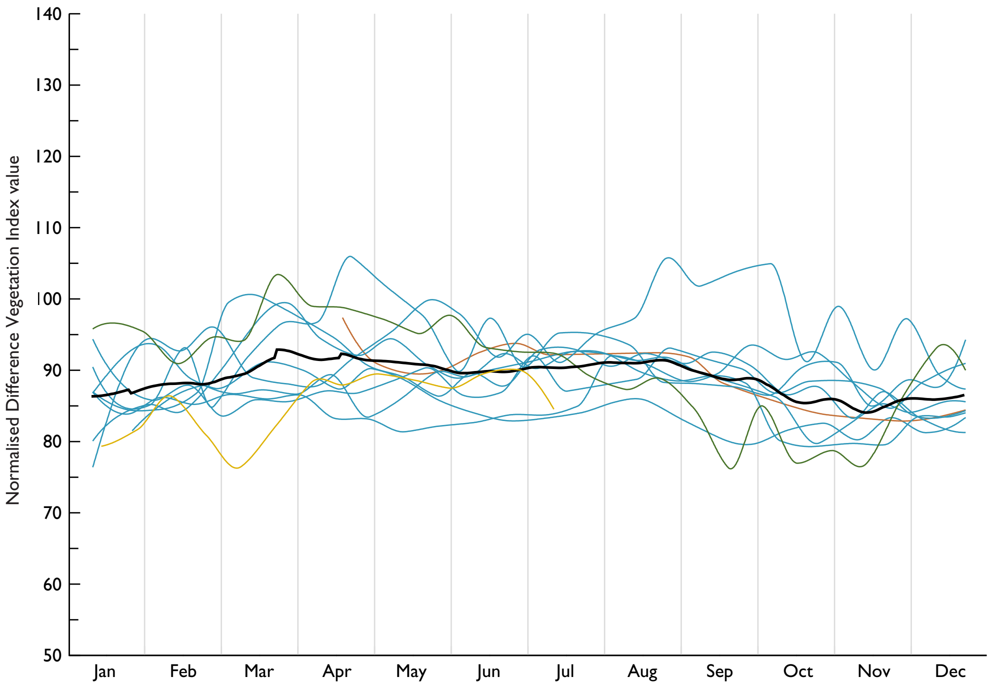
Cridland & Fitzgerald 2001.

Data used are assumed to be correct as received from the data suppliers.

Mulga (*Acacia aneura*): an important food source for Indigenous peoples

Flush provides an excellent estimate of seasonal quality. Figure 26 is a time trace of the variation in greenness for the Mulga Lands bioregion. Figure 27 show the flush for Australia and the Mulga Lands, categorised in 10% increments to provide an indication of seasonal quality.

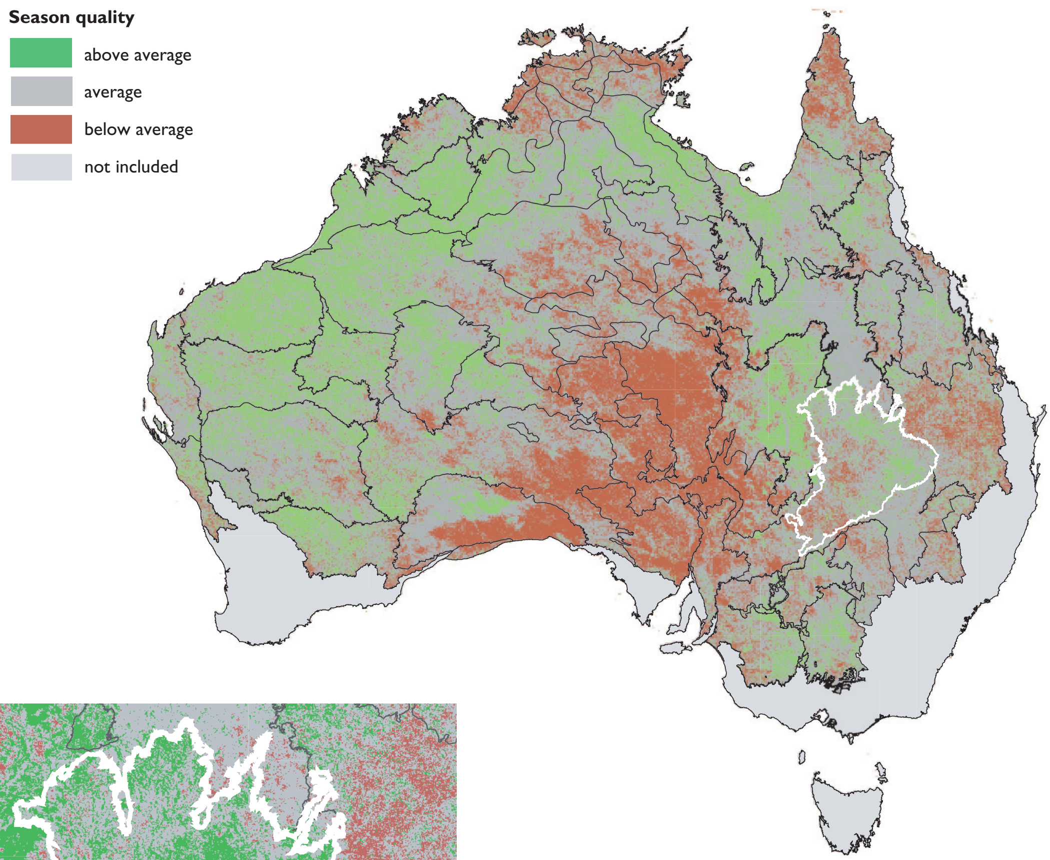
Figure 26. Variation of greenness within years for the Mulga Lands bioregion. The yellow line represents the time trace of the current year (2001). The green line represents the time trace of the previous year (2000). The red line is for the first year (1991). The black line represents the time trace for the average of past years (1991–2000). The blue lines represent the time traces for individual years since 1992.

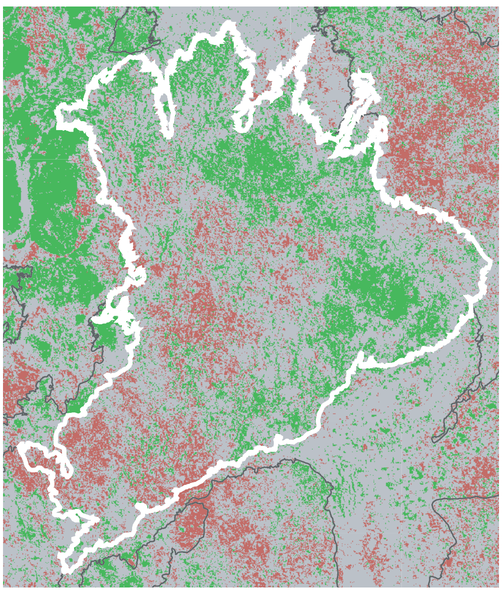


Source: Cridland & Fitzgerald 2001.

Figure 27. Season quality for Australia's rangelands. In 1999, parts of New South Wales, Queensland, Western Australia and the Northern Territory had an above average season whereas most of South Australia had a below average season.

At a finer resolution (see inset) it is possible to see which areas of the Mulga Lands bioregion in New South Wales and Queensland had an above average season or below average season in 1999.





Source:

Cridland & Fitzgerald 2001.

Data used are assumed to be correct as received from the data suppliers.

Product 8. Total grazing density

Products collated by the Audit for total grazing density include historical and current estimates of domestic stock (sheep and cattle), kangaroos and some feral animals (goats and rabbits). They will help understand the pressures on rangeland flora and habitat and allow trends to be determined.

Data collation activities required to complete the analysis were:

- collation of Australian Bureau of Statistics historical domestic stock information from 1956 to present for statistical local areas (available through the Atlas and Data Library);
- collation of historical and simulated data on macropod and feral animal numbers from the 1950s to present day (data on decadal time-steps available in the Atlas and Data Library);

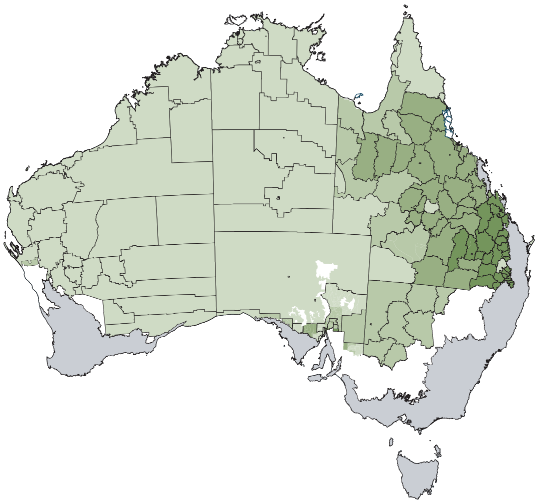
A further data collation activity is required to infer stocking rates for bioregions:

- data comparison between bioregions, tenure types and the Australian Bureau of Statistics stock information for statistical local areas.

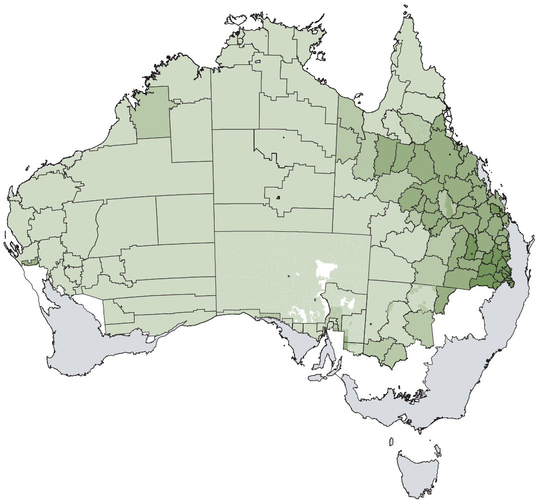
In the 1990s total grazing density was highest in eastern and northern Australia (New South Wales, Northern Territory and Queensland). There has been a decrease in animal density in most areas since the 1950s (Figure 28).

Figure 28. Total grazing density for Australia's rangelands by statistical local area (1950s, 1960s, 1970s, 1980s, 1990s).

1950s

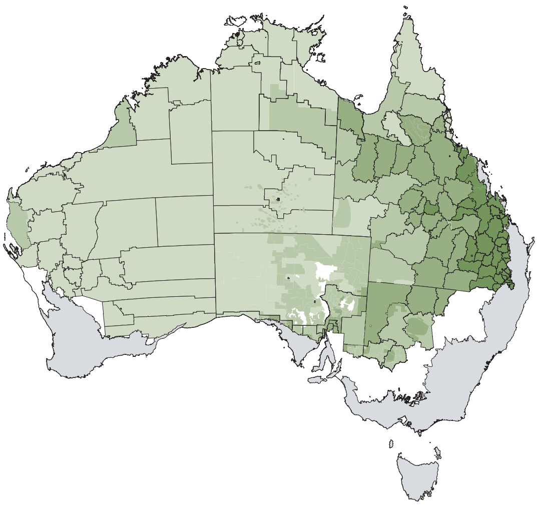


1960s

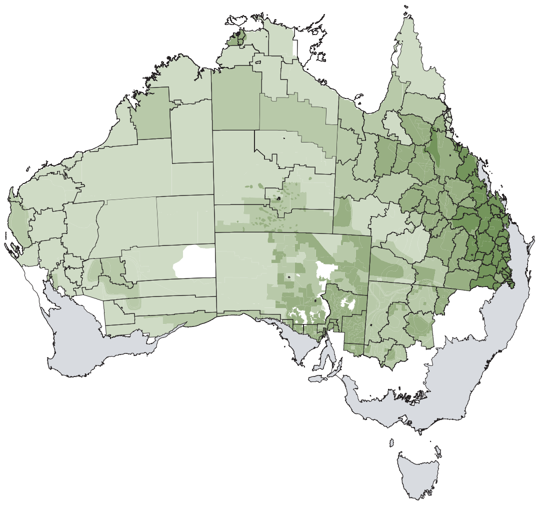


Total grazing density was calculated using annual data on sheep and cattle and decadal data on macropods and feral animals (goats and rabbits). Each class of animal was converted to dry sheep equivalents in order to allow total grazing density to be calculated.

1970s



1980s

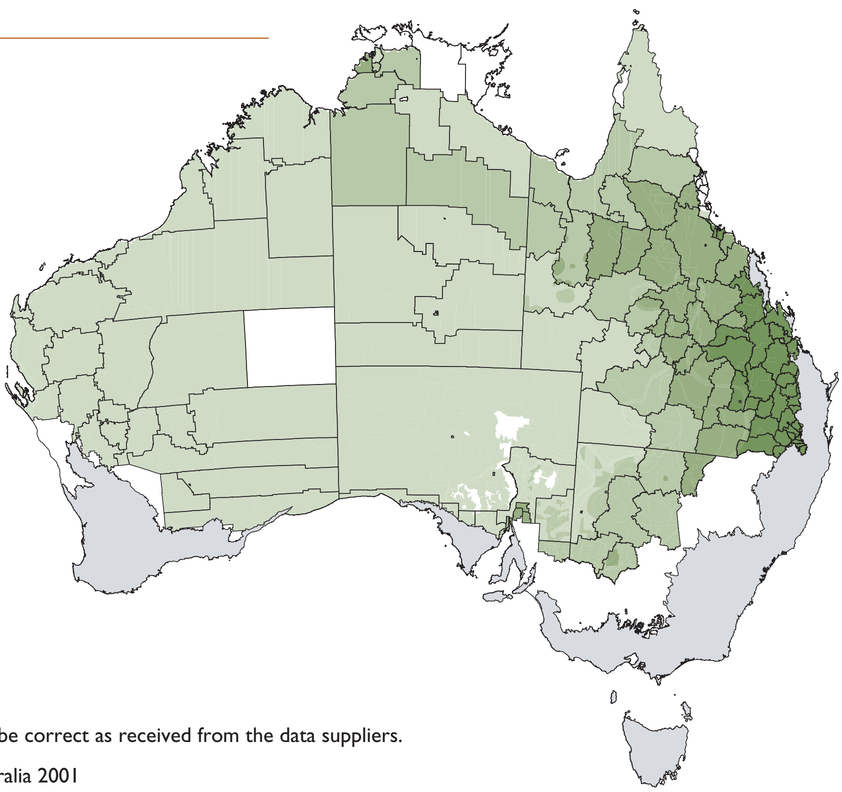


1990s

Total grazing pressure

(dse/km^2)

- 0
- 1 – 2000
- 2000 – 4000
- 4000 – 10 000
- 10 000 – 40 000
- 40 000 – 120 000
- no data
- not included



Data source:

Gutteridge et al. 2001.

Data used are assumed to be correct as received from the data suppliers.

Cattle: more than 13 million across Australia's rangelands in 1999

Stock density

The only national, regular coverage of stock density is available from the Australian Bureau of Statistics agricultural census and survey data. Stock density has been compiled annually by statistical local area since 1956 (except for South Australia where data were only available as Hundreds and Counties prior to 1983) (Appendix 2). Stock included in the final database are beef bulls, beef heifers, beef calves, dairy cattle, rams, ewes, wethers, lambs and horses. The reliability of these data has been questioned (e.g. Mortiss 1995) with suggestions that the figures are likely to be underestimates.

Beef cattle density increased in Queensland, New South Wales, South Australia and the Northern Territory in the mid- to late-1970s; in this period, sheep density fell in all States. Sheep density peaked again in the early 1990s. Cattle density increased by 50% across Australia from 1956 to 1999 while sheep density fell to half of what it was in the 1950s (Figures 29, 30 & 31).

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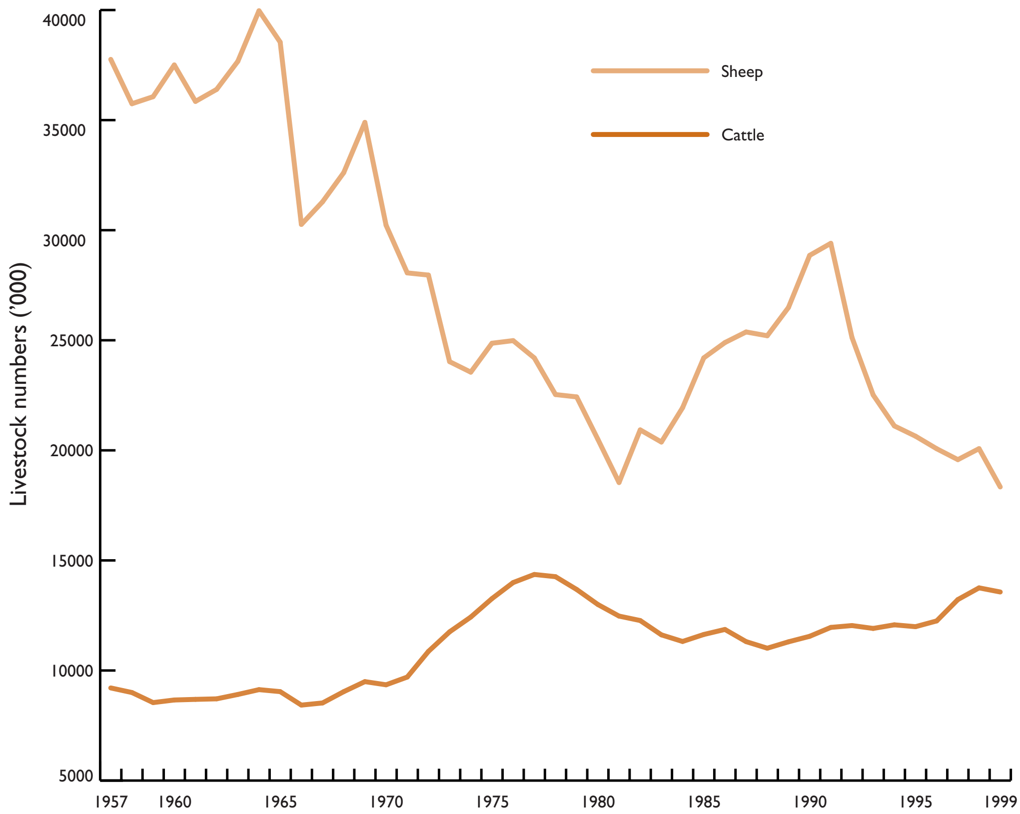
Figure 29. Total cattle and sheep numbers in Australia (1957 to 1999).



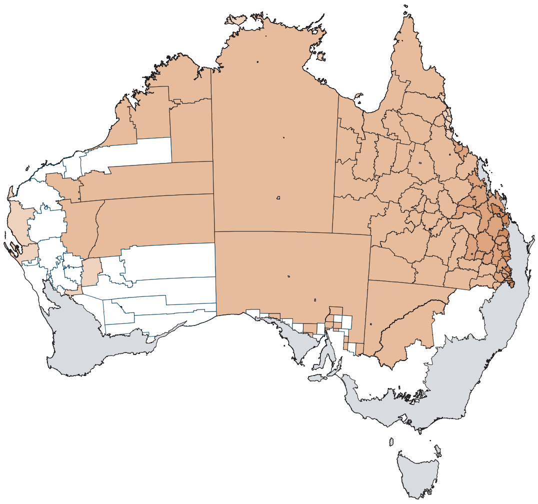
Source: Gutteridge et al. 2001. See also Appendix 2.

Figure 30. Cattle density for Australia's rangelands by statistical local area (1950s, 1960s, 1970s, 1980s, 1990s).

Cattle density
(dse/km²)

- 0
- 1 – 60
- 60 – 150
- 150 – 300
- 300 – 500
- 500 – 1500
- no data
- not included

1950s

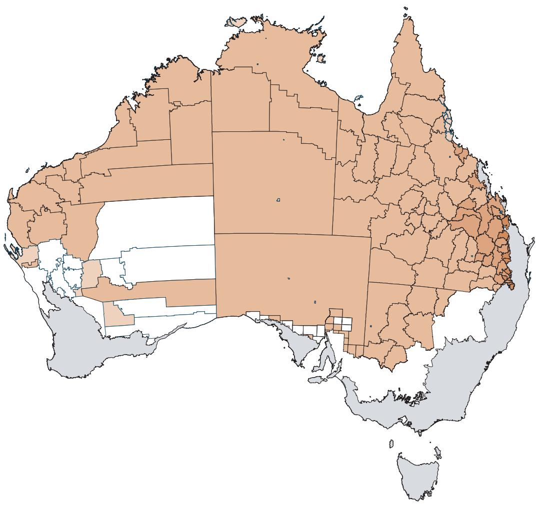


Data source:

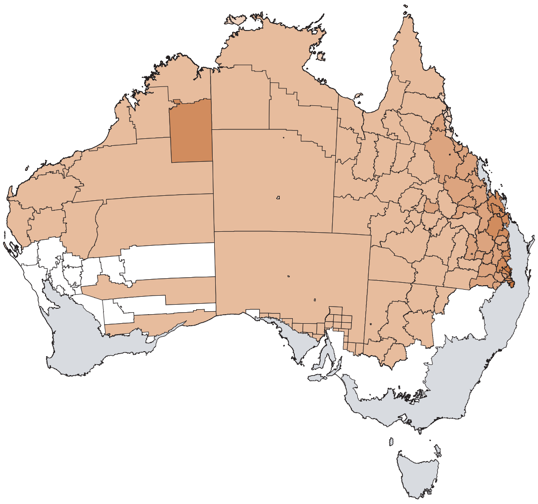
Gutteridge et al. 2001.

Data used are assumed to be correct as received from the data suppliers.

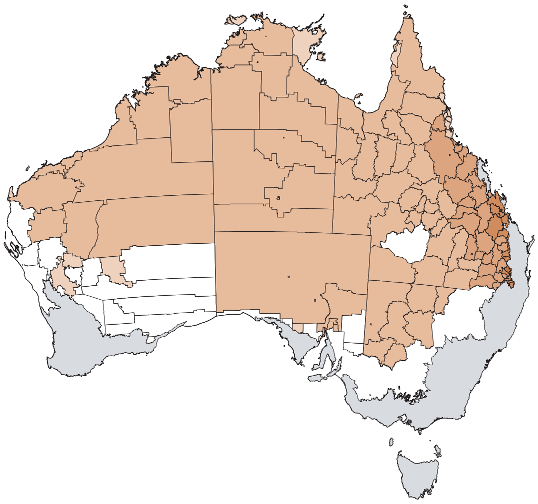
1960s



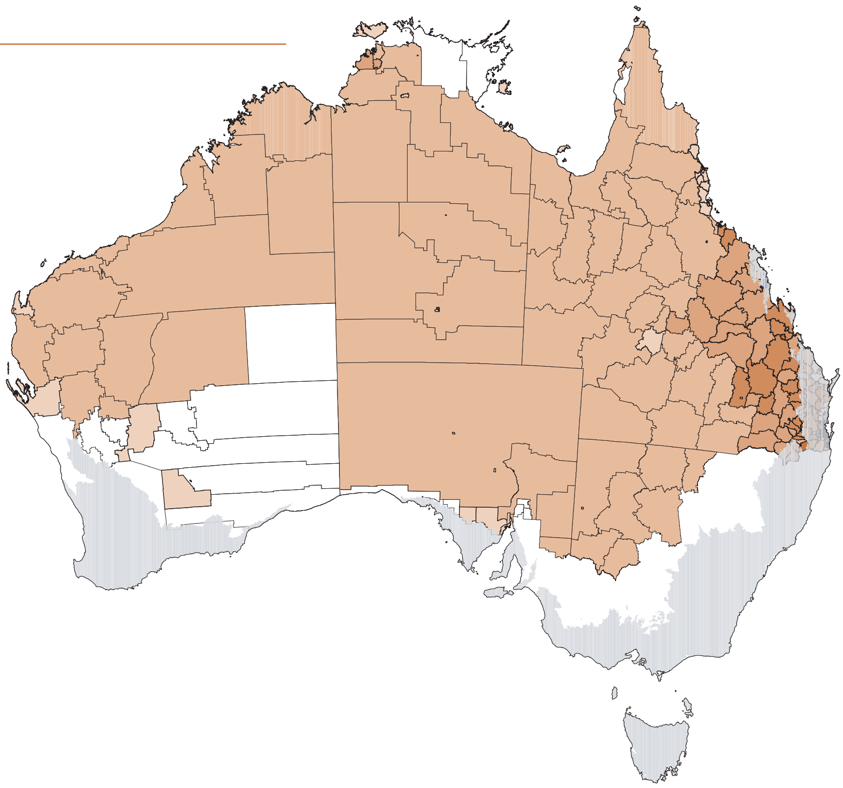
1970s



1980s



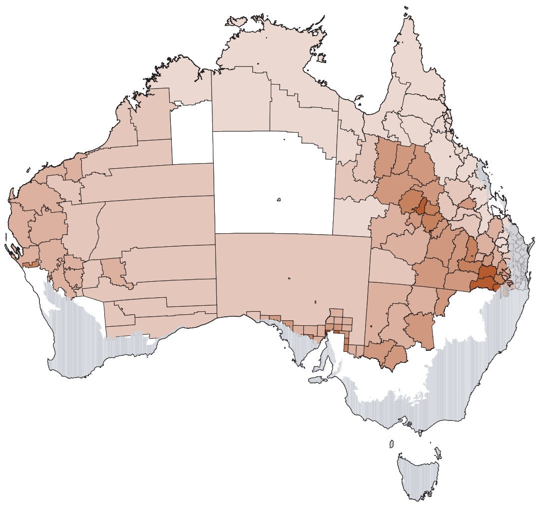
1990s



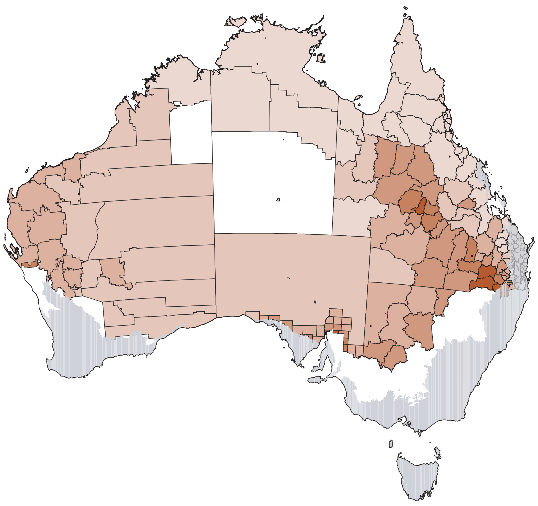
Sheep: more than 18 million across Australia's rangelands in 1999

Figure 31. Sheep density for Australia's rangelands by statistical local area (1950s, 1960s, 1970s, 1980s, 1990s). Generally sheep are found south of the dingo-proof fence which runs from Yalata near the Great Australian Bight, north to Coober Pedy, across to Tibooburra in New South Wales and across Queensland.

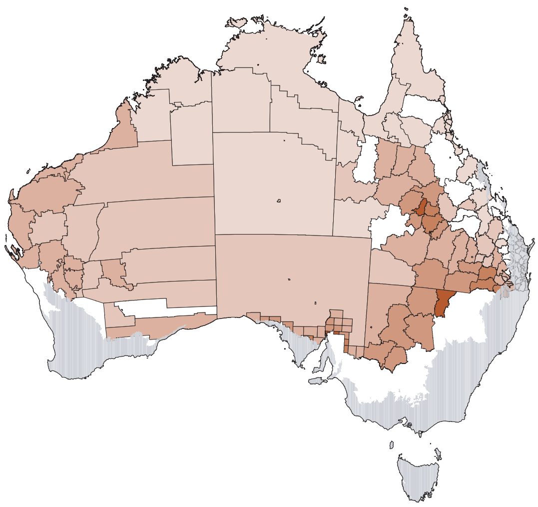
1950s



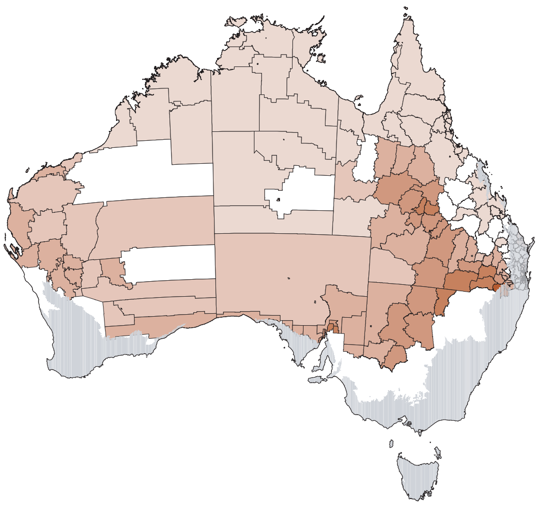
1960s



1970s



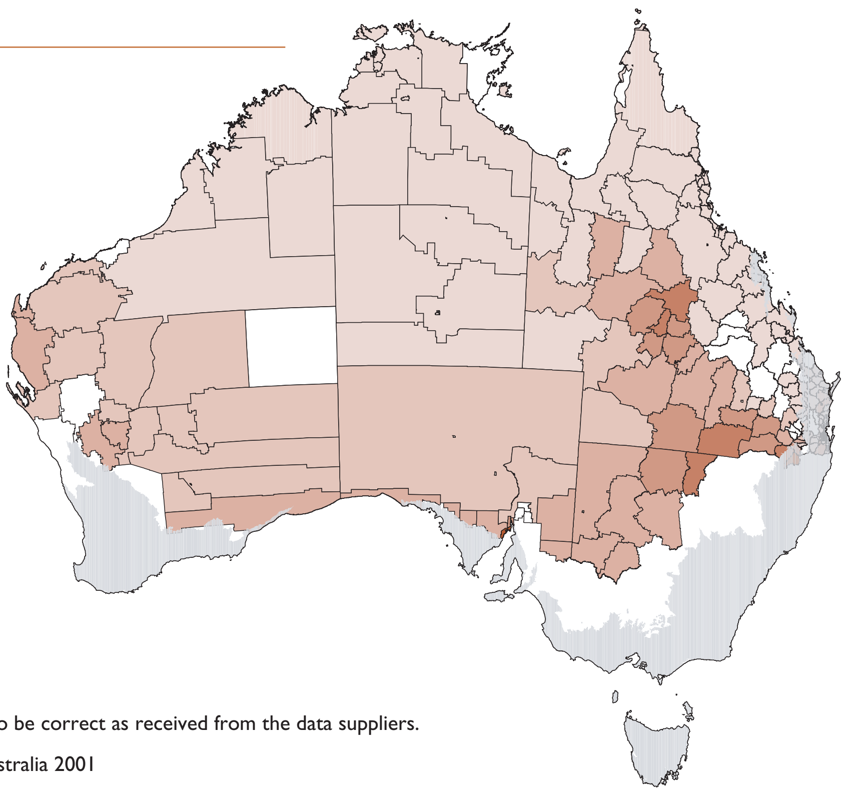
1980s



1990s

Sheep density
(dse/km²)

- 0
- 1 – 5
- 5 – 20
- 20 – 40
- 40 – 60
- 60 – 110
- no data
- not included



Data source:

Gutteridge et al. 2001.

Data used are assumed to be correct as received from the data suppliers.

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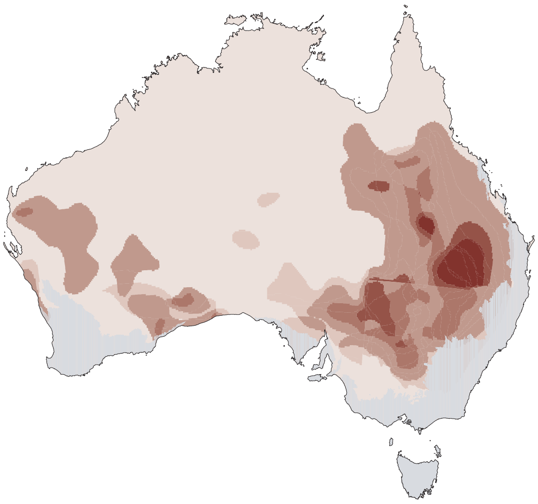
Western red kangaroo (*Macropus rufus*): populations vary with climate

Kangaroo density

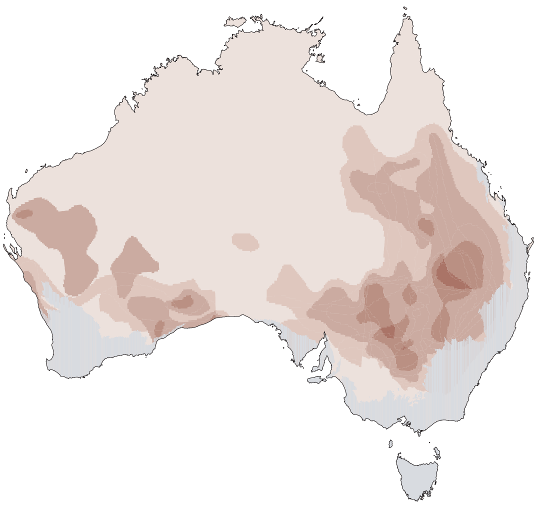
Very little data were available on kangaroo numbers before the late 1970s and little was understood of kangaroo population dynamics or their adaptation or response to the highly variable rangeland environment. The first comprehensive maps of kangaroo distribution and density were published in the early 1980s and were used as the starting point for the Audit's analysis of kangaroo distribution and density. The data were used as inputs to models to produce maps of kangaroo density for earlier decades on the basis of seasonal conditions (as measured by rainfall and simulated pasture growth). The maps presented here are approximate and should be considered as indicative only (Figure 32).

Figure 32. Kangaroo (*Macropus rufus*, *M. fuliginosus* and *M. giganteus*) density for Australia's rangelands (1950s, 1960s, 1970s, 1980s, 1990s). The modelled data suggest that kangaroo numbers are erratic and coincide with rainfall and available feed.

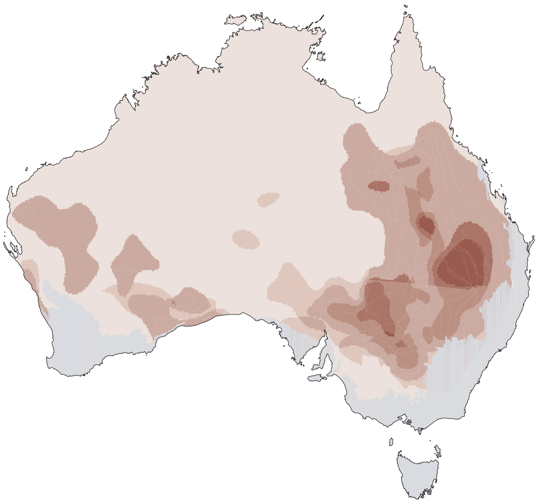
1950s



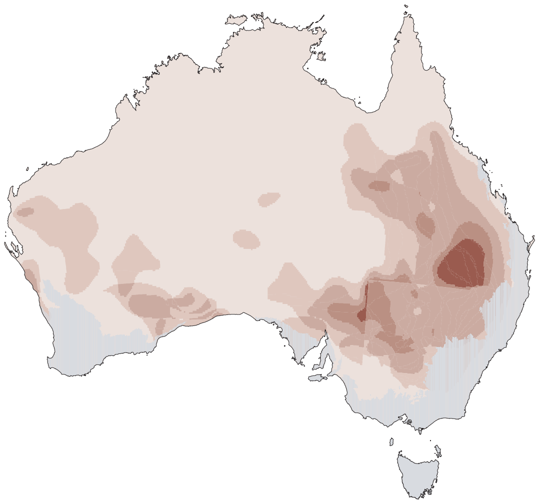
1960s



1970s



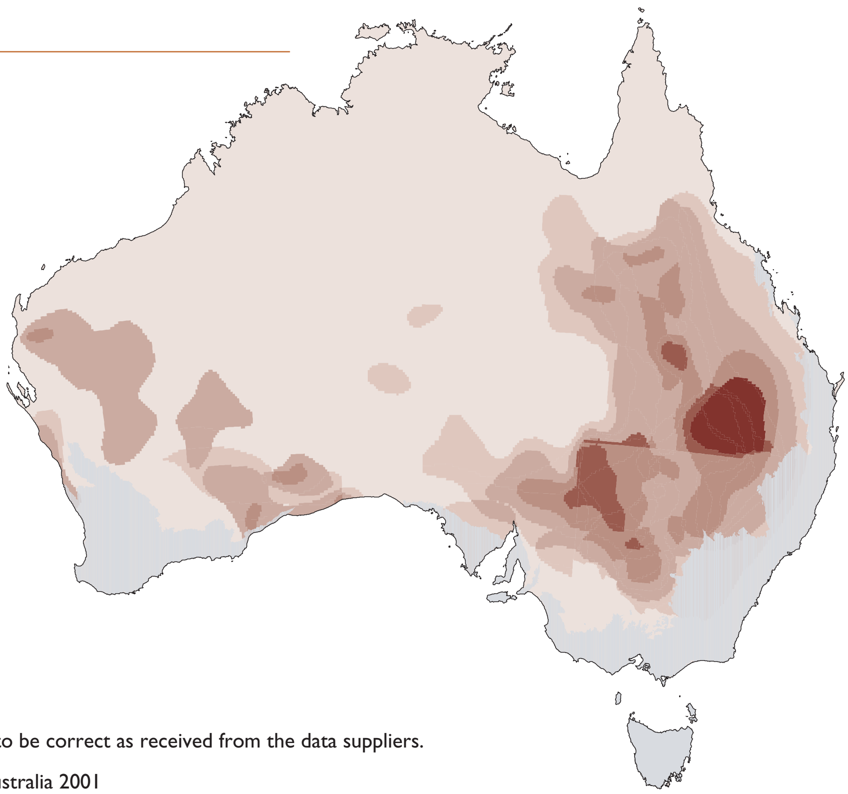
1980s



1990s

Kangaroo density
(dse/km^2)

- < 1
- 1 – 3
- 3 – 10
- 10 – 18
- 18 – 27
- 27 – 43
- not included



Data source:

Gutteridge et al. 2001.

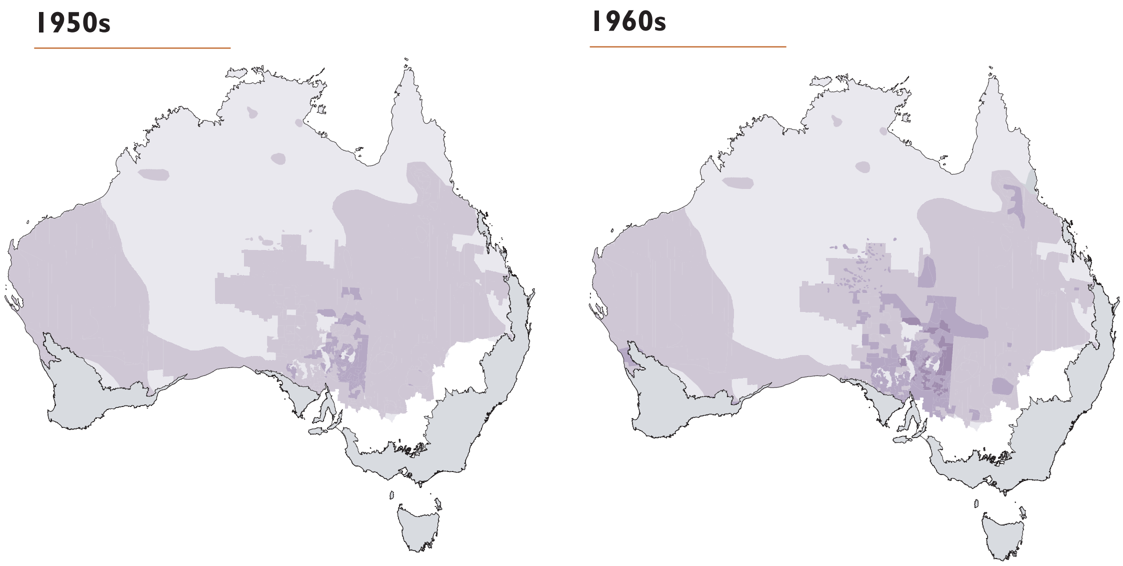
Data used are assumed to be correct as received from the data suppliers.

Feral camels: with no predators, their numbers are increasing

Feral animal density

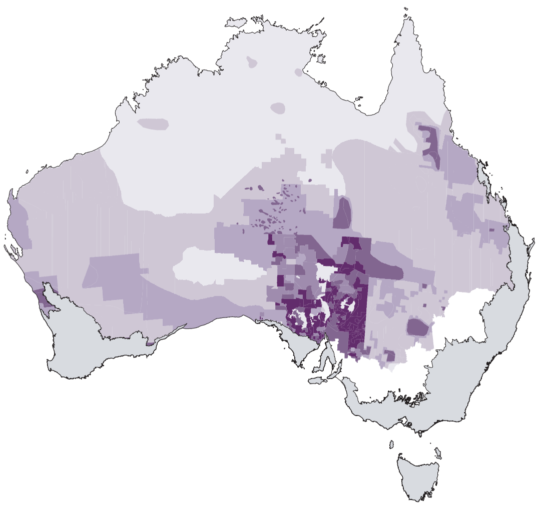
Feral camels, buffaloes, horses and donkeys are known to cause ecological impact. Data are limited so that collation of historical data by the Audit on feral animal abundance and distribution has been restricted to goats and rabbits (Figure 33). These are key feral animal species because of their high impact on the resource base.

Figure 33. Total density of feral goats and rabbits for Australia's rangelands (1950s, 1960s, 1970s, 1980s, 1990s).*

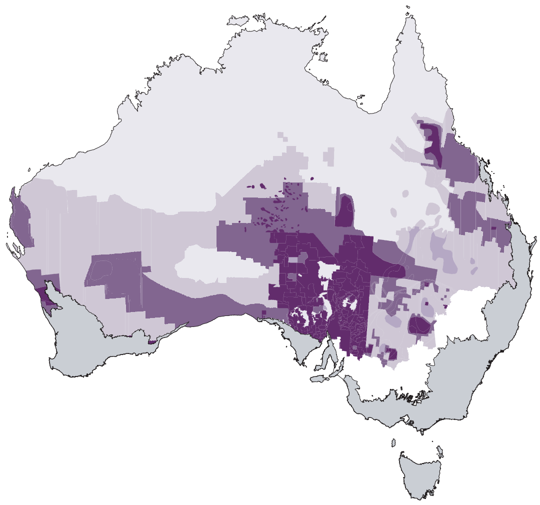


* Feral goat and rabbit maps have been compiled using data from a variety of sources, in conjunction with simulations and extrapolation of data based on factors such as the assessment of seasonal conditions as measured by rainfall and pasture growth. The scarcity of both time-series and spatial data on goats and rabbits means that, although they are the best available, the maps are indicative only.

1970s



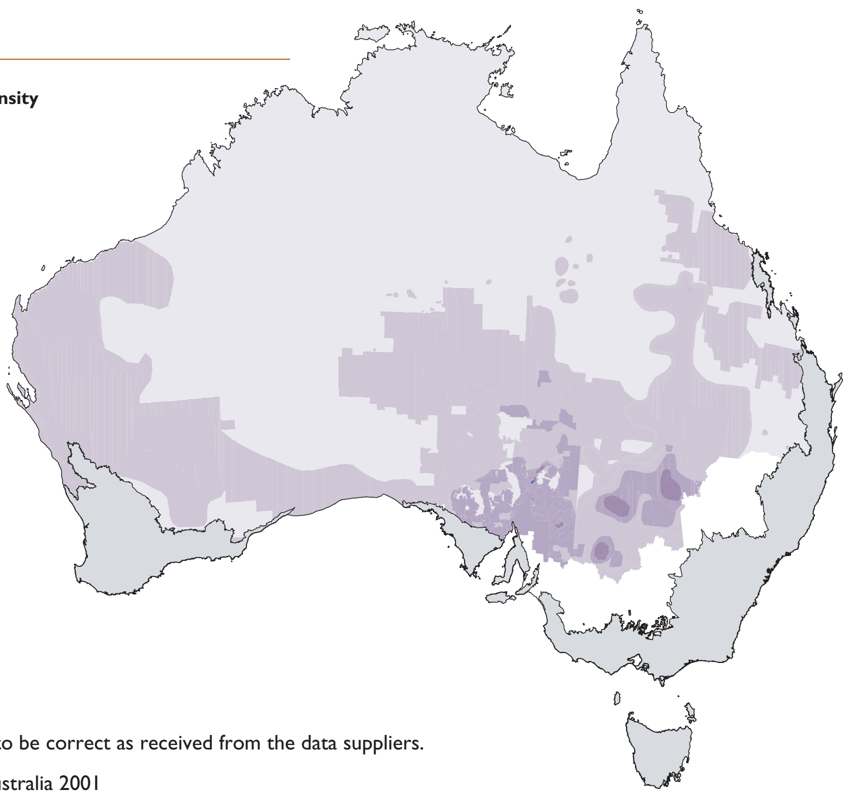
1980s



1990s

Feral goat and rabbit density
(dse/km²)

- 0
- 1 – 500
- 500 – 1000
- 1000 – 1500
- 1500 – 2000
- 2000 – 10 000
- no data
- not included



Data source:

Gutteridge et al. 2001.

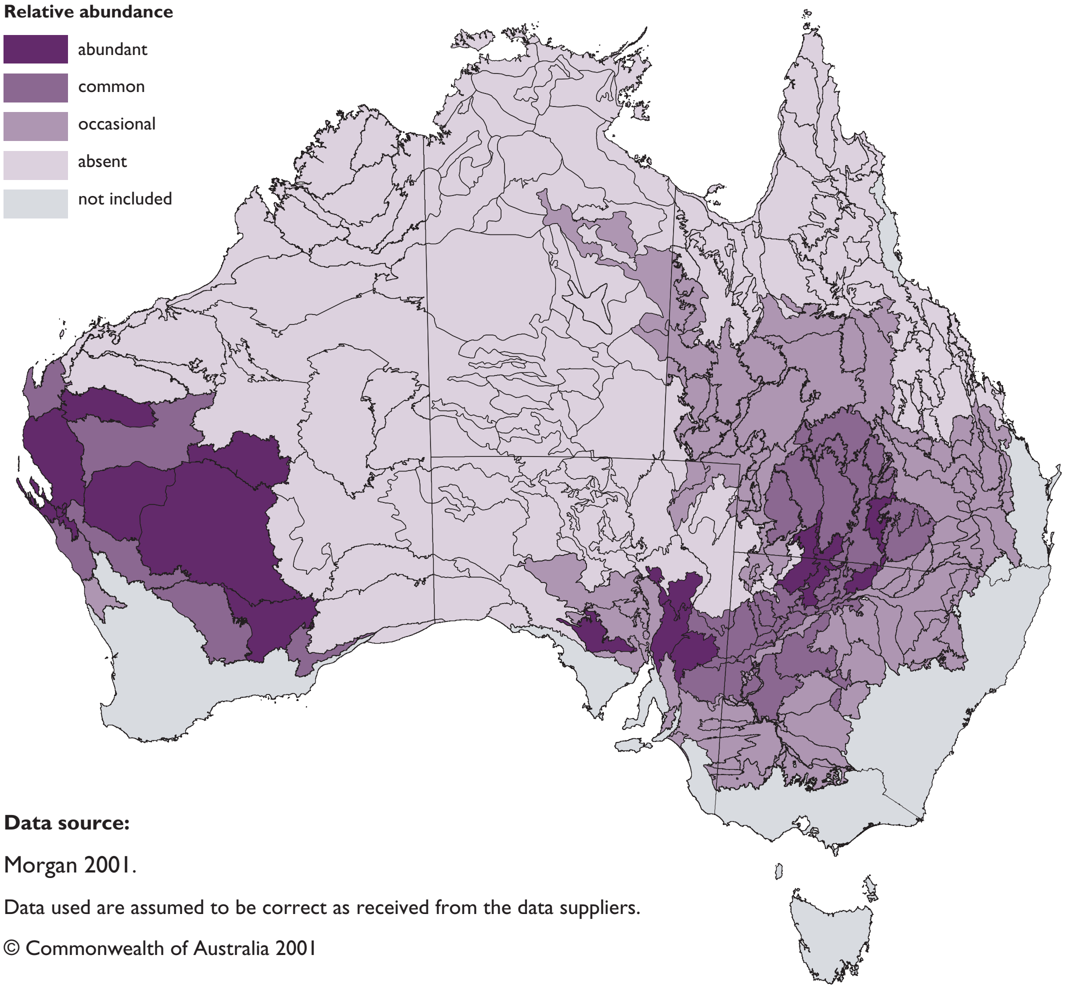
Data used are assumed to be correct as received from the data suppliers.

Feral goats: a key cause of degradation

Goats were introduced to Australia in 1788. By 1993 an estimated 2.6 million feral goats were spread across the country (Figure 34). They prefer high protein feed and green annual plants when available. They will eat shrubs and trees in dry conditions and will eat a wider variety of plants than sheep and cattle. Goats have a dramatic impact on ecosystems that have evolved without browsing animals. Control is difficult due to their high mobility and high reproduction rate.

Only limited data on the distribution and density of goats across Australia's rangelands were available before the mid-1970s. Available evidence and reports indicate that goats were widely distributed as domestic herds may subsequently become feral. From the mid-1970s, statistics and maps were produced for each of the States where feral goats were found.

Figure 34. Extent of goats by sub-bioregion.



Data source:

Morgan 2001.

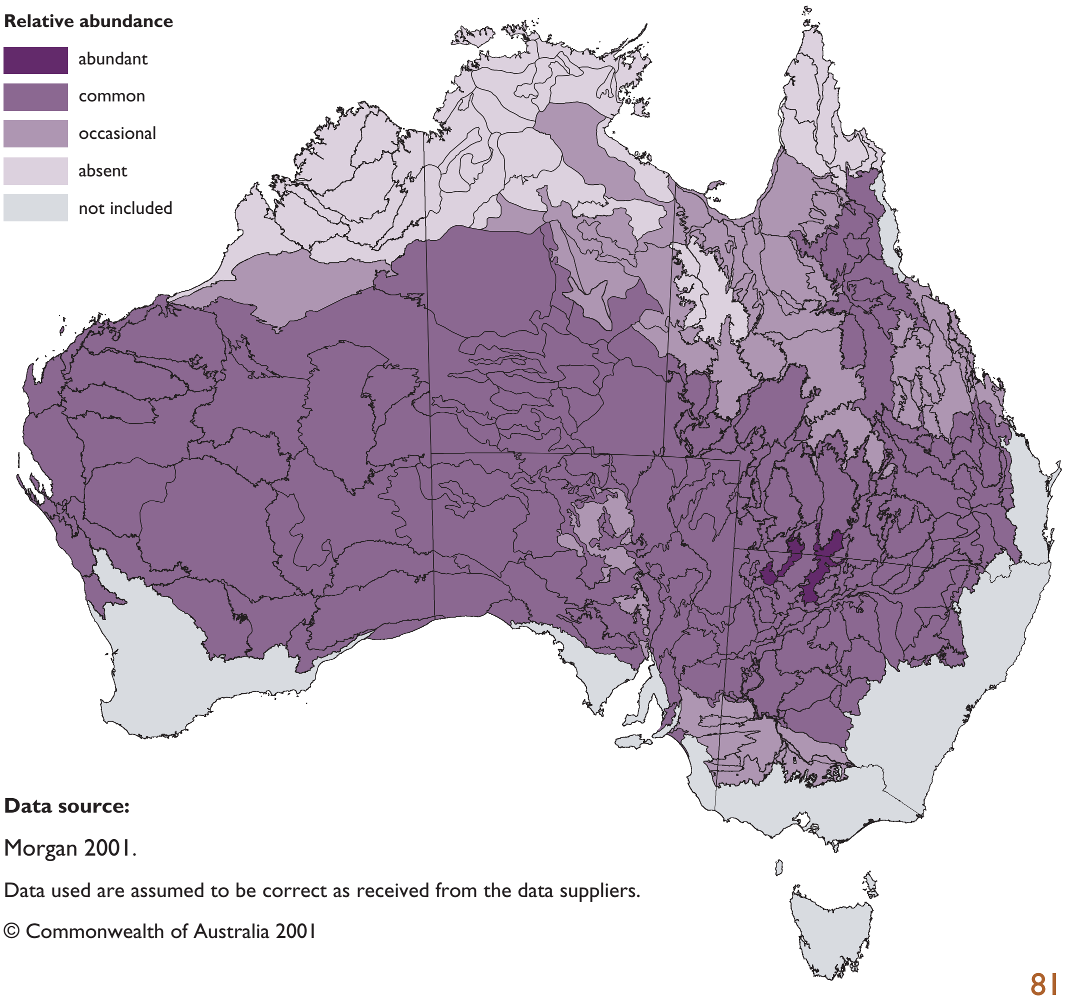
Data used are assumed to be correct as received from the data suppliers.

Rabbits were released in 1859 onto a property in Victoria for sport and food, and subsequently at a number of other locations. They have since spread over much of the continent (Figure 35). The rate of spread across Australia was the fastest known of any colonising mammal in the world.

Rabbits have had a devastating impact on Australia's rangelands. They prevent regeneration of native plants and compete with livestock and native animals for available feed. The environmental changes caused by rabbits have contributed to the decline of many rangeland animal and plant species. Landowners are legally obliged to control rabbit populations.

The distribution of rabbits reached its greatest extent before the 1950s for most of the rangelands. The physical environment and control programs mainly determine their presence and number. The two most well-known and effective control programs have been the introduction of myxomatosis in the early 1950s, and the escape and subsequent administering of calicivirus in the late 1990s. Continued management to further reduce rabbit populations is essential and would be cost-effective following the control programs.

Figure 35. Extent of rabbits by sub-bioregion.



Data source:

Morgan 2001.

Data used are assumed to be correct as received from the data suppliers.

Fire: a critical part of rangeland ecology

Product 9.
Fire extent, timing and frequency

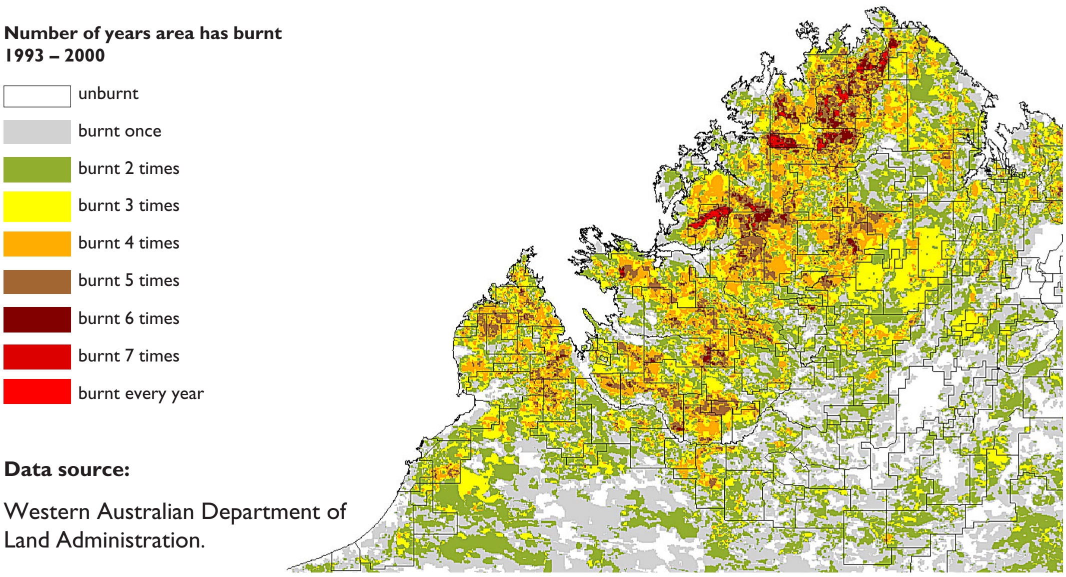
Fire has shaped much of the vegetation and ecology of the rangelands and is an integral part of rangeland management. The frequency of fires used by Indigenous people to hunt and manage vegetation sometimes changed vegetation types (e.g. open savanna replaced open forest). European settlement and grazing have led to a generally lower frequency of burning and less fuel in the understorey. In semi-arid areas, woody weeds (both native and exotic) have become a major problem that needs to be controlled by fire and/or grazing.

The Tropical Savannas Management Cooperative Research Centre—among other research institutions—has researched the effects of fire on ecosystems and biodiversity (www.savanna.ntu.edu.au/). Frequent fires and fires late in the dry season are the most damaging to ecosystems and biodiversity. Australia-wide fire monitoring—beginning in 1997 and ending in 1999—provided information on location, timing and frequency of fires. The total area burnt from 1998 to 2000 represents 13% of the continent. Fires were started by lightning strikes and deliberately (e.g. control burns for hazard reduction, pasture management, Indigenous cultural reasons or for biodiversity objectives).

Remote sensing allows managers to view large areas of the rangelands and to track fire activity in real time, enhancing the ability to manage the effects of fire and assess impacts over time. The Western Australian Department of Land Administration has been conducting real-time fire monitoring of the Kimberley region since 1993 using NOAA-AVHRR satellite thermal signals from night images (Figure 36). These images provide 'hot spot' base data for verification with maps of visible burnt areas and ground truthing.

Annual assessments of fire-affected areas need to be continued as part of a rangeland monitoring program.

Figure 36. Remotely sensed image showing fire frequency in the Kimberley. Large parts of the Kimberley experience late burns at the end of the dry season. The area burnt in the Kimberleys has increased every year since monitoring began (5 million hectares area of fire scars in 1994 compared to 25 million in 1998).



Data source:

Western Australian Department of Land Administration.

Product 10.
Land tenure

An understanding of land tenure and how it has changed over time provides a basis for evaluating land use impacts (Figure 37). Land management and administration have been integral to the Australian landscape since its first human occupation.

- Indigenous people managed the land using fire and selective harvesting and developed complex systems for the administration of land through tribal lore and the 'dreaming' (the Indigenous system of beliefs, morals, family and the afterlife).
- The arrival of Europeans saw development of land management and administration systems that were thought to be the most appropriate at the time but lacked understanding of ecological factors that interplay on the Australian landscape (Childs 2000).

The hierarchical 'property rights' system has resulted in land held under a variety of tenures (e.g. freehold, Crown leasehold and unallocated Crown land) each with differing land use covenants. Lease tenures have evolved prescribing dominant and sometimes exclusive land use types (Holmes 2000) (Table 4).

Table 4. Phases of the evolution of lease tenures. These leases usually prescribed a dominant and sometimes exclusive land use type (Holmes 2000).

Phase	Policy orientation	Participants and other role players	Policy role of lease tenures
I 1847 – 1861	Managing the pastoral frontier	British colonial, squatters, Colonial Governor, Legislative Council	Providing temporary low-cost access for pioneer pastoralists while preserving future options on land allocation and use
II 1861 – 1884	'Unlocking the land' facilitating closer settlement	Colonial governments, squatters, selectors, agrarian idealists, landless ex-miners	Enabling free selection of small holdings under specified conditions to bona fide settlers
III 1884 – 1950s	'Progressive' closer settlement	Colonial/State governments, pastoralists, agricultural and grazing small holders, agrarian idealists, landless ex-miners, development advocates, emerging urban sector	Enabling the sequential, managed subdivision of pastoral runs into family-sized small holdings
IV 1950s – 1970s	Policy vacuum and 'clientism'	State governments, lessees	No clear policy function, tinkering with the system and lessees' concerns about tenure upgrading, reduced rentals and other concessions
V 1980s – 1996	Sustainability, existence values and multiple use	State governments, lessees	Emerging role in rangeland monitoring, sustainable use, preservation of biodiversity and providing controlled public access, limited role in restructuring non-viable holdings
VI 1997 –	Co-existence	Ratified intenational convenants, High Court, Federal Government, State governments, Colonial/State governments, Native Title claims, reconciliation advocates, conservationists, recreationists, tourist operators, research and extension workers	Settlement of Native Title claims and of the practicalities of co-existing titles, as well as ongoing involvement with issues emerging in Phase V, which further expand the circumstances requiring co-existence between pastoralists and other interests

Mining: worth over $12 billion each year

Covenants on pastoral leasehold land generally limit use to grazing activity, with access to the public provided certain conditions are met. However, other stakeholders (e.g. those involved in mining, tourism and agriculture) may also have a vested interest in the land. The case for flexibility is strongest on marginal lands where the economic returns from pastoralism are lower (Holmes 2000). A system of flexible use would require increased responsibility from governments to ensure coordinated administration, and for land administration to be an extension of public policy.

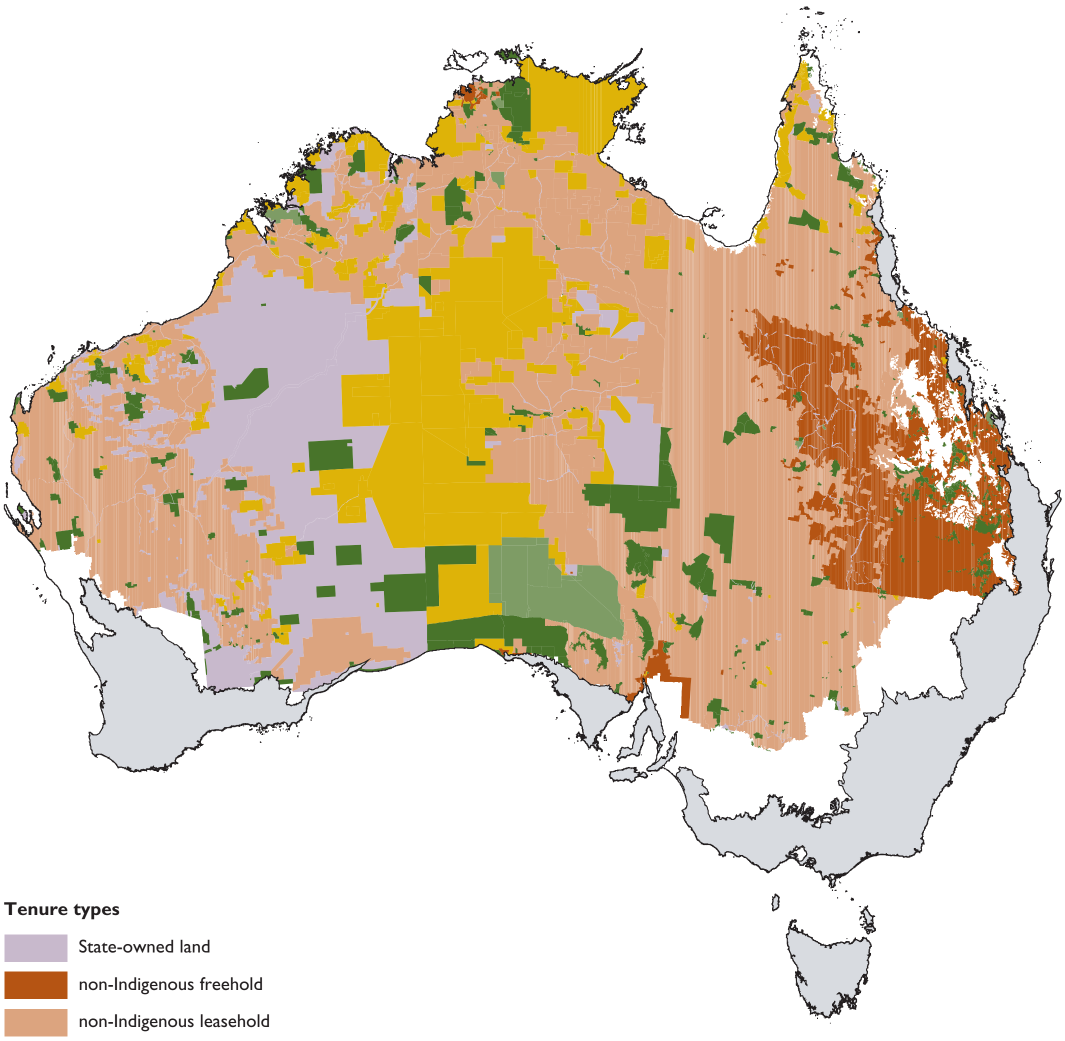
The Audit collated changes in land tenure for the 1950s to 1999 as context information to assess trends in rangelands use and management.

Key Audit findings are:

- Land set aside for nature conservation purposes has increased more than fifteen-fold since the 1950s from 29 100 km^2 to 441 200 km^2 (7.8% of the total rangelands area) (Figure 38).
- In the 1950s, land reserved for Indigenous use and benefit (covering a variety of titles but no Indigenous groups actually owned land) was 347 200 km^2. In 1999, Indigenous-held land and land reserved for Indigenous use and benefit was 925 200 km^2 (16% of the total rangelands area and an increase of about 2.5 times) (Figure 39).
- Total freehold and leasehold land has remained substantially the same—approximately 57% of the total rangelands area. The majority of these lands are leasehold. Nature conservation and Native Title holdings come principally from unallocated lands (Figure 40).

The full data set is available in Appendix 3.

Figure 37. Land tenure across Australia's rangelands (1999).



Tenure types

- State-owned land
- non-Indigenous freehold
- non-Indigenous leasehold
- reserved for Indigenous use and benefit, and Indigenous-held (freehold and leasehold)
- reserved land (national park, conservation, forest, water and other reserves)
- defence
- no data
- not included

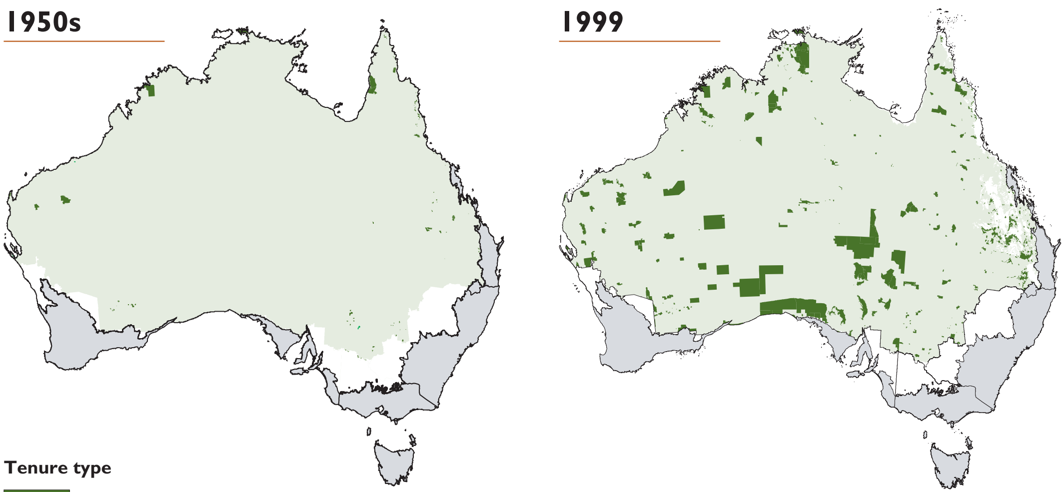
Data source:

Hall & Gutteridge 2001.

Data used are assumed to be correct as received from the data suppliers.

Tenure plays a role in protecting cultural heritage

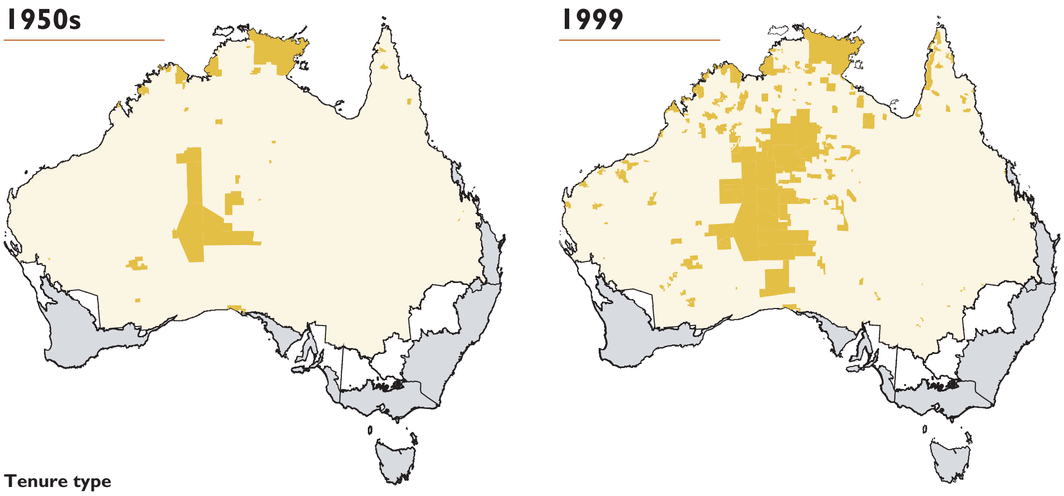
Figure 38. Land set aside for nature conservation purposes in the 1950s and in 1999.



Tenure type

- reserved land (national park, conservation, forest, water and other reserves)
- non-reserved land
- no data
- not included

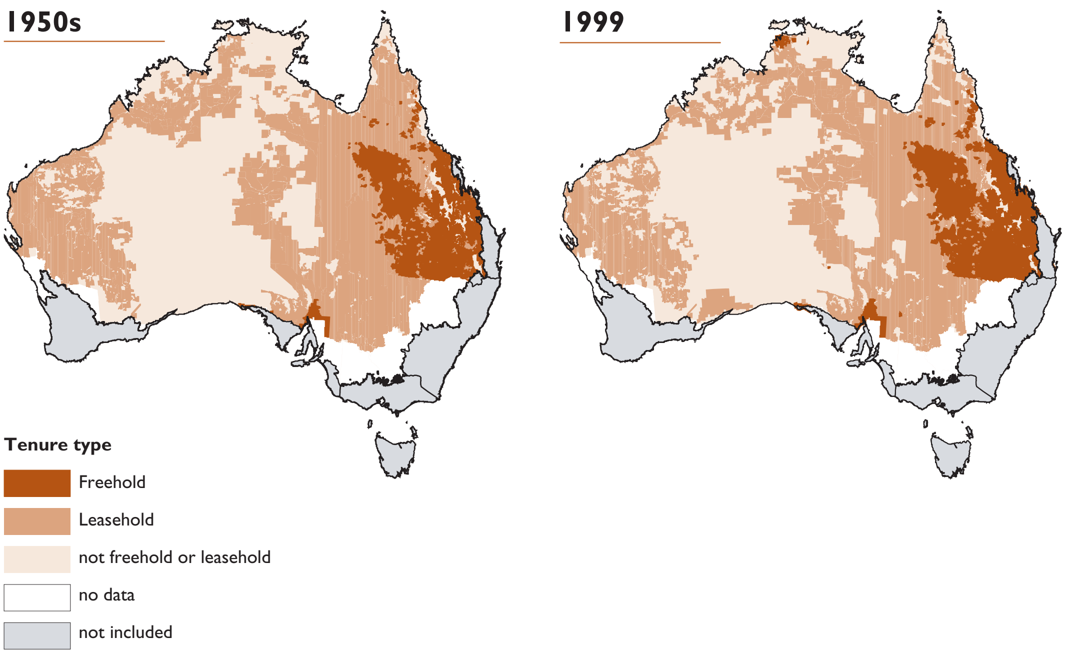
Figure 39. Land reserved for Indigenous use and benefit in the 1950s. The second map shows land reserved for Indigenous use and benefit, plus Indigenous-held land in 1999.



Tenure type

- reserved for Indigenous use and benefit and Indigenous-held (freehold and leasehold)
- non-Indigenous land
- no data
- not included

Figure 40. Freehold and leasehold land in the 1950s and in 1999.

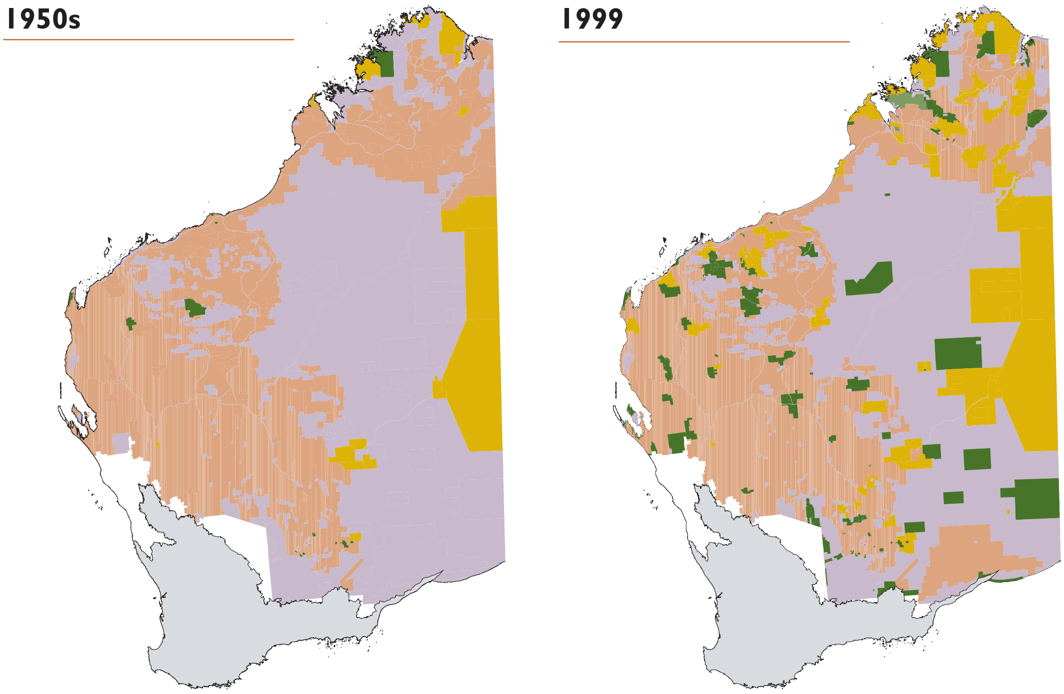


Data source:

Hall & Gutteridge 2001.

Data used are assumed to be correct as received from the data suppliers.

Figure 41. Land tenure in Western Australia 1950s and 1999 highlighting the spatial resolution of available data.



Tenure types

- State-owned land
- non-Indigenous freehold
- non-Indigenous leasehold
- reserved for Indigenous use and benefit, and Indigenous-held (freehold and leasehold)
- reserved land (national park, conservation, forest, water and other reserves)
- defence
- no data
- not included

Data source:

Hall & Gutteridge 2001.

Data used are assumed to be correct as received from the data suppliers.

Product 11. Introduced plants and animals

Weeds

More than 3000 exotic plant species cause billions of dollars worth of damage each year to Australia's productive capacity and natural resources (National Weeds Strategy Executive Committee 2000). A detailed breakdown of costs for the rangelands is not available. Invasive weeds displace native species and some are unpalatable or poisonous to livestock. Production from rangelands has a marketing edge in that pastoralists are able to be certified organic because historically agricultural chemicals have not been used. Conflict arises over weed control since chemical control over large areas affects organic status of graziers.

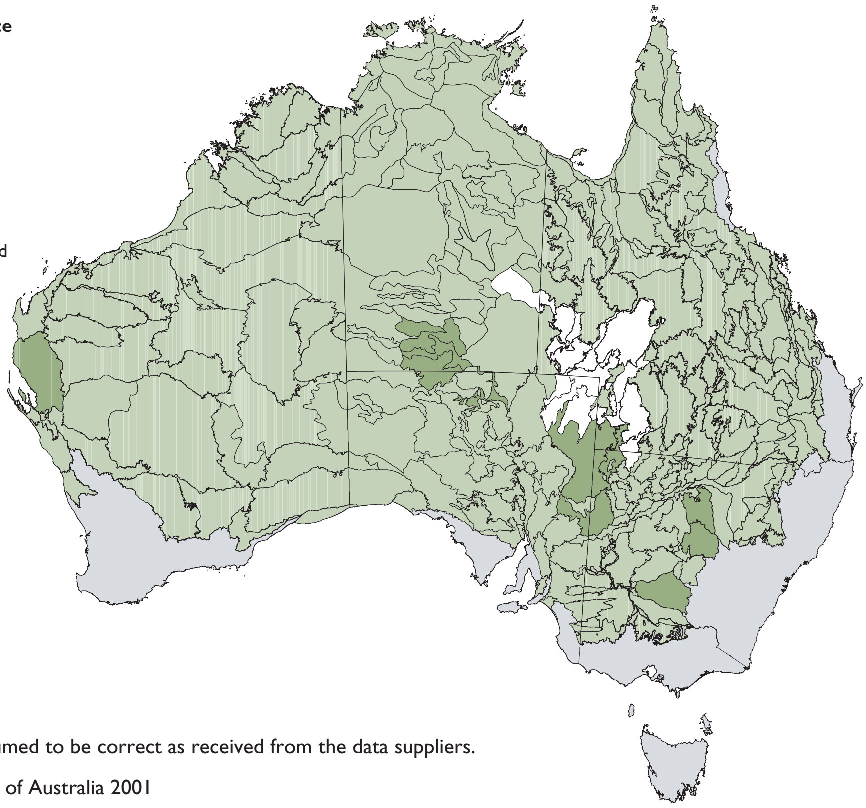
The National Weeds Strategy is concerned with managing priority weeds that pose threats to primary industries, land management, human and animal welfare, biodiversity, and conservation values. It has listed 20 weeds of national significance; a full list is available on the National Weeds Strategy website (www.weeds.org.au). Four species that affect rangelands are athel pine, mesquite, prickly acacia and parkinsonia.

Athel pine (*Tamarix aphylla, T. articulata*) grows rapidly and can be very invasive. It mainly affects riparian areas in central Australia and displaces native vegetation and alters natural habitat (Figure 42). Once established it is difficult and costly to control.

Figure 42. Extent of athel pine by sub-bioregion.

Relative occurrence

- abundant
- common
- occasional
- absent
- no data
- not included



Data source:

Morgan 2001.

Data used are assumed to be correct as received from the data suppliers.

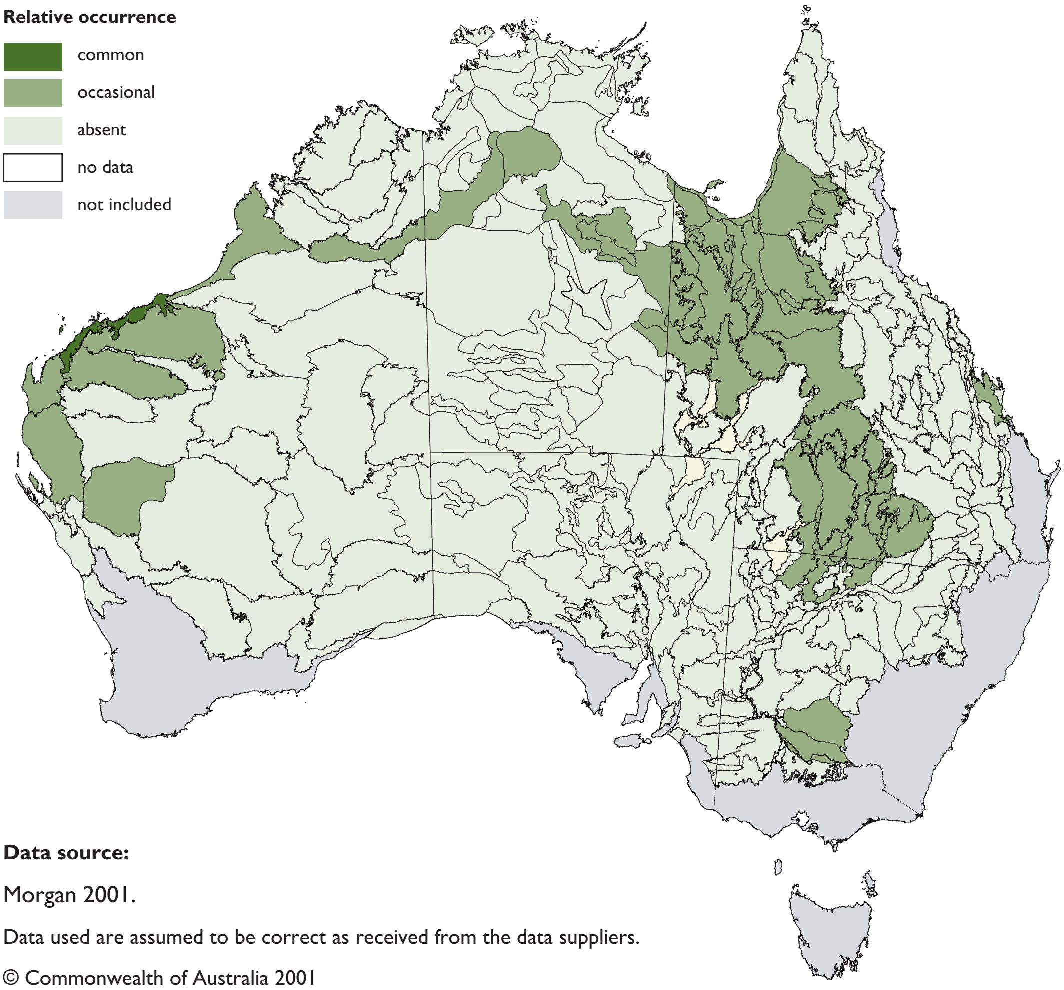
Mesquites (*Prosopis* spp.): a group of non-native thorny shrubs and trees that aggressively replace grasses and shrubs

Mesquites (*Prosopis* spp.) are a group of thorny shrubs and trees native to North and South America. They aggressively replace grasses and shrubs and have the potential to widely affect Australia's pastoral region. Current infestations cover 800 000 ha. Preventing spread is difficult as seed is easily and rapidly dispersed by animals and floodwaters (Figure 43).

Figure 43. Extent of mesquite by sub-bioregion.

Relative occurrence

- common
- occasional
- absent
- no data
- not included



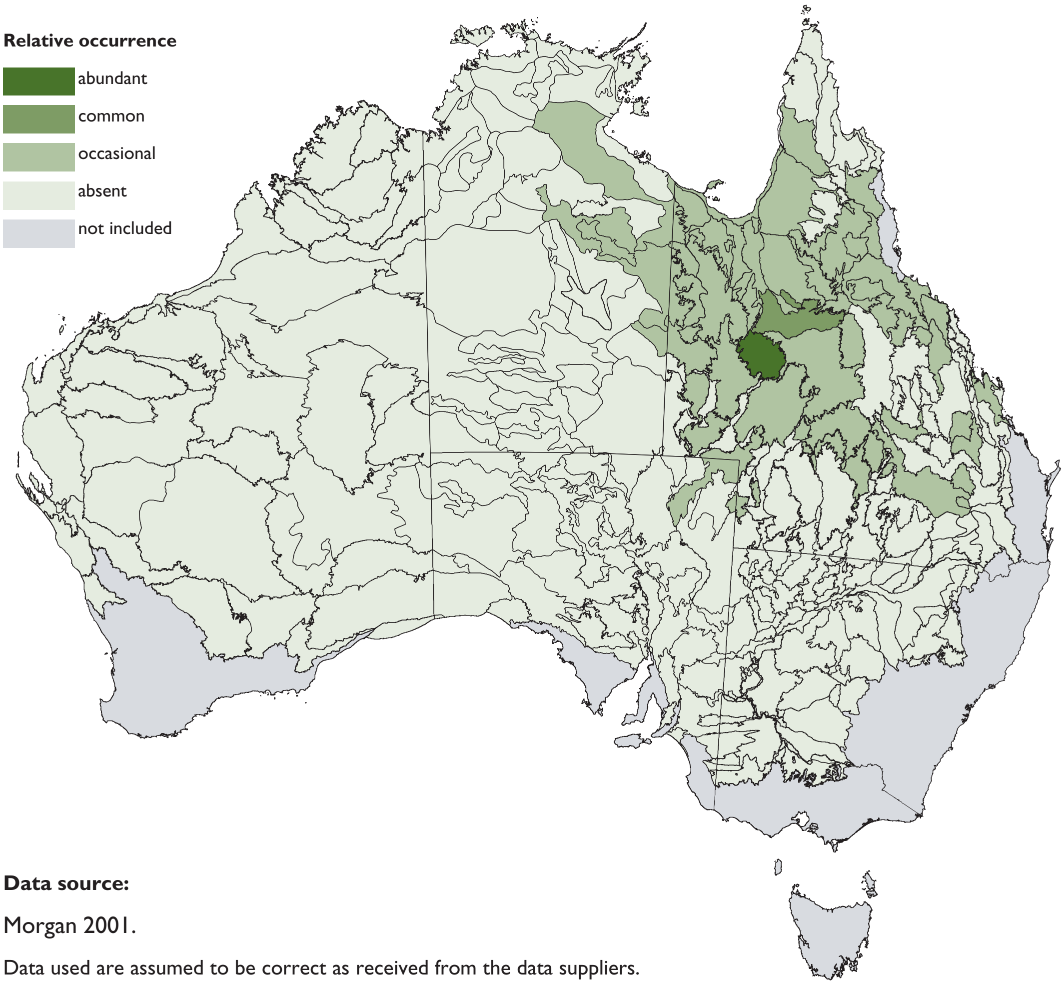
Data source:

Morgan 2001.

Data used are assumed to be correct as received from the data suppliers.

Prickly acacia (*Acacia nilotica, A. arabica, A. indica, Mimosa nilotica*) is a woody shrub imported from India and Pakistan as a fodder and shade tree in the early 1900s. Its impacts on production and biodiversity significantly outweigh the benefits gained from shade and drought fodder, and it is now a major weed. Prickly acacia infests over 6 million hectares of arid and semi-arid Queensland, with small infestations in other States (Figure 44). Prickly acacia costs the grazing industry $5 m annually due to reduced production and increased management costs.

Figure 44. Extent of prickly acacia by sub-bioregion.



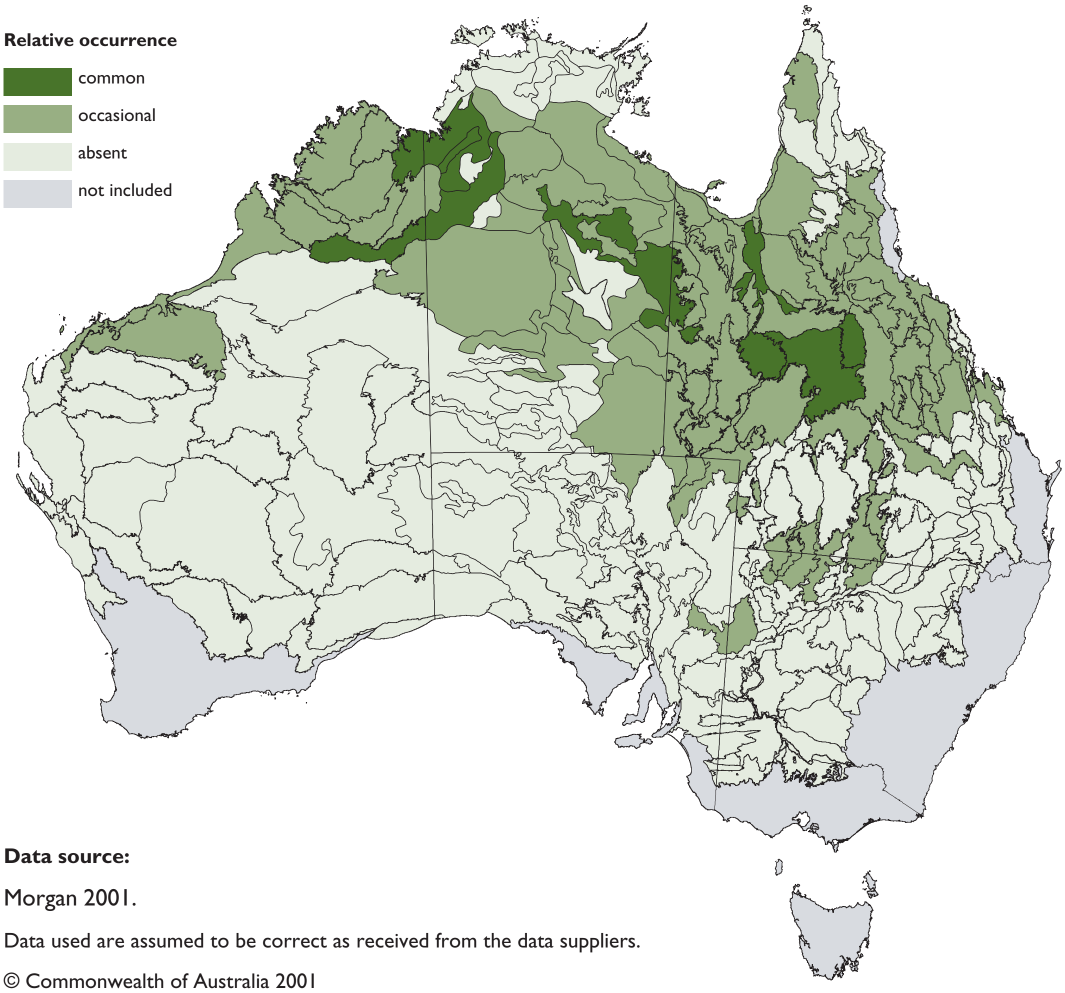
Data source:

Morgan 2001.

Data used are assumed to be correct as received from the data suppliers.

Parkinsonia (*Parkinsonia aculeata*) is a thorny shrub native to central America that was introduced as an ornamental and shade tree around 1900. It is now a major weed and infests large areas of Western Australia, the Northern Territory and Queensland, amounting to over 800 000 ha primarily along waterways (Figure 45). The spread of parkinsonia urgently needs to be prevented.

Figure 45. Extent of parkinsonia by sub-bioregion.



Data source:

Morgan 2001.

Data used are assumed to be correct as received from the data suppliers.

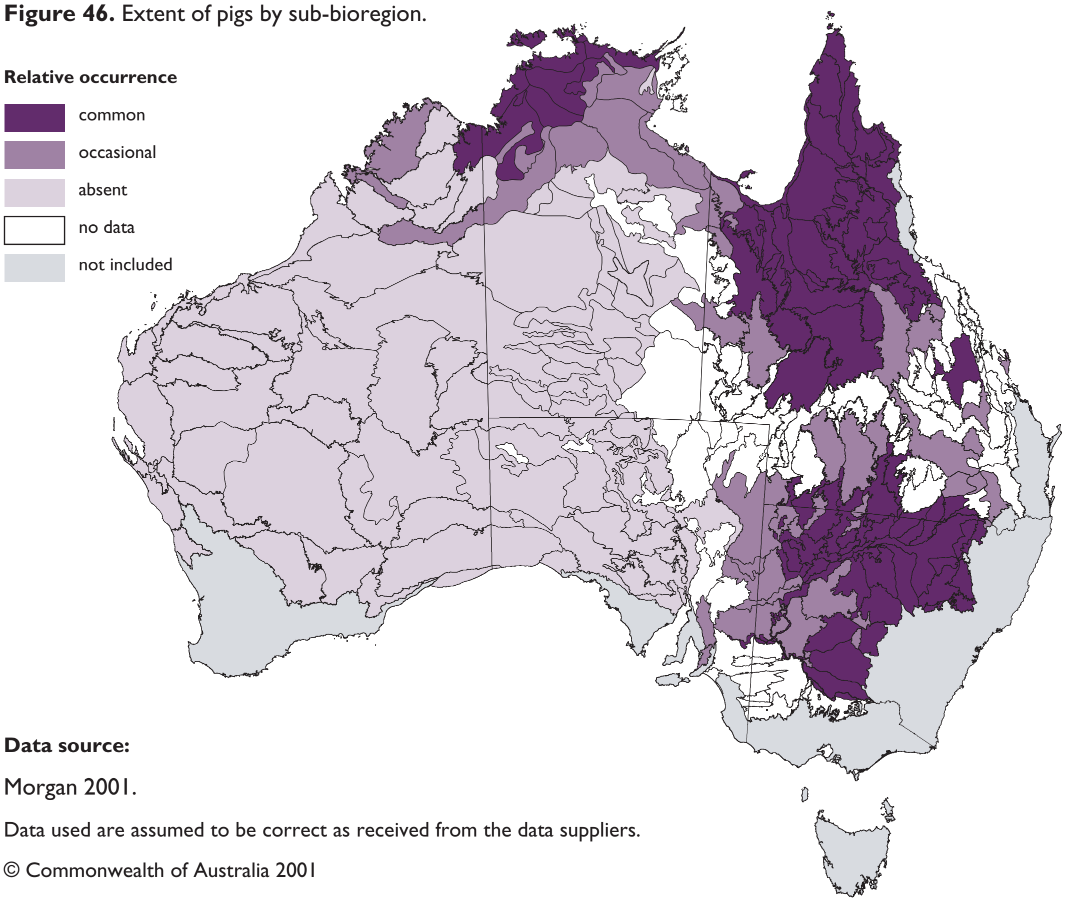
Feral animals

The major introduced species affecting rangelands—goat, rabbit, pig, buffalo, donkey, camel, horse, cat, fox and cane toad—now make up over 10% of Australia's fauna. Impacts on production include competition with livestock for food and shelter, predation on stock, land degradation (especially in localised areas of high feral population), and spread of diseases. Impacts on biodiversity include predation, competition for food and shelter, and displacement of native species.

The National Feral Animal Control Program aims to reduce the damage to agriculture and the environment caused by feral animals. It is administered by the Bureau of Rural Sciences and the Biodiversity Group of Environment Australia.

Domestic pigs were first introduced into Australia in 1788 to provide food for early settlers. Feral pigs are Australia's most popular game animal and the associated meat industry is worth $10 m to $20 m annually. Pigs have a varied diet: they prefer tender green vegetation, fruit and grain, but also eat rodents, lizards, frogs and insects. Pigs often prefer wetter areas and cause most damage to habitat in wetlands, marshes and watercourses (Figure 46). They are partially responsible for spreading the seeds of exotic plant species (e.g. *Mimosa pigra*).

Figure 46. Extent of pigs by sub-bioregion.



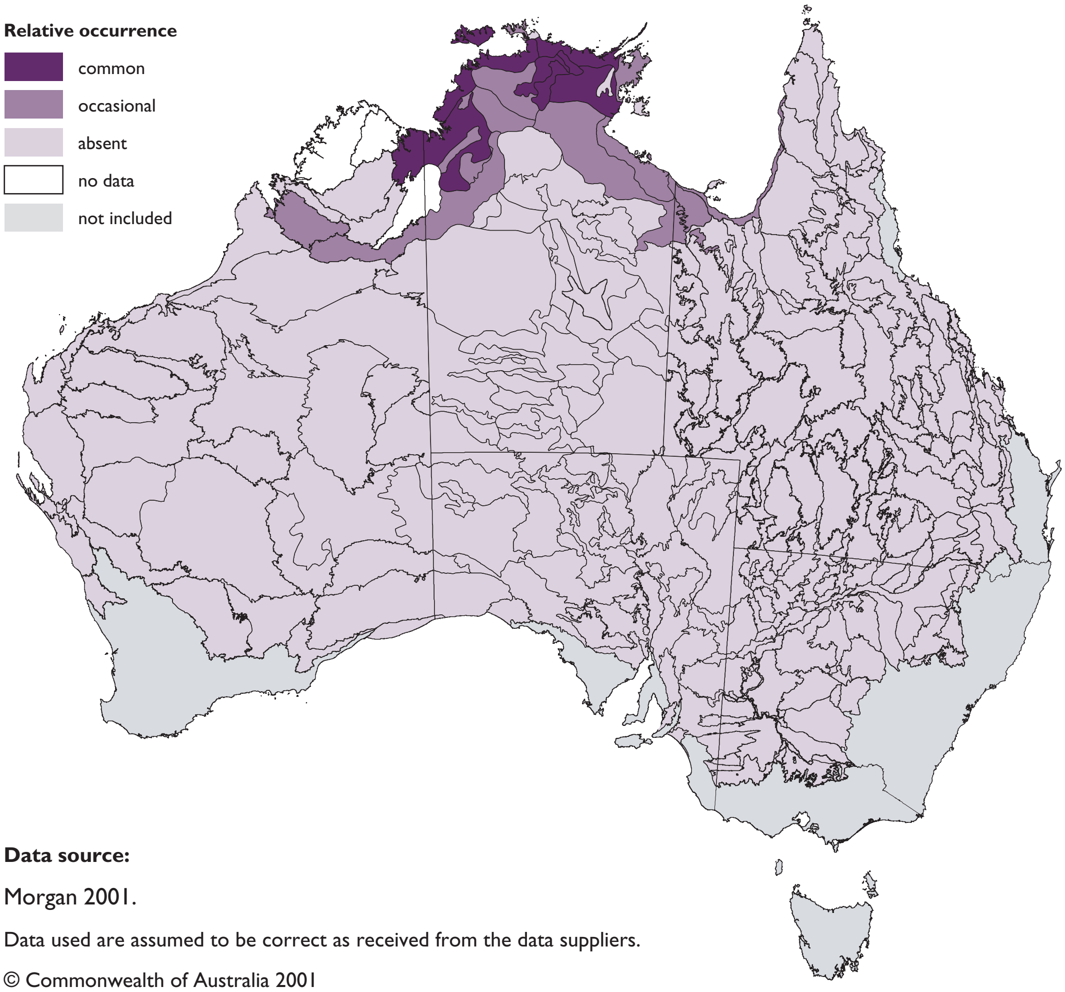
Data source:

Morgan 2001.

Data used are assumed to be correct as received from the data suppliers.

Water buffalo occupy the northern coastal floodplains of the Northern Territory (Figure 47). They compact soil, trample and destroy most of the vegetation in areas they occupy, and are a potential reservoir for bovine diseases. They cause most damage to hydrological regimes in floodplain wetlands where their pathways and wallowing contribute to saltwater intrusion.

Figure 47. Extent of water buffalo by sub-bioregion.



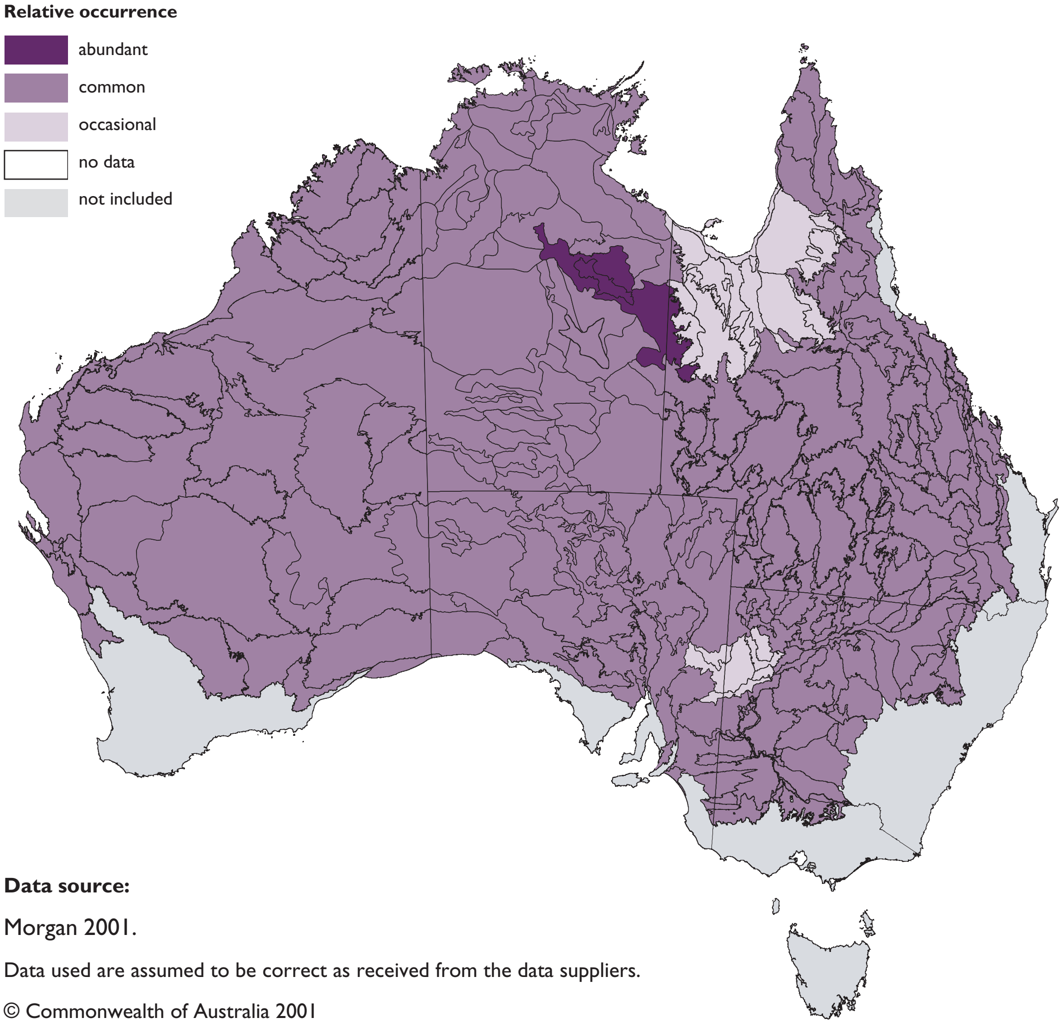
Data source:

Morgan 2001.

Data used are assumed to be correct as received from the data suppliers.

Domestic cats are known to have been released to control mice and rabbits in the 1800s. They have since spread over the entire continent (Figure 48). Cats feed mainly on young rabbits and birds but also eat small native mammals (e.g. ring-tailed possums, bush rats and marsupial mice). Current control methods are unreliable and not effective over large areas.

Figure 48. Extent of feral cats by sub-bioregion.



Data source:

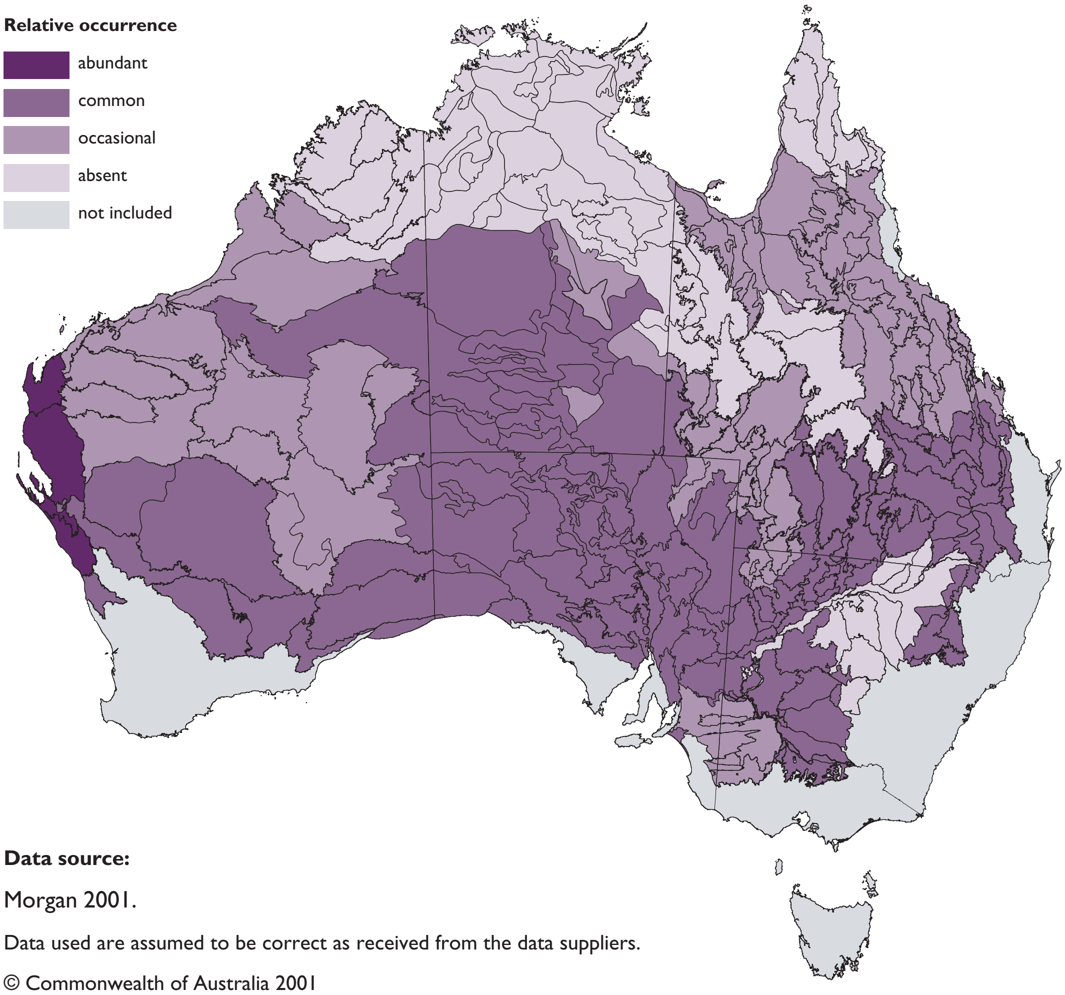
Morgan 2001.

Data used are assumed to be correct as received from the data suppliers.

European red fox (*Vulpe vulpes*): opportunistic predators and scavengers

The European red fox was released for recreational hunting over 100 years ago. Its early spread and establishment were associated with the introduction and spread of the rabbit. It is now common in most parts of Australia except in humid tropical regions (Figure 49). The fox is recognised as a major predator and threat to small and medium-sized native animals.

Figure 49. Extent of European red foxes by sub-bioregion.



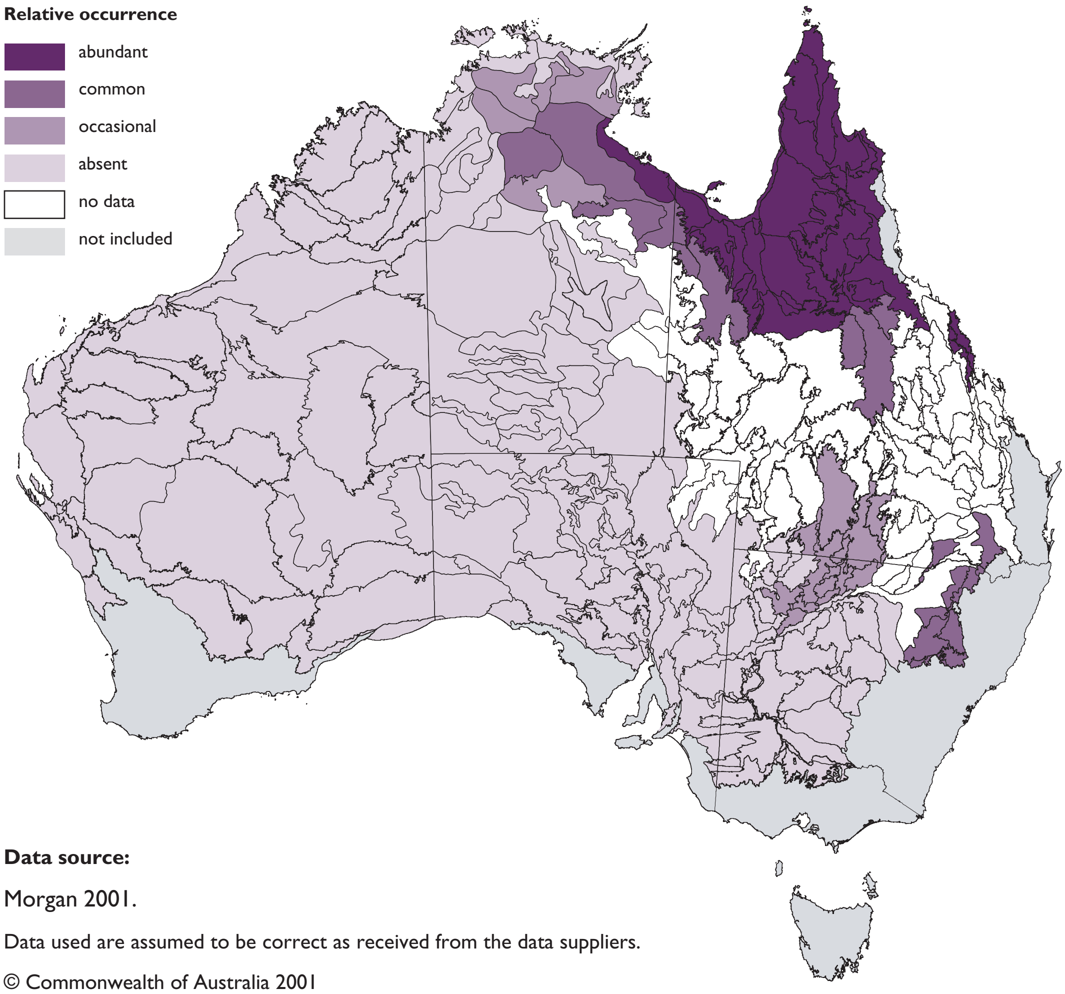
Data source:

Morgan 2001.

Data used are assumed to be correct as received from the data suppliers.

The cane toad was introduced to the Cairns area in 1935 in an attempt to control beetle pests in sugar cane. Cane toads were unsuccessful at controlling the insects but have since become widespread. They are still colonising Australia and their range is extending west across the Gulf of Carpentaria and into the Northern Territory (Figure 50). Cane toads have an impact on native fauna by predation, poisoning and competing for food and habitat.

Figure 50. Extent of cane toads by sub-bioregion.



Data source:

Morgan 2001.

Data used are assumed to be correct as received from the data suppliers.

Bulldozer and chain used to clear brigalow (*Acacia harpophylla*)

Product 12. Native vegetation clearing

Change in the extent of native vegetation indicates loss of habitat and is a key part of biodiversity monitoring and assessment (see Audit project: *Developing an adaptive framework for monitoring biodiversity in rangelands* available on the Atlas).

Australia-wide change in the extent of native vegetation has not yet been compiled. The Australian Greenhouse Office has Landsat data (as part of the National Carbon Accounting System) that will provide an Australia-wide assessment of vegetation change. Linking these data to the Audit's National Vegetation Information System will provide information on types and loss of native vegetation.

In some States, data collection systems (often linked to clearing permits) allow collation of finer-scale information on clearing. When readily available, it will be able to replace data derived from analysis of the Australian Greenhouse Office clearing register.

Complete analysis also requires an assessment of vegetation condition (e.g. the overstorey might be intact but of declining vigour, while the understorey is completely absent through grazing). Assessment of vegetation condition requires data covering a range of attributes. Some of these are core values that are applicable to a range of condition assessments (e.g. vigour); the remainder are specific to the particular values being assessed.

The Audit's *Native Vegetation Assessment 2000* (National Land and Water Resources Audit 2001b) notes that the immediate priority is to develop and implement a robust clearing register for Australia's native vegetation. Scientists and managers also need to develop agreement on core values for forest products, biodiversity, catchment health and carbon accounting; and on key attributes to measure and allow assessment for each value set.

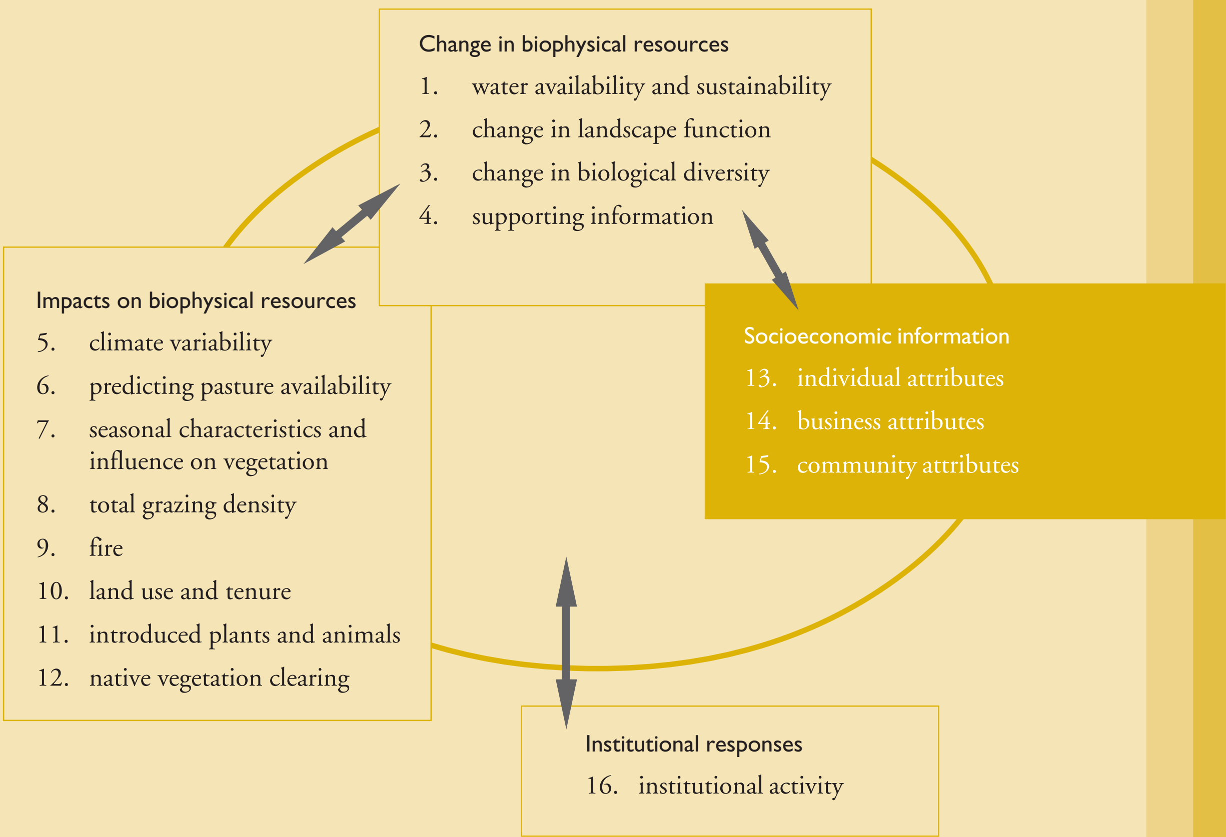
Socioeconomic information

In order to adopt sustainable resource management practices, managers need to:

- understand problems and identify opportunities and management practices (key drivers are knowledge, information and communication) (Gordon et al. 2001);
- be motivated to adopt sustainable management practices (key drivers are environmental attitudes, stewardship approaches, security, and peer and other pressure) (Gordon et al. 2001); and
- have the capacity to adopt sustainable management practices (key drivers are available finances, skills, mentors, decision support and access to infrastructure) (Gordon et al. 2001).

Information products under this component are summarised in Table 5.

Sources of socioeconomic data are the Census of Population and Housing by the Australian Bureau of Statistics and the Australian Agricultural and Grazing Industry Survey (annual farm survey) by the Australian Bureau of Agricultural and Resource Economics.



Recommended enhancements to socioeconomic data capture that provide economic and social information for informing rangeland management policy (Haberkorn et al. 2001) include:

- revision of collection of Australia's agricultural statistics so that data collection and information management systems provide information to better understand and support natural resource management practices;
- collection of data on land, property management, environmental management and demographic attributes;
- inclusion of regular data gathering of a sufficient sample size and with geographic coding to assess changes in a particular region of interest;
- expansion of data collection to include small-scale agricultural/rural landholders and other client groups such as Indigenous landholders rather than only focusing on operators of agricultural establishments; and
- inclusion of institutional indicators (e.g. expenditure relating to sustainable resource management practices) and links to systems that track changes in the biophysical environment.

Australia-wide interpretation and analysis must be treated with caution—there are as many exceptions as agreements in any proposed correlation. Local and issue-specific, community surveys are the best and most appropriate way to obtain information for detailed socioeconomic analysis.

Core attributes to be included in a comprehensive rangeland monitoring system have been specified (Table 5) and key findings from the Audit's collation of existing social and economic information are that:

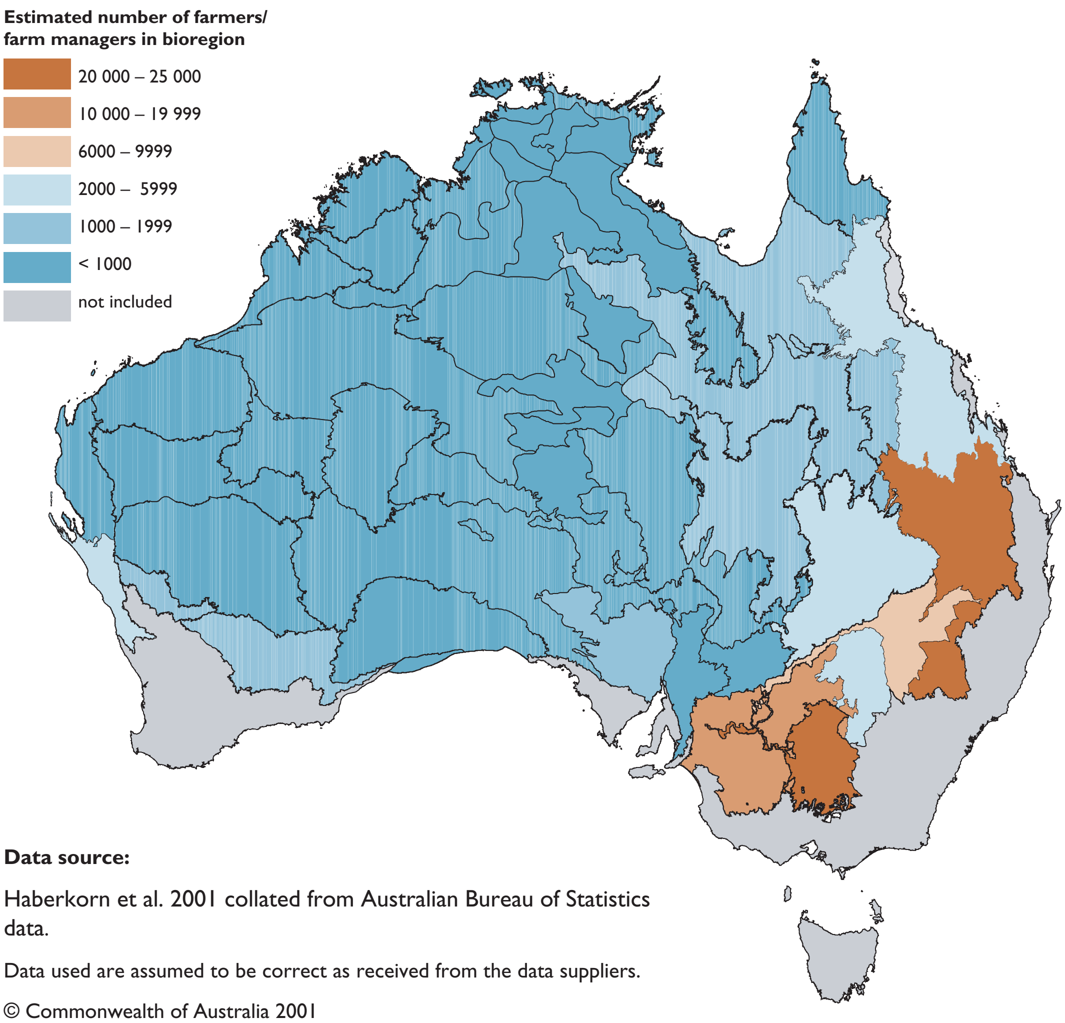
- remote parts of rangelands have younger land managers than the national average;
- remote parts of rangelands have the lowest age dependency ratios (i.e. the population has few children or older people relative to people at working age);
- young people (15–24 years) are moving out of the south of Australia's rangelands to seek education or work; and
- young people are moving into the northern and western regions to find pastoral or casual work.

People: part of the rangelands

Table 5. Information products for socioeconomic information (Haberkorn et al. 2001).

Key attributes	Description and current status	Rationale for inclusion
Product 13. Individual attributes		
Median age of farmers and farm managers	The most basic socio-demographic indicator—median age—divides a population into halves. Data are collected as part of the Australian Bureau of Statistics Housing and Population Census.	Age statistics can help explain the likely desire of property owners/managers to remain on the property, their exposure to environmental concepts, their attitude towards stewardship, and their adoption of different resource management practices.
Product 14. Business attributes		
Total farm family income	Total income refers to family share of farm income; any wages paid to the owner manager, spouse and dependant children; and all off-farm income. Data are collected as part of the Australian Bureau of Agricultural and Resource Economics Farm Survey.	Level of income can explain potential opportunities to experiment with new sustainable management practices.
Farms with property management plans	This attribute is defined as active use of property management plan in the last 12 months. Data are collected as part of the Australian Bureau of Agricultural and Resource Economics Farm Survey.	Property management plans reflect motivation to manage more sustainably, skills in management, and access to and use of different information for management decisions.
Product 15. Community attributes		
Net migration of young Australians	Net migration is defined as the difference between the number of persons moving into a particular area between the 1991 and 1996 censuses, and the number of people moving out. It is expressed as a proportion of the 1991 resident population of a given area. Data are collected as part of the Australian Bureau of Statistics Housing and Population Census.	Net migration assists in understanding population changes, particularly in those beginning their careers, and those most able to be mobile and/or completing their education.
Population structure to age dependency ratio	This measure refers to the proportion of children and elderly people that are economically dependent on the working age population. Data are collected as part of the Australian Bureau of Statistics Housing and Population Census.	Provides a useful socio-demographic snapshot of the population structure/ composition of a specific area, particularly in situations where detailed social and economic data are lacking.

Figure 51. Locations of farmers and farm managers in Australia's rangelands (1996).



Data source:

Haberkorn et al. 2001 collated from Australian Bureau of Statistics data.

Data used are assumed to be correct as received from the data suppliers.

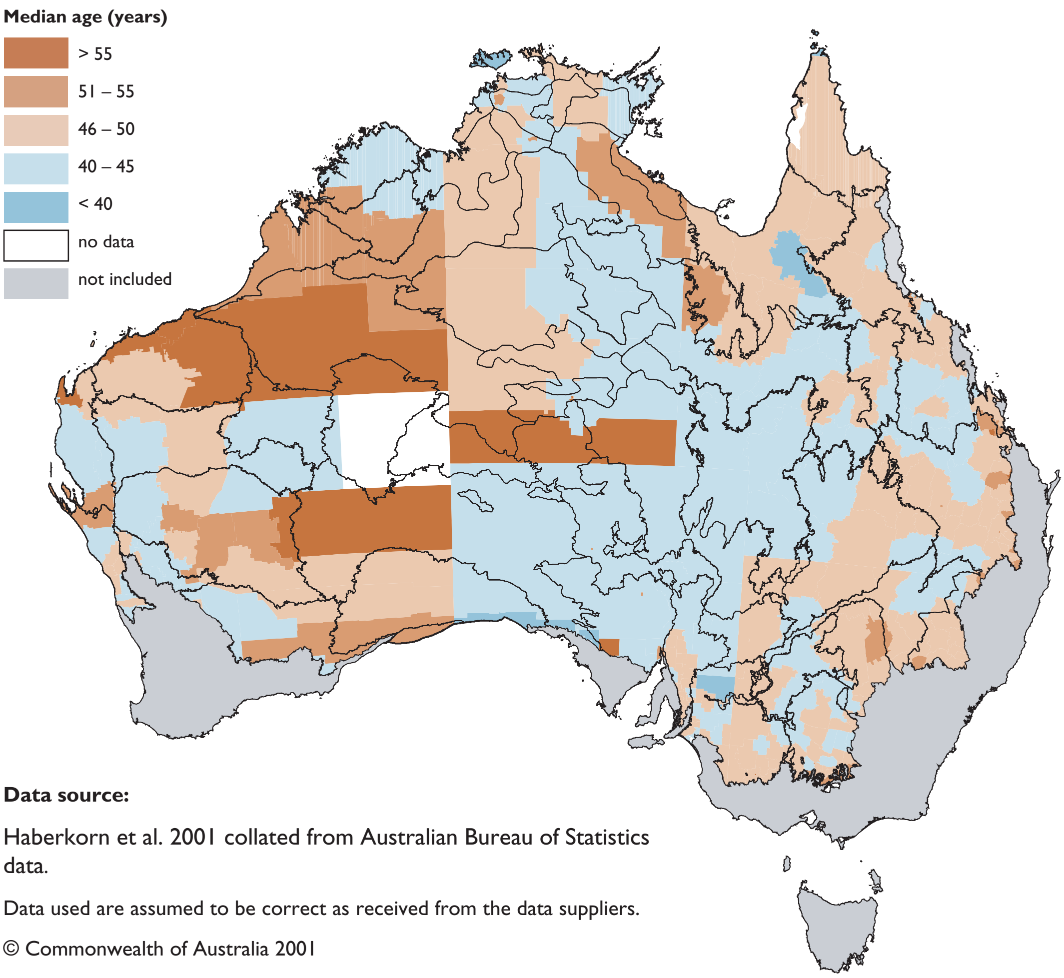
Product 13. Individual attributes

Median age of farmers and farm managers

Median age divides a population in half. These data are collected by the Australian Bureau of Statistics. In 1996, the median age of Australia's total population was 34 (i.e. half of all Australians were younger than 34 years and half were 34 years or older). The median age of Australian farmers and farm managers was 48 years. Farm operators in rangelands are younger than colleagues on the east coast of Australia (in some areas along the east coast of Australia the median age was 58 years).

Farmers and farm managers in rangelands of Western Australia and the Gulf region of the Northern Territory are older than in other areas (Figure 52). In other States, there appears to be an inverse relationship between remoteness and age, with the more remote rangelands having younger farmers and farm managers. The youngest median age of farmers and farm managers (40–45 years) occurs in South Australia.

Figure 52. Median age of farmers and farm managers across Australia's rangelands (1996).



Data source:

Haberkorn et al. 2001 collated from Australian Bureau of Statistics data.

Data used are assumed to be correct as received from the data suppliers.

Product 14. Business attributes

Many business attributes currently collected are not suitable for a rangeland monitoring system because the Australian Bureau of Agriculture and Resources Economics farm survey data on which they are based have limitations when applied to bioregions across the rangelands.

The sample of 1430 broadacre farms representing 71 600 farming operations across Australia is not sufficiently large to permit an analysis at the bioregion level. While most maps based on Australian Bureau of Agricultural and Resource Economics farm survey data show regional variations, in most cases the standard errors are so high that regional differences are more a reflection of sample selection than true regional patterns.

The Australian Bureau of Agricultural and Resource Economics farm survey targets agricultural operations with an estimated value of $22 500 or more. Twenty-seven per cent of broadacre operations and 54% of beef cattle operations fall below this cut-off point at last time of survey (1996).

Two of the Australian Bureau of Statistics sourced attributes provide some insight into rangeland business activities—total farm family income and farms with property management plans.

Total farm family income

Total farm family income includes:

- any wages (that are included as farm costs for taxation assessment) paid to the owners/ managers, spouse and dependant children; and
- all off-farm income of owners/managers and spouse (Figure 53).

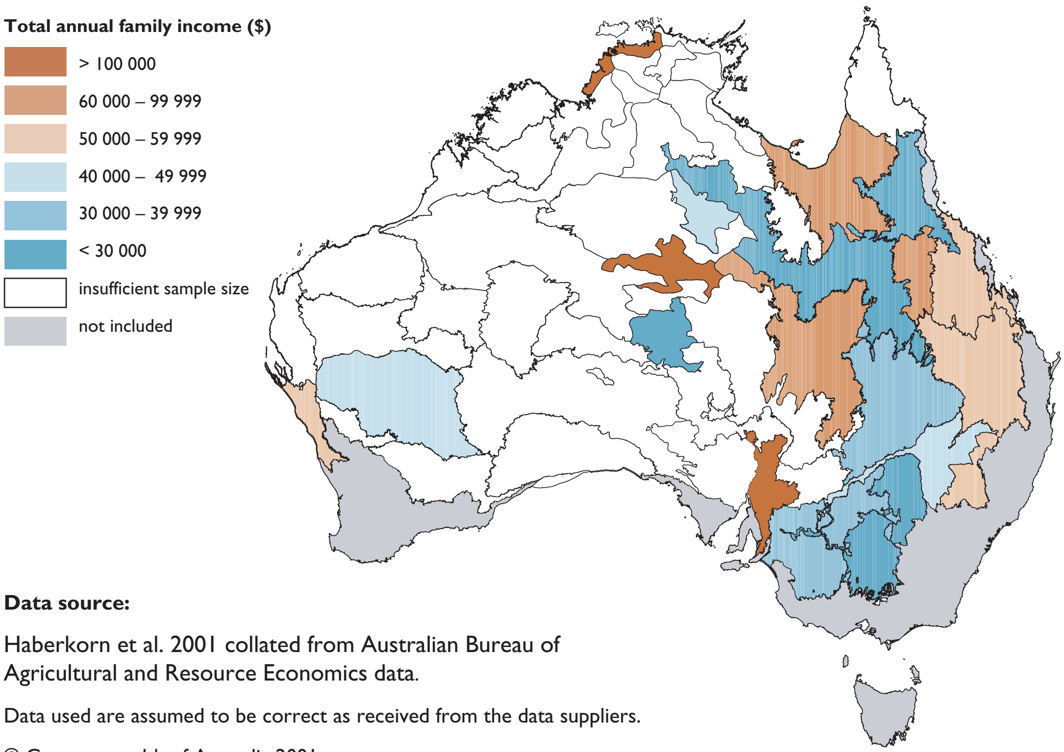
The family share of farm income is the share of net farm business income of owner manager, spouse and dependant children.

Net farm business income is farm cash income plus change in trading stocks, less depreciation and wages (that are included as farm costs for taxation assessment) paid to the owners/ managers' family or other family members.

Farm family income is thought to be directly related to adoption of sustainable resource management practices because of the financial constraints or opportunities it may provide (Gordon et al. 2001). A high level of income potentially provides greater opportunities to experiment with new and untried management practices, while lower incomes exert greater pressure on farm families, making experimentations and investment in improved practices, techniques and equipment difficult or impossible.

Farm family income is also considered to be indirectly related to adoption of sustainable management practices through farm profitability, the desire to remain on the property and a sense of security.

Figure 53. Total farm family income across Australia's rangelands (1996/1997 to 1998/1999) (3 year average).



Data source:

Haberkorn et al. 2001 collated from Australian Bureau of Agricultural and Resource Economics data.

Data used are assumed to be correct as received from the data suppliers.

Farms with property management plans

Farms with property management plans are those that have actively used a property management plan in the last 12 months, whether or not the owner/manager has participated in property management plan workshops and activities (e.g. FarmBis) in the last three years (Figure 54).

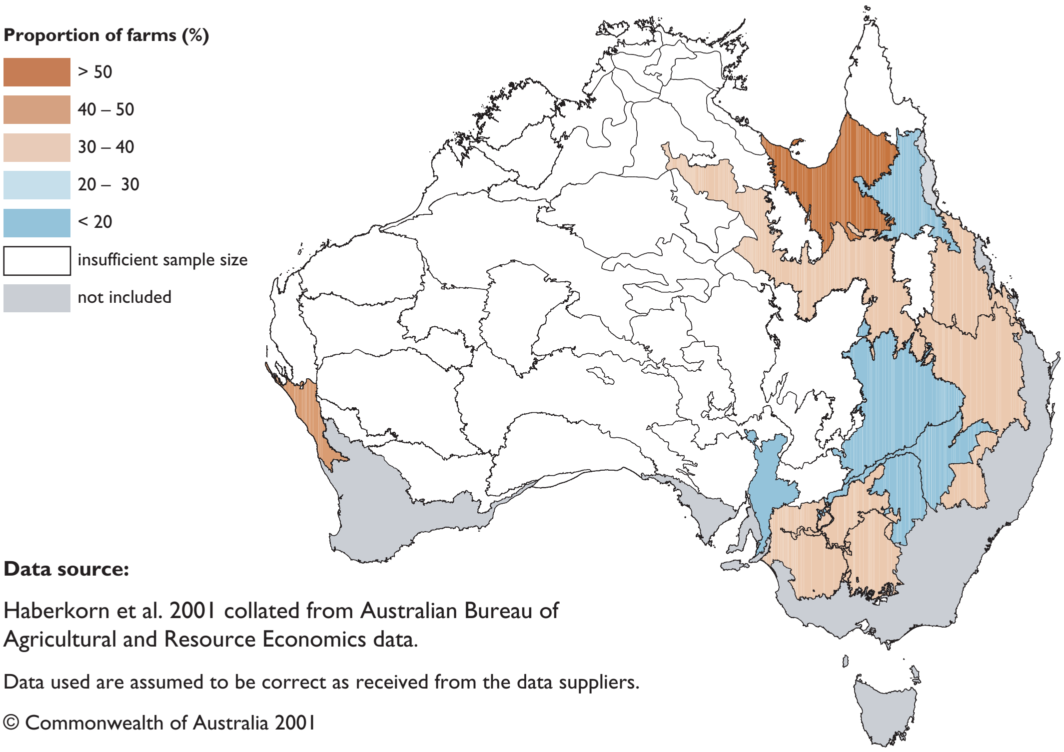
The establishment of a property management plan is an indicator of capacity to adopt sustainable resource management practices. It reflects skills in management, information available for management decisions and willingness to use such information (Gordon et al. 2001). Farmers and managers may also have been required by funding institutions to develop a property management plan as a condition of credit; they have also been encouraged to develop plans as participants in government programs. In this context, the presence of such a plan is indicative of general pressure to adopt sustainable management practices (Gordon et al. 2001).

Managers with a property management plan were more likely to:

- adopt measures to monitor pasture;
- match stock type to pasture;
- lower stocking rates (and consequently increase potential production);
- construct fences to assist conservation; and
- have changed their management toward more conservation-oriented practices.

This strong relationship with adoption suggests that having a property management plan also reflects motivation to manage more sustainably.

Figure 54. Farms across Australia's rangelands with property management plans (1998–1999).



Data source:

Haberkorn et al. 2001 collated from Australian Bureau of Agricultural and Resource Economics data.

Data used are assumed to be correct as received from the data suppliers.

Product 15. Community attributes

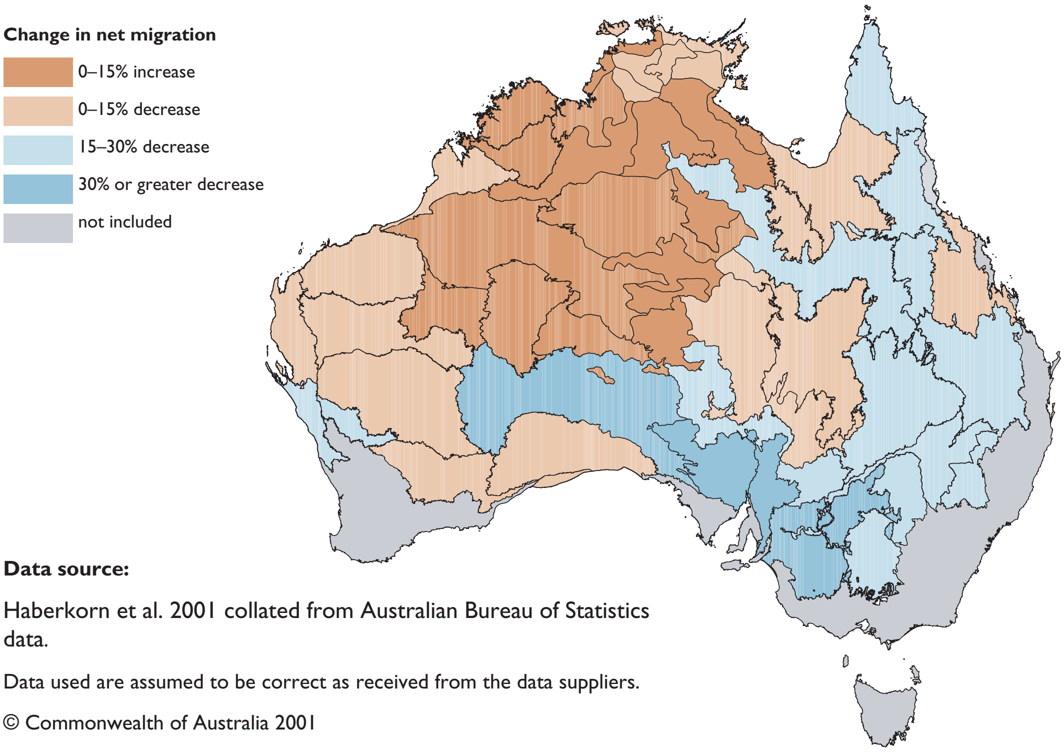
Net migration of young Australians

Net migration of young Australians is the difference between the number of young people (15–24 years) moving into a particular area and the number of young people moving out (based on the 1991 and 1996 censuses). It is expressed as a proportion of the 1991 resident population and assists in understanding population changes. Net migration applies particularly to people at the beginning of their careers (most able to be mobile) and/or completing their education.

Young Australians display a high level of mobility with 20% having changed their place of residence at least once between 1991 and 1996. Rural and regional Australia has long experienced a decline in youth populations as young people seek employment and other opportunities offered by major cities and regional centres. Population mobility of young Australians is prominent across rangelands. Twice as many bioregions show net migration out as those showing net migration into rangelands. There is a significant net migration into the northern and western parts of the rangelands (Figure 55).

- Remote rangeland areas offer young people employment and travel opportunities. Employment is often seasonal in the pastoral, mining and tourism industries.
- Rangelands have a high proportion of Indigenous Australians who show a high degree of mobility.

Figure 55. Net migration of 15–24 year olds across Australia's rangelands (1996).



Data source:

Haberkorn et al. 2001 collated from Australian Bureau of Statistics data.

Data used are assumed to be correct as received from the data suppliers.

Population structure to age dependency ratio

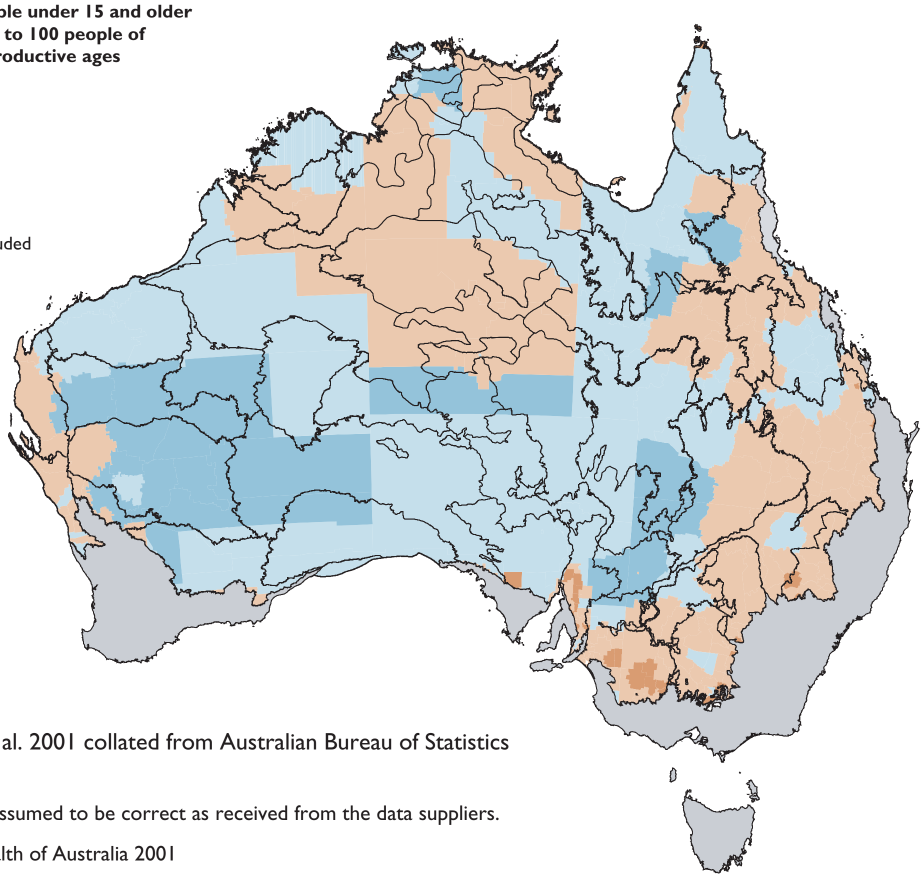
The ratio of people in the dependent ages (under 15 and over 65 years) to those in the economically productive ages (15 to 65) is a measure of population structure. A comparison between bioregions and statistical local areas was not attempted for this attribute because it cannot be assumed that all three population subgroups (children, labour force, elderly) are distributed equally across statistical local areas.

Many remote areas of rangelands show low dependency ratios—well below the average for non-metropolitan Australia—indicating a population with few children and older people relative to people of working age (Figure 56).

Figure 56. Population structure to age dependency ratio (1996).

Number of people under 15 and older than 65 relative to 100 people of economically productive ages

> 66
50 – 66
34 – 50
< 34
not included



Data source:

Haberkorn et al. 2001 collated from Australian Bureau of Statistics data.

Data used are assumed to be correct as received from the data suppliers.

Institutional responses

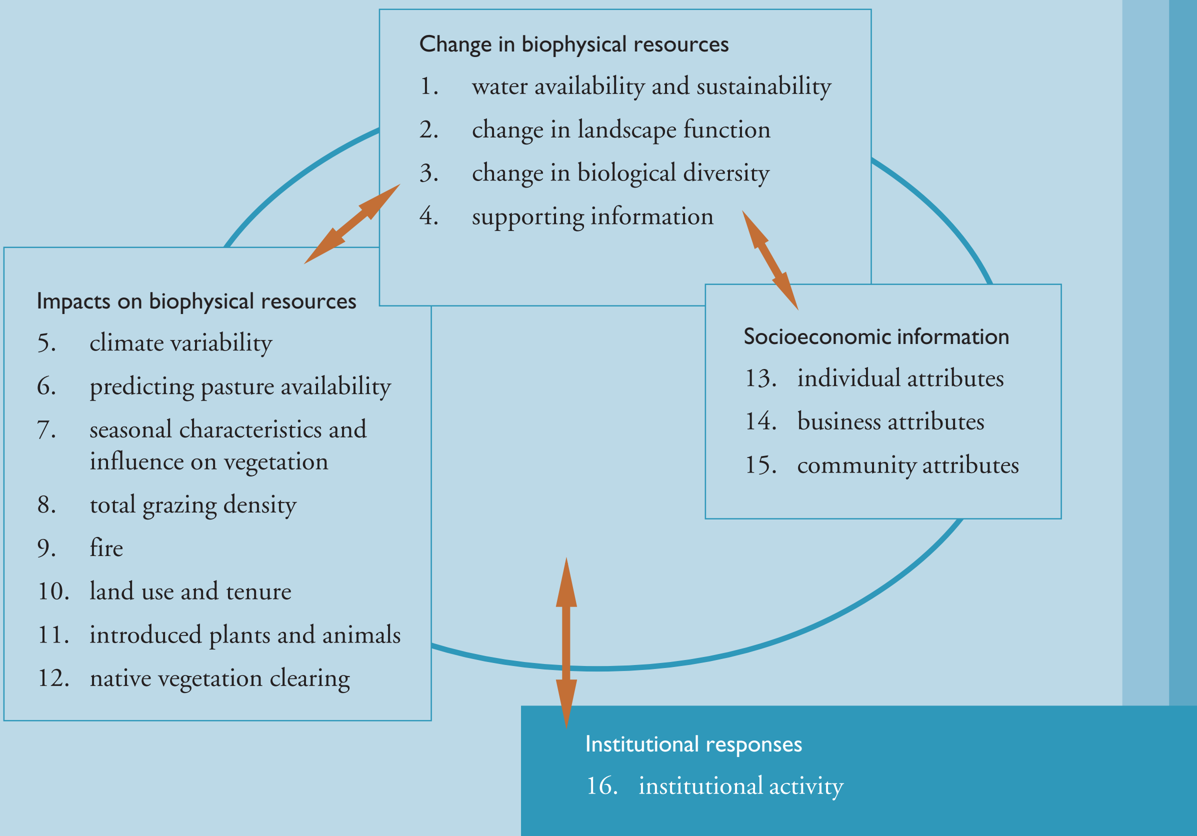
Much of Australia's rangelands are under either public or corporate ownership and administration. Institutional policies have a wide and varied impact on rangeland management.

Institutional responses to problems arising in rangelands include:

- change in lease conditions;
- rural assistance schemes;
- drought support;
- nature conservation through declaration of parks, reserves and off park conservation incentives;
- weed and feral animal control programs;
- Indigenous support activities and Native Title;
- training and skills development (e.g. property management planning); and
- stewardship support including technical advice on fire, stock and vegetation management.

The information product under this component is summarised in Table 6.

There is value in ongoing and improved collection of consistent information about institutional operations.



The western black-naped snake (*Neelaps bimaculatus*): in decline in South Australia.

Table 6. Information product for institutional responses.

Key attributes	Description and current status	Rationale for inclusion
Product 16. Institutional activity		
Financial support by government institutions for sustainable management of rangelands	Information on annual expenditure by local, State/Northern Territory and Commonwealth institutions on natural resource management, conservation, extension, subsidies, works and program administration.	Provides context for program evaluation in terms of rangeland management outcomes in productivity, biodiversity and well being of rural communities.
Progress towards a Comprehensive, Adequate and Representative reserve system	Jurisdictions collate reports on protected areas established as part of the National Reserve System Program.	The addition of parks and reserves within Australian rangelands to the National Reserve System is one direct measure of progress towards conservation of biodiversity. Progress towards a network of off-reserve conservation areas would constitute another measure of progress towards conservation of biodiversity.

Product 16. Institutional activity

Financial support

Institutional indicators include:

- total expenditure on resource management (funding transfers between levels of government must only be counted once); and
- share of total expenditure allocated for:
  - surveys, data collection and monitoring (activities to be distinguished by objective);
  - stewardship, nature conservation, and on-ground remedial works (detailed by expenditure on parks and equivalent reserves, Crown lands, off-reserve, and defence and Indigenous lands);
  - skills development, training and extension work (distinguished by subject matter);
  - subsidies and other transfers to private managers for resource management (distinguishing between programs targeting various groups such as pastoralists, Indigenous or other managers); and
  - other purposes (e.g. administration of programs).

Each local government and State/Territory and Commonwealth department dealing with resource management in rangelands could provide annual expenditure data for each region. Data would include documentation on program aims and outputs achieved, and allow for systematic assessments and comparative analysis to determine return on investment and required changes in emphasis.

Reserve systems

Evaluation of return on investment will be based on specified program policies and outputs. One Commonwealth policy already in place is the development of a Comprehensive, Adequate and Representative reserve system in which States collate reports on protected areas established as part of the National Reserve System program. The addition of parks and reserves within Australian rangelands to the National Reserve System is one direct measure of progress towards conservation of biodiversity (Figure 57, Table 7).

Comprehensive, Adequate and Representative reserve system

Comprehensive

The degree to which the national reserve system encompasses the full range of biological/biophysical diversity and other values as identified by an agreed, nationally recognised system of scientific classifications.

Adequate

The capability of the National Reserve System to maintain biological diversity, ecological patterns and processes, and other values, under both natural and human-influenced disturbance across time and space.

Representative

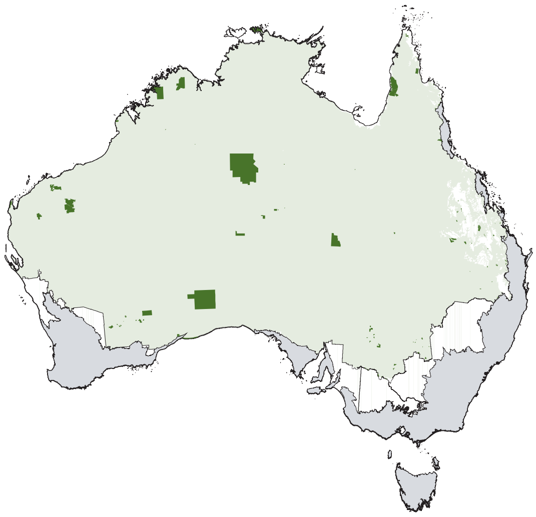
How much areas selected for inclusion in the National Reserve System sample known biological/biophysical diversity and other values.


Macquarie Marshes are an area of high conservation value

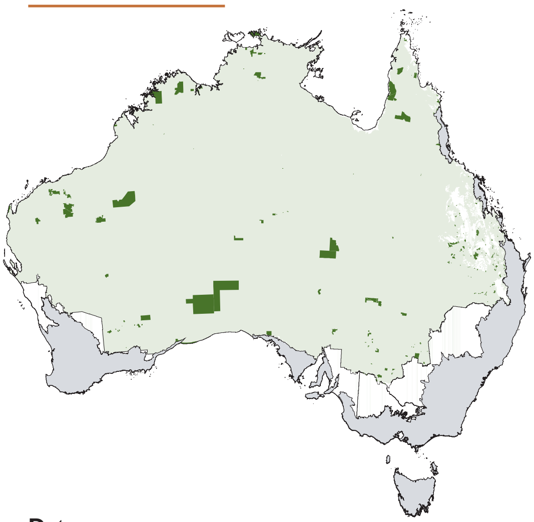
Figure 57. Change in land set aside for nature conservation purposes (1950s, 1960s, 1970s, 1980s, 1999).

1950s

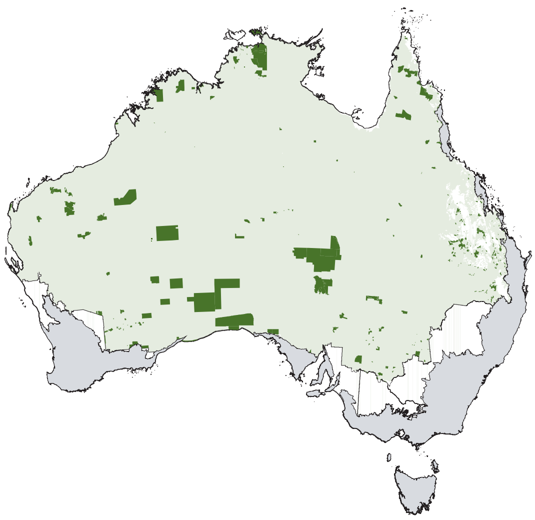
1960s



1970s



1980s

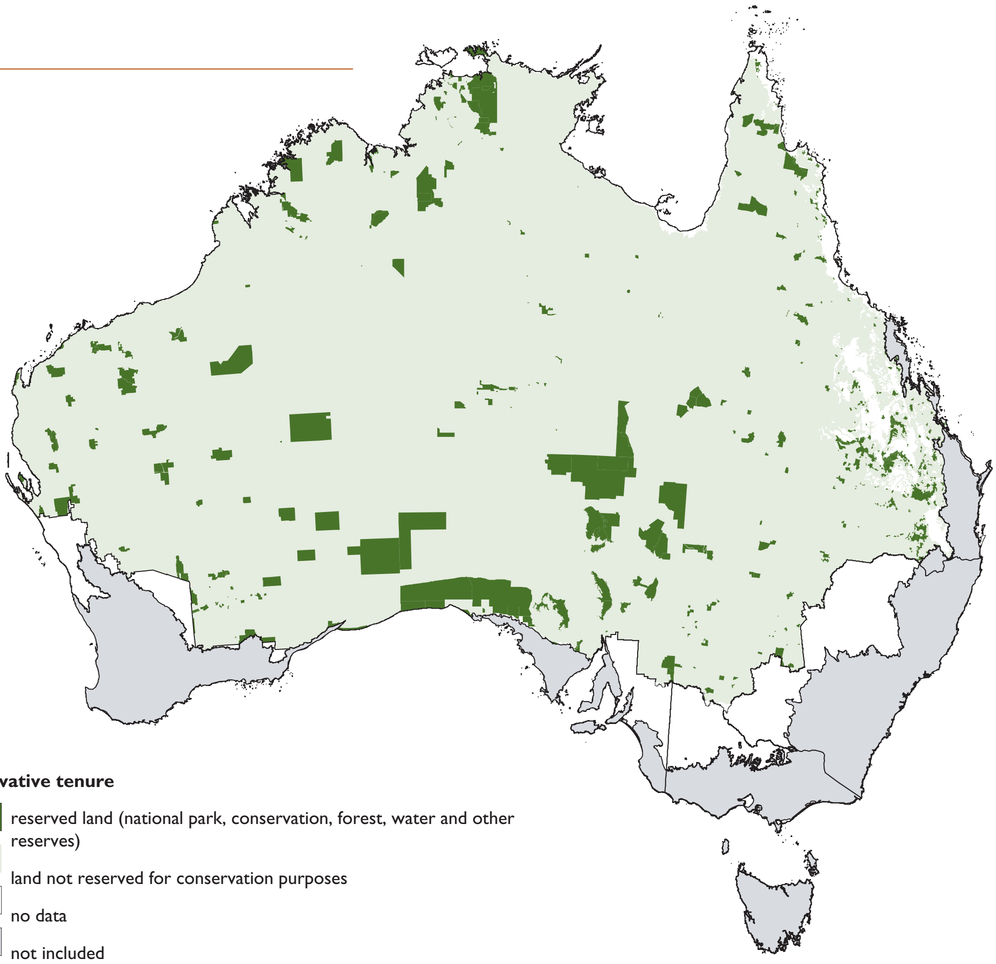


Data source:

Hall & Gutteridge 2001.

Data used are assumed to be correct as received from the data suppliers.

1999



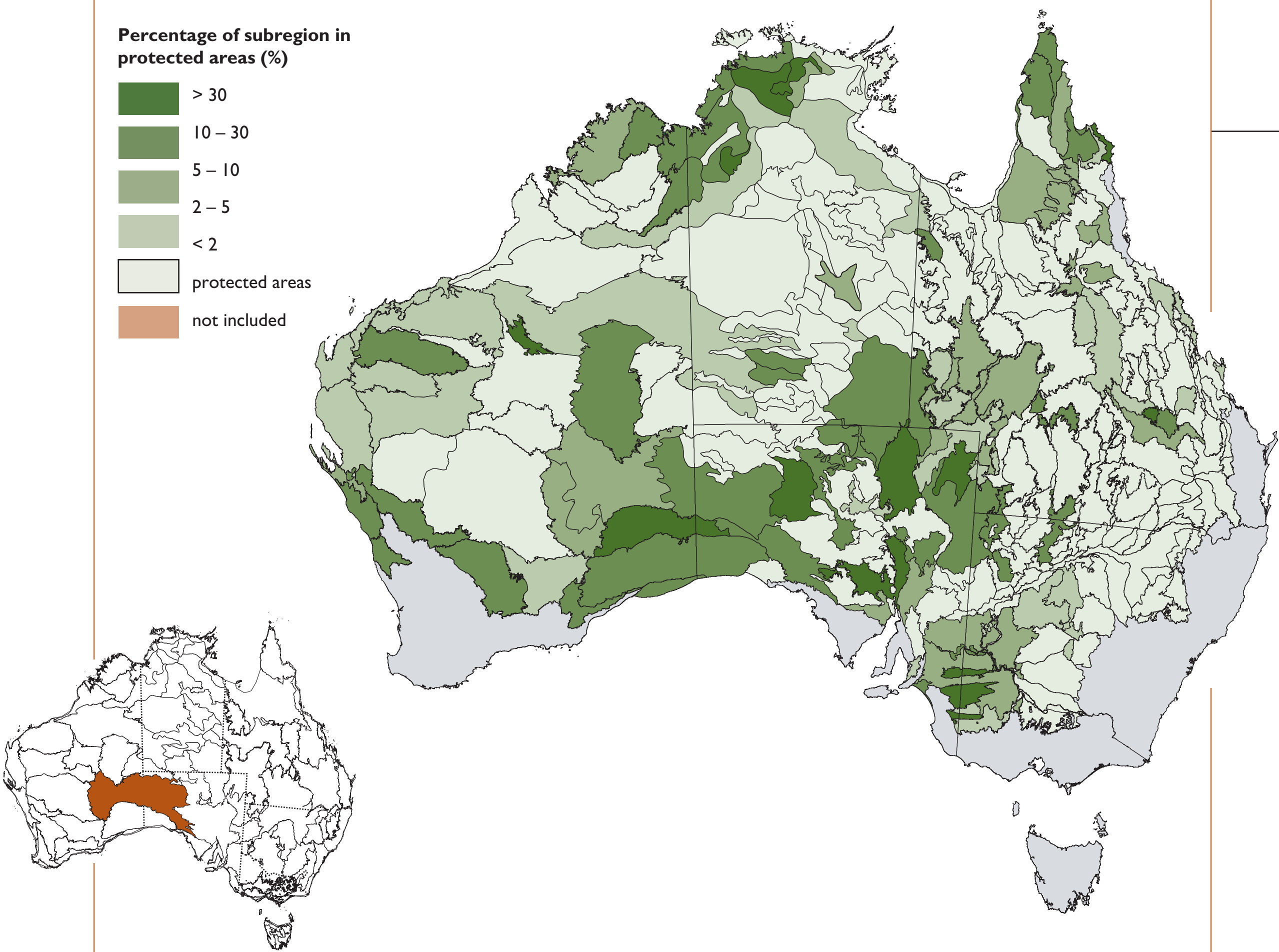
Conservative tenure

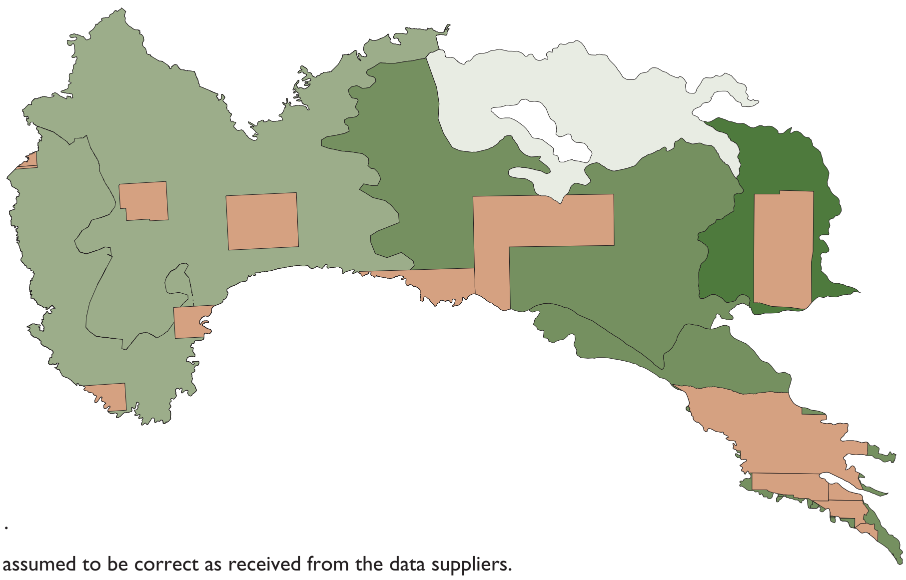
- reserved land (national park, conservation, forest, water and other reserves)
- land not reserved for conservation purposes
- no data
- not included

Table 7. Area of land under each conservation land tenure type (km^2).

Class of tenure	1955	1965	1975	1985	1995	1999
National parks (proclaimed and gazetted)	1 399	10 529	27 909	80 174	143 413	156 982
Conservation lands (not gazetted)	22 341	91 995	100 138	184 136	225 268	244 905
Forested areas (State forest, forest reserve	4 075	5 409	10 511	19 349	32 787	32 787
Other reserves (hunting, historical, heritage)	759	786	835	877	2 454	2 473

Figure 58. Percentage of subregions in protected areas in Australia's rangelands and detail of the Great Victoria Desert bioregion and its protected areas.

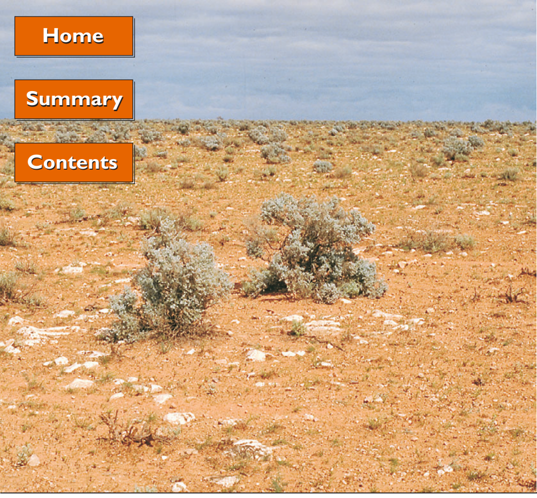




Source:

Morgan 2001.

Data used are assumed to be correct as received from the data suppliers.



Drought: part of Australia's climate variability

AUSTRALIAN COLLABORATIVE RANGELAND INFORMATION SYSTEM

A comprehensive Australia-wide rangeland monitoring system

The preceding chapter has detailed proposed components of a monitoring program, provided compilations of these products, and demonstrated the application of the various products to support improved and protective management of Australia's rangelands. The complexity and extent of the data required to adequately track changes in the biophysical, economic and social aspects requires a coordinating mechanism.

This chapter details the processes and activities to establish such a mechanism: Australian Collaborative Rangeland Information System. Funding such a system will have multiple benefits. Principal among these benefits is more effective and efficient return on current management investment—essential if we are to ensure protective management and development in the widest community interest. Wise investment will ensure we avoid extremely costly remedial activities as is now necessary in temperate Australian agricultural landscapes as we struggle to minimise the impact of dryland salinity.

Australia's rangelands are a national resource with many issues extending across jurisdictional boundaries.

Integrated data management

The Australian Collaborative Rangeland Information System will undertake the integrated data management and reporting necessary to achieve the efficiencies and cost-savings of a coordinated and collaborative Australia-wide information system.

Coordination

The Australian Collaborative Rangeland Information System will be a coordinating mechanism that collaboratively brings together rangeland information from State and Northern Territory agencies and other sources.

Readily available information

The Australian Collaborative Rangeland Information System will make information readily available, providing updates as new information becomes available.

Why monitor?

The Australian Collaborative Rangeland Information System proposal has been developed in recognition of unique rangeland management challenges and recognises:

- the institutional need for a higher level of cooperation across State and Northern Territory boundaries;
- the need for a more inclusive and Australia-wide approach to rangeland management;
- the need to maximise return on the limited resources available for rangeland assessment and management;
- the failure of existing State and Northern Territory monitoring systems to provide integrated information; and
- the need to foster a protective management ethos for Australia's rangelands, securing their sustainable future through strategic investment well before degradation becomes a major issue and an unaffordable cost imposition.

The system will build on assessment capabilities established as a result of Audit activities and advocate further investment in rangelands assessment and management to deliver information products (e.g. biodiversity assessment).

Linked activities will produce regular products fundamental to the system, and other specifically commissioned products as demanded by client need.

BUILDING INTEGRATED ASSESSMENT AND REPORTING

Landscape health as an example

The Audit has undertaken a Landscape Health Assessment project (Morgan 2001) that has attempted to make an integrated Australia-wide nature conservation based assessment of Australia's landscapes. It does not replace a full biodiversity assessment of threats to, or status of, biodiversity in terms of species richness nor is it a fully integrated assessment in terms of the components of the Australian Collaborative Rangeland Information System (e.g. landscape function, seasonal events, and socioeconomic factors). It does provide an assessment of condition of the rangelands from a biodiversity perspective.

In compiling this Australia-wide assessment, rangeland areas containing intensive agriculture have been assessed differently to the rest of the rangelands to reflect differences in climate and land use potential (yellow border line). Attributes assessed in the rangelands are:

- percentage of subregion with least impact from total grazing pressures;
- percentage of native vegetation in land tenures associated with conservative land use practices;
- density of weeds;
- density of feral animals; and
- number of threatened species.

In regions containing intensive agriculture the attributes are:

- current extent of native vegetation;
- continuity of native vegetation;
- percentage of native vegetation in land tenures associated with conservative land use practices;
- percentage of ecosystems threatened;
- percentage of native vegetation with high salinity; and
- weeds, feral and threatened species.

In rangeland subregions, natural vegetation is under increasing stress from a variety of threatening processes. Twenty-five percent of subregions are relatively heavily grazed and have high densities of weeds and/or feral animals. Although moderate areas of native vegetation remain, continuity in native vegetation is typically low, and relatively little of the native vegetation is conservatively managed. In these subregions, grazing pressures are moderate and only limited areas are in conservative tenures.

There are six classes of landscape condition. To allow a greater resolution of analysis, subregions, based on major geomorphic patterns or aggregations of ecosystems, were used.

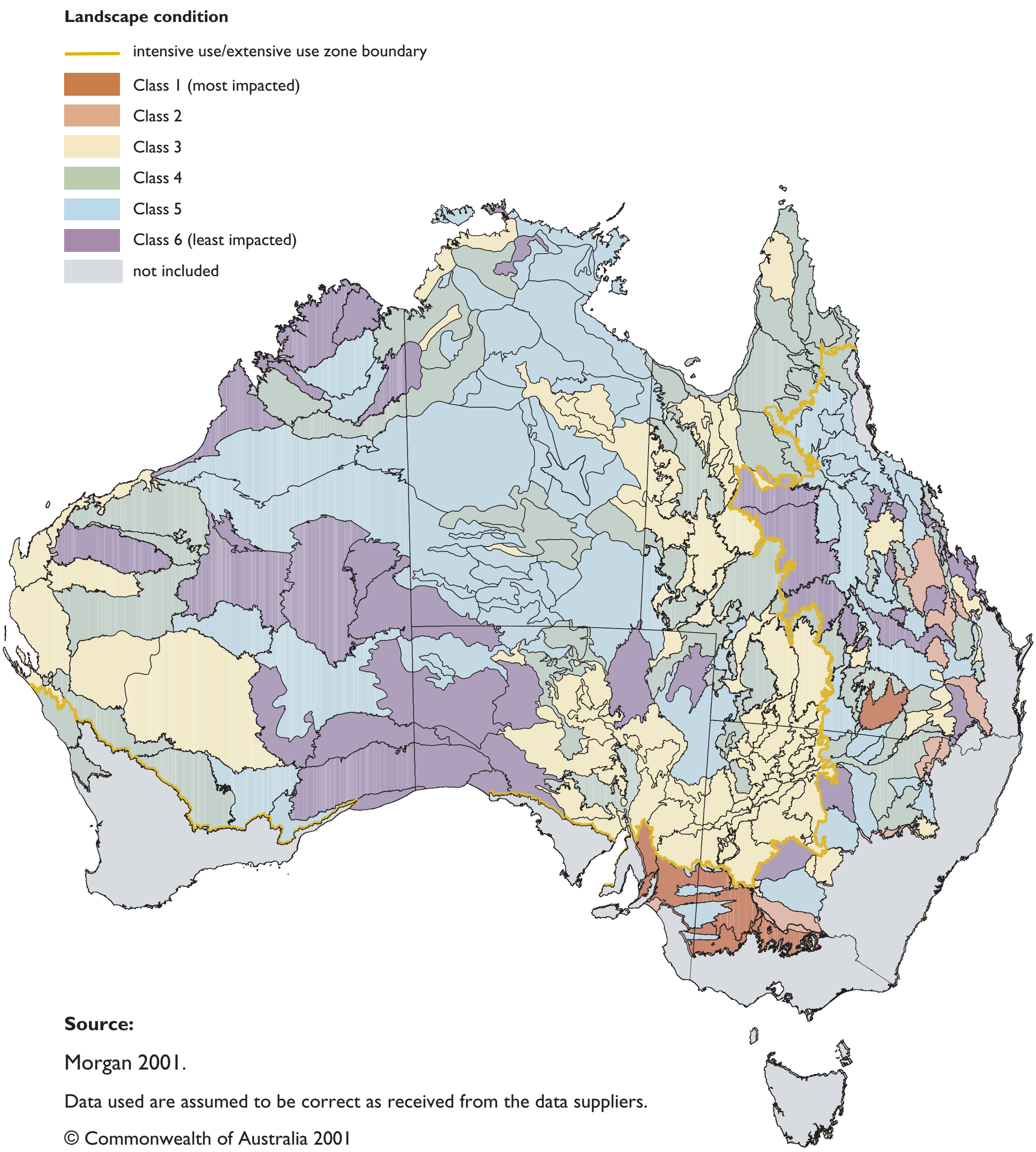
Nature conservation agencies have agreed to 350 subregions within the 80 designated bioregions for Australia. Class 1 is the most impacted where nature conservation values are under the highest pressure from land use activities. Class 6 is the least impacted and nature conservation values are largely intact.

In rangeland subregions, nature conservation values are under pressure from a number of threatening process including grazing, clearing, weeds, feral animals and changes to fire regimes. About 10% of these subregions are in Class 6 (e.g. the Nullarbor and the Little Sandy Desert). The remainder of the rangelands subregions are distributed evenly across Classes 3, 4 and 5, which have increased intensity of impact from land use activities on nature conservation values. Rangeland subregions within Class 3 include Carnarvon and Murchison.

Subregions in Classes 1 and 2 include parts of the Murray–Darling Basin, Riverina and the Mulga Lands. These bioregions contain mixed land use with both extensive uses such as grazing and nature conservation and more intensive uses such as agriculture.

Key activities to improve or at least retain nature conservation values in rangeland subregions include:

- ceasing clearing;
- improving grazing land and pasture management;
- changing infrastructure such as fencing and watering points; and
- undertaking control programs for feral animals and weeds.



Source:

Morgan 2001.

Data used are assumed to be correct as received from the data suppliers.

Boab trees: important in Indigenous culture

Support

It is anticipated that the small unit supporting the Australian Collaborative Rangeland Information System will be co-located with a rangeland-oriented agency. Duties will include:

- coordinating reporting; and
- fostering and facilitating efficient and effective monitoring and assessment across Australia's rangelands.

Fundamental activities

The Australian Collaborative Rangeland Information System will make best use of, and value-add to State, Northern Territory and Commonwealth rangeland monitoring activities. The system will be able to integrate additional information where this is collected. Fundamental activities will include:

1. Collation, interpretation and presentation of information products at a range of scales based on data collected from current activities. Examples include:
    - surface and groundwater data to report on water resources sustainability;
    - currently collected State and Northern Territory pastoral estate information;
    - updating of the photographic sequences record;
    - seasonal climate outlooks;
    - information on seasonal characteristics;
    - land tenure and use; and
    - clearing extent.
2. Updates of data to be compiled and distributed through the Atlas. The Atlas will also present an analysis of change over time. This information is particularly important given the long-term nature of climate and natural resource variability in Australia's rangelands.
3. Integrated analysis of information that provides five-yearly reports of Australia-wide rangeland condition assessments. Timing will coincide with other reporting agendas (e.g. Australian State of Environment reporting).

These reports will draw on information products coordinated and produced over the intervening period, standard reports produced by individual jurisdictions and working groups, and specifically commissioned assessments. Reports will make interpretations in the context of known climatic and socioeconomic factors, and make judgements about the direction and desirability of any observed change. The reports will also highlight the need for any additional information and provide justification for the brokering of new partnerships or projects to address those needs.

Commissioned activities

In addition to Australia-wide aggregation of data already being collected by the States and the Northern Territory (mainly associated with the use of rangelands for pastoral activities), supplementary monitoring needs to be undertaken. Key activities include:

Biodiversity monitoring

- Most rangeland monitoring systems have been established on pastoral land and focus on pasture response to grazing of domestic stock. Rangeland habitats support high levels of species diversity. Information on the status and trends of biodiversity is critical to providing a sound basis for effective management. The Audit has developed a framework for monitoring biodiversity that is yet to be applied and funded.

Expanded application of remote sensing techniques

- Existing rangeland monitoring systems have been based on ground-based data collection methods. Remotely sensed information allows assessment of landscape change, condition and trend over large areas. Audit-funded techniques for appraisal at scales from local to regional have been demonstrated and are now available for rangeland-wide implementation.

Purpose-built socioeconomic surveys

- Although people and communities are a key part of the rangeland environment, limited socioeconomic data are available. Socioeconomic profiles and trends are key inputs to decision making in rangeland management. Rangeland monitoring systems need to be enhanced with issue- and locality-specific social and economic information to support analysis of consequences of different management strategies.

Such information is not provided by the broadscale Australian Bureau of Statistics or Australian Bureau for Agricultural and Resource Economics surveys. It remains for such surveys to be funded and results to be collated and made available. The Audit has identified additional types of information required.

Indigenous information needs

- While some specific Indigenous people's land management information needs have been documented, limited information or knowledge exists on how to serve these needs through land management agencies and partnerships with Indigenous people. Work will need to build on an existing project that is exploring information and skills requirements for Indigenous land use and management, and to develop a shared understanding of types of Indigenous land ownership and the implications for land management.

The Australian Collaborative Rangeland Information System will also provide a forum for continuous appraisal of client decision support needs and will seek to identify areas for applied research where existing approaches prove to be inadequate, or where alternatives may be more cost-effective. Further components can be added to the system to meet emerging client needs and address gaps in information over time.

Strengths

The real strength of the Australian Collaborative Rangeland Information System will be its ability to:

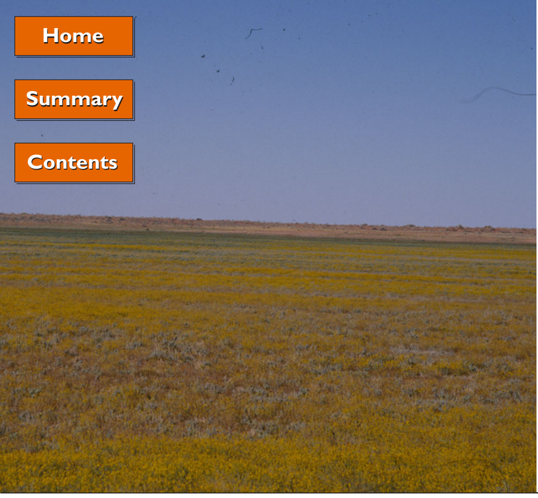
- coordinate timely, multidisciplinary assessments across Australia's rangelands;
- build a multidisciplinary approach to rangeland management, recognising rangeland values, limited resources for investment and community expectations;
- build on the culture of collaboration and commitment that has developed as a result of the Audit;
- broker access to data and information that are either not widely published and/or are difficult to access;
- interpret data and provide pragmatic guidance for management activities at scales from lease or park to bioregion to Australia wide;
- generate cost savings through the adoption and sharing of new technologies and tools; and
- be able to deal with different data types, scales and levels of interpretation.

Potential shortcomings

The Australian Collaborative Rangeland Information System will not be able to meet every need of all clients in its early stages (e.g. biodiversity monitoring data are not yet available at the scale required to make informed judgements on management imperatives for threatened species). Likewise there is much work to be done to meet Indigenous needs. However, the system will be iterative and based on a philosophy of continuous improvement. Eventually, reporting and assessment will provide a more complete picture of status, change and trends in condition of Australia's rangelands.

Key applications of the Australian Collaborative Rangeland Information System

- To gain an improved understanding of the response of landscapes to management strategies at a regional and local scale.
- To assist rangeland managers in the development and evaluation of management systems and strategies.
- To assess returns on government investment in rangeland management programs.
- To predict the impact of new policy initiatives.
- To support development of priorities for government, community and industry investment (e.g. drought relief, feral animal and weed control and other community support activities).



Floodplain herbfield: channel country south-west Queensland

Partnership arrangements

Implementation of the Australian Collaborative Rangeland Information System will require formalisation of institutional arrangements through partnership agreements:

- between each of the States and the Northern Territory and the Commonwealth; and
- within each jurisdiction, to build a coordinated cross-agency approach to information gathering and reporting, and rangeland management.

Memoranda of understanding are proposed between governments at a national level, and within States and the Northern Territory between participating agencies and their key client groups.

An Australia-wide memorandum of understanding between jurisdictions would note the importance of, and provide processes for, involving all key clients to ensure their needs are met. It would identify a coordinating agency for this initiative and include agreement on roles and responsibilities for:

- reporting and assessment;
- providing information products;
- data exchange and licensing;
- information standards;
- institutional arrangements for coordination and continued development;
- funding arrangements;
- accountability, financial reporting and review mechanisms; and
- dispute resolution.

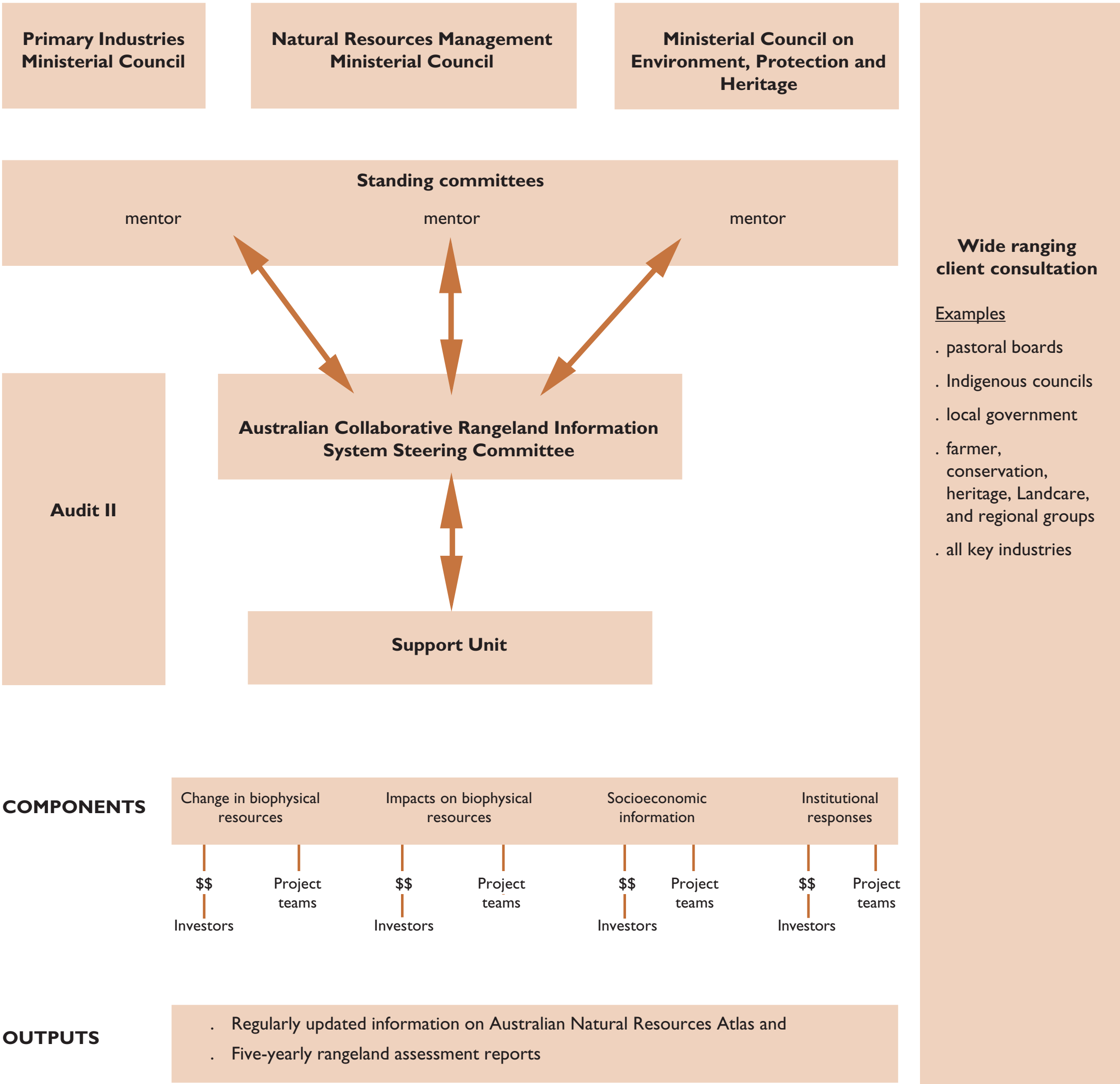
A memorandum of understanding across agencies within a State or the Northern Territory would provide a framework for extensive and ongoing client interaction, preferably through existing administrative structures. It would include agreement on roles and responsibilities for activities at the operational level.

As information products demonstrate their value and relevance to clients in the rangelands, additional partnerships may be formalised to provide these additional information products and foster more widespread involvement in reporting and assessment.

Structural arrangements

It is proposed that a steering committee should coordinate the Australian Collaborative Rangeland Information System. This committee would oversee Australian Collaborative Rangeland Information System activities and could consist of senior representatives from States, the Northern Territory and Commonwealth, with an independent chairperson. It could report to appropriate Commonwealth, State and Northern Territory ministers, through the Natural Resource Management Ministerial Council (Figure 59).

Figure 59. Proposed structural arrangements for the Australian Collaborative Rangeland Information System.



Committee interaction and consultation with rangeland clients would ensure that information products are relevant and demand-driven. Consultation would take place through formal consultative forums that could include peak industry groups, and informal networks.

Technical support to the committee would be through specific working groups.

The committee would:

- link assessment findings to rangeland management programs so that return on investment is in excess of implementation costs;
- foster flexible, progressive and collaborative arrangements (across agencies, institutions and clients) that lead to improved monitoring techniques, information products, assessment activities and reporting;
- advocate and establish data and technical standards, and ensure technical credibility of products and distributed information (quality assurance);
- oversee the preparation of regular five-yearly, Australia-wide reports on sustainable use of rangelands, integrating and incorporating the findings of regional assessments and reports;
- prepare five-yearly Australian Collaborative Rangeland Information System operational plans for approval by the Natural Resources Ministerial Council or its delegate;
- regularly review the ability of information products to meet client needs and seek continuous improvement through adaptation and research;
- explore opportunities to foster research, including developing strategic alliances with research institutions, corporations and other related organisations;
- continually update the *Operational Manual* (Holm 2000) specifies the initial standards for data collection, analysis activities, information provision and reporting, and provides a basis for including methods and data assessment for additional information products) developed as a companion to this report; and
- overview the management of rangeland-specific databases within the Australian Natural Resources Data Library and their presentation on the Australian Natural Resources Atlas.

Accountability

The Steering Committee would be accountable to the Natural Resources Management Ministerial Council; individual members would be accountable to their constituents and to their ministers through their departmental heads. Financial accountability for steering committee activities would be achieved through standard auditing procedures.

Program review

Program review would occur at mid–term intervals, between each five-year cycle of assessment and reporting. These evaluations would assess effectiveness, efficiency and outcomes of investment in the Australian Collaborative Rangeland Information System; and recommend areas for improvement.

This review would also propose the operational plan for the following five-year period. The plan would take into account:

- evaluation;
- progress in implementation;
- expenditure and outputs of the plan for the previous five years; and
- return on investment.

Termite mounds

Return on investment is defined through improved efficiencies and effectiveness in implementation of Commonwealth, State and Northern Territory management programs in the rangelands. Regular evaluation, reporting and planning of expenditure would ensure transparency and probity, and encourage public confidence in the monitoring system.

Funding

Existing State and Northern Territory investment in rangeland monitoring is about $24 m per year (Table 8). This includes monitoring assessment, inventory and survey activities for rangelands:

- water availability and sustainability;
- monitoring and assessment of grazing lands;
- biodiversity surveying and monitoring;
- resource inventory, range condition surveys and pastoral lease inspections;
- pasture modelling and land condition alerts using *Aussie GRASS*;
- satellite data for greenness estimates and fire mapping;
- geographic information system and other data management (e.g. natural resource management mapping, lease infrastructure, livestock management);
- maintenance of herbaria that contribute to vegetation monitoring and biodiversity survey;
- monitoring and assessment of weed, feral animal and native herbivore (i.e. kangaroo) populations; and
- mapping and monitoring the clearing of native vegetation.

Additional investment of $480 000 each year (Table 9) will deliver the fundamental activities of the Australian Collaborative Rangeland Information System (coordination and integration of existing data). This relatively minimal investment would value-add to State and Northern Territory investment to provide coordinated Australia-wide information products and the framework and forum for continuous improvements to rangeland monitoring and management.

Table 8. Current State and Northern Territory expenditure on rangeland monitoring.

State/Territory	Expenditure ($'000)
Western Australia	3 200
New South Wales	3 200
Queensland	4 250
South Australia	1 800
Northern Territory	11 800
Total	**24 250**

Table 9. Proposed annual budget of the Australian Collaborative Rangeland Information System and indicative costs for commissioned activities. Precise costs will depend on the user specification and the comprehensiveness of the monitoring.

Australian Collaborative Rangeland Information System: establishment and current data collation

Information product number		Budget ($/year)
	Infrastructure for national collation, synthesis and reporting, (including Atlas)	480 000
1	Collation of rangeland surface and groundwater information to report on water resource sustainability	
2	Australia-wide collation, interpretation and reporting of currently collected State and Northern Territory pastoral estate information	
4	Continued updating of the national photographic sequences record	
5	Collation of seasonal climate outlooks	
7	Australia-wide interpretation of changes in seasonal characteristics	
10	Australia-wide collation, interpretation and reporting of change in land use and tenure datasets	
12	Interpretation and reporting of clearing extent	

Potential for sponsoring augmented Australia-wide rangeland information through commissioning, collating and reporting of additional rangeland monitoring parameters

Information product number		Budget ($/year)
2	Rolling program of landscape assessment based on linking remote sensed data with site data	650 000 per core monitoring area
3	Biodiversity monitoring and analysis	800 – 2 000 per site
4	Regional resource condition assessments	2–5 per km^2
6	Predicting and managing pasture availability (*Aussie GRASS*)	700 000
8	Total grazing pressure assessment	100 000
9	Extent, timing and frequency of fire	20 000
11	Exotic plants and animals	not estimated
13, 14, 15	Socioeconomic data collation, analysis and reporting	100 000
16	Institutional performance outcomes	not estimated

Getting started

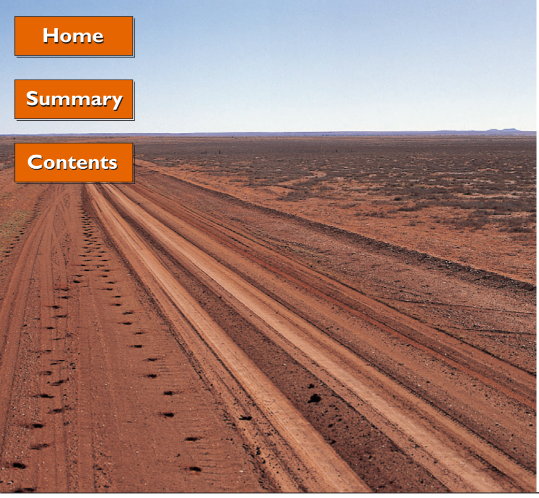
The Australian Collaborative Rangeland Information System requires an institutional foundation. In preparation for its implementation, the Audit is funding activities for 2001/02 in each State and the Northern Territory, including study into the information needs of Indigenous peoples.

Each State and the Northern Territory will:

- develop a framework that links existing pastoral monitoring programs, contextual information and new monitoring data from a range of agencies, and provides for regular local, regional and State/Northern Territory-wide reports on rangelands;
- define and plan activities and data collection protocols to underpin biodiversity monitoring; and
- improve data management so that synthesis and reporting from existing State and Northern Territory monitoring can be efficiently undertaken as part of the Australian Collaborative Rangeland Information System.

The Indigenous information needs study will:

- determine the information and data needs specific to Indigenous land use and management;
- determine the special requirements for dissemination of information to Indigenous land mangers;
- identify skills development needs among Indigenous land managers to build an appreciation and understanding of rangeland management issues and the links to community values (e.g. health); and
- better understand Indigenous land ownership and its implications for land management.



INVESTING FOR THE FUTURE

The way forward

Australian rangelands and their communities are under increasing environmental and economic pressure. Australia needs to ensure their protective management while maximising economic and social development opportunities.

Information and understanding are the key to a sustainable future of Australian rangelands. The Australian Collaborative Rangeland Information System will provide that information.

Essential components to achieve success include:

- *Commitment.* Implementation of the Australian Collaborative Rangeland Information System requires significant and continued commitment by the Commonwealth, rangeland States (Queensland, New South Wales, Western Australia and South Australia) and the Northern Territory.
- *Coordination.* Coordination between participating agencies could probably be best provided by the agency that will be responsible for long-term arrangements proposed for the continuation of the Audit.
- *Institutional arrangements.* Institutional arrangements will facilitate the effective introduction and ongoing conduct of an Australia-wide approach to rangeland information and management.
- *Budget.* An annual additional core budget of $480 000 above and beyond existing State and Northern Territory investment will implement, maintain and continue to improve the core components of the Australian Collaborative Rangeland Information System. It will advocate increased investment so that other projects such as biodiversity monitoring can be funded in time.

The Australian Collaborative Rangeland Information System will be a valuable and worthwhile investment and will deliver savings and effectiveness in a wide range of Commonwealth, State, Northern Territory and regional programs.

Its true success will become apparent when rangeland managers use a wide scope of natural resource management information to develop and implement management decisions that enhance and sustain Australia's rangelands.

Planning is complete. The only remaining need is for core funding to be allocated so that the plan can be progressively developed and implemented.

Lake Eyre Dragon

APPENDIX 1. STATE MONITORING ACTIVITIES

Rangeland monitoring, range condition assessment, resource inventory and other activities

The following section is a summary of the rangeland monitoring, range condition assessment, resource inventory and other activities for each rangeland State and the Northern Territory. More detail can be found in Anderson et al. (in press), Gould et al. (2001), Green et al. (2001), Karfs et al. (2001), and Watson et al. (2001).

New South Wales

- Rangelands cover 57% of the State.
- The climate is semi-arid with rainfall decreasing from 400 mm per year in the east to 200 mm in the west; rainfall tends to be summer-dominant in the north of the State and winter-dominant in the south.
- Rangelands topography is mainly flat to gently undulating.
- Vegetation types include grassland, chenopod shrublands, open woodlands and tall riverine woodlands.
- Tenure is mainly Crown leasehold under the *Western Lands Act 1901* (NSW) with small areas of freehold, Aboriginal land and national parks; the Willandra Lakes Region is a World Heritage Area.
- Pastoralism is the dominant land use and sheep are the main enterprise (where protected by the dingo fence).
- Government agencies with responsibility for natural resource management in rangelands include: Department of Land and Water Conservation; National Parks and Wildlife; New South Wales Agriculture; State Forests of New South Wales; The Environment Protection Authority; NSW Fisheries. The Department of Land and Water Conservation oversees the use of pastoral lands and rangeland monitoring.

Rangeland Assessment Program

The Department of Land and Water Conservation manages the Rangeland Assessment Program, the most advanced of the range monitoring programs in Australia. Almost 340 ground-based sites within seven range types have been recorded annually since the early 1990s (Table A1). Its emphasis is on reporting changes in both trend and condition of vegetation and soil attributes at a regional scale. Attributes assessed at each site include:

- species of vascular plants;
- biomass;
- frequency and composition of pasture species; and
- soil surface characteristics.

The density of perennial chenopods and percent canopy cover of trees and shrubs are measured in selected range types.

There is no operational remote sensing program to monitor changes in New South Wales rangelands, although this is intended by site design. Sites are read in conjunction with over 300 participating landholders. This increases landholder access to a range of related rangeland services provided by Department of Land and Water Conservation.

The Rangeland Assessment Program has collected annual data from 1989 to 2001 for most sites. Information products from the program have been produced on a site, range type and regional basis.

Table A1. Representation of Rangeland Assessment Program sites by bioregion in western New South Wales.

Range type	**Bioregion**								**Total**
	Mulga Lands	Murray Darling Depression	Riverina	Broken Hill Complex	Cobar Peneplain	Darling Riverine Plains	Channel Country	Simpson Strzelecki Dunefields	
Saltbush	1	5	40	14	–	–	3	2	**65**
Sandplain	39	9	–	–	–	–	–	–	**48**
Bluebush	–	36	7	6	–	1	–	–	**50**
Granite	–	1	–	–	24	–	–	–	**25**
Rosewood/Belah	–	48	2	–	–	–	–	–	**50**
Hard Red	–	–	–	–	45	4	–	–	**49**
Northern Floodplain	–	–	–	–	–	51	–	–	**51**
Total									**338**

Species diversity of vascular plants

Total species diversity (Figure A1 & A2) recorded at all sites over the period 1989 to 2000 is approximately 1147 species.

Figure A1 Total flora, and tree and shrub species diversity of bioregions in western New South Wales.

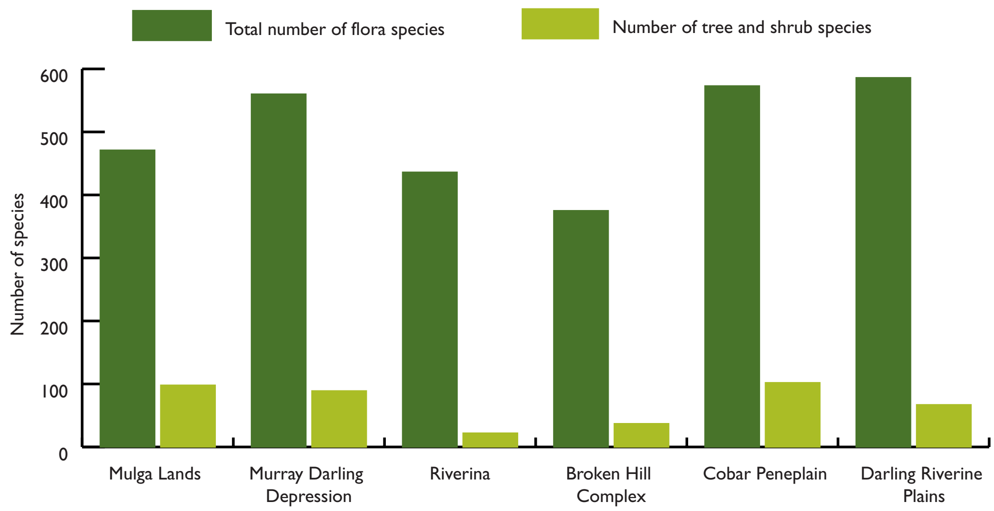
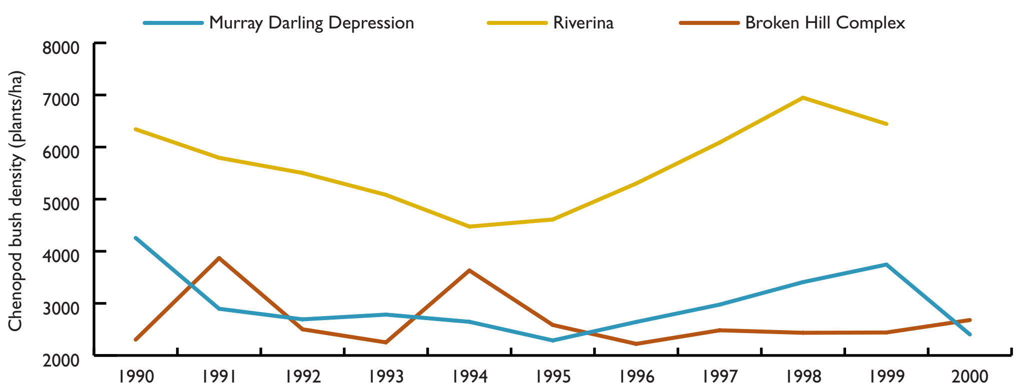


Figure A2 Chenopod bush density (1990 to 2000) in three bioregions in western New South Wales.



For most bioregions, biomass levels increased in the 1993 to 1994 period then declined in the 1995 to 1998 period with large increases in biomass observed in 2000 (Figure A3, A4 & A5). While the amount of fluctuation of biomass is generally low for those bioregions with low overall average biomass levels, the Cobar Peneplain shows an enormous increase in the 1999 to 2000 period due to favourable seasonal conditions.

Figure A3 Biomass levels for bioregions in western New South Wales.

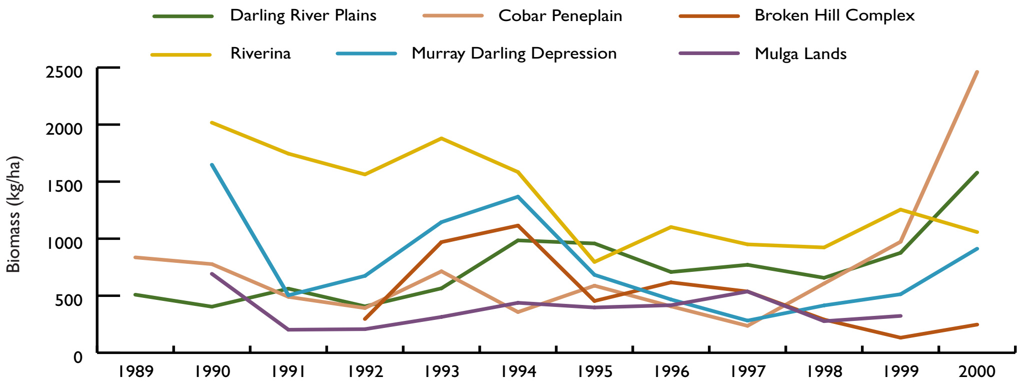
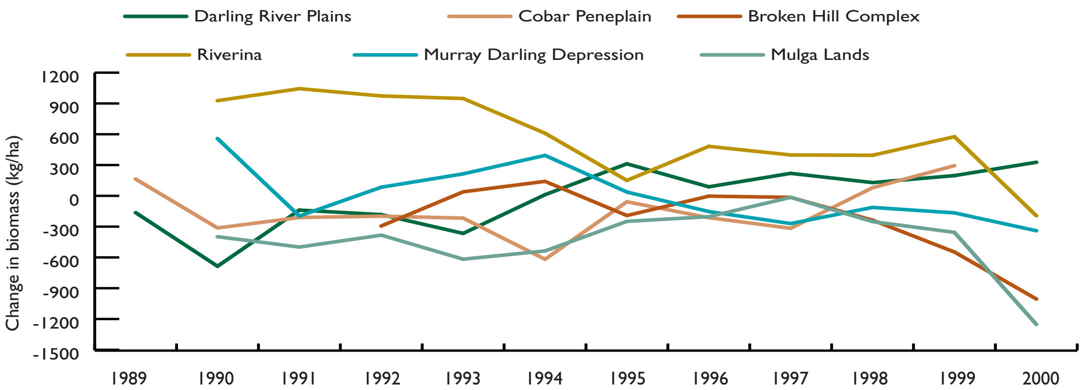


Figure A4 Change in biomass after subtracting the average biomass trend for each bioregion. Deviations are from the mean or zero line: 1990 was an exceptional year for Riverina and 2000 was an exceptional year for Darling Riverina Plains. The severe drought that the south west experienced in the 1995 to 1998 period is indicated by the exceptionally low biomass for Riverina and Murray Darling Depression.

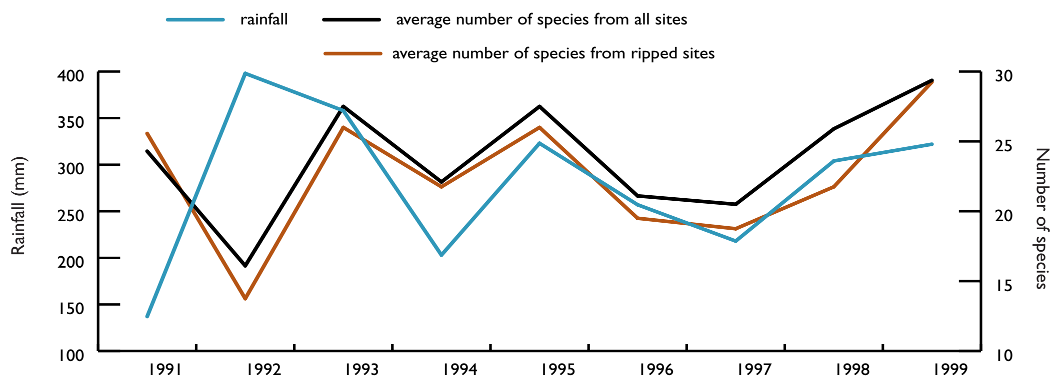


Ivanhoe, central western New South Wales

Approximately 20 sites in the Bluebush range type have been in existence in the Hay West district since 1991. At each of these sites a systematic assessment (Green et al. 1994) are made of vegetation and soil parameters. Pasture species composition, frequency and biomass are measured along with perennial chenopod community composition and density. Overall increase can probably be partially attributed to rainfall (Figure A6).

Additional data (e.g. rainfall, stocking rates and management actions likely to influence the dynamics of the site) were collected at each site. Information recorded on management actions included total grazing pressure control (e.g. kangaroo/goat control programs and rabbit ripping operations). A coordinated rabbit-ripping program began in the early 1990s in the Ivanhoe area, with ripping operations taking place on several properties. Rangeland Assessment Program sites were established on these properties in the summer of 1994/95. Ripping operations took place within paddocks where sites were established and this management action was recorded as a likely contributor to influence site data.

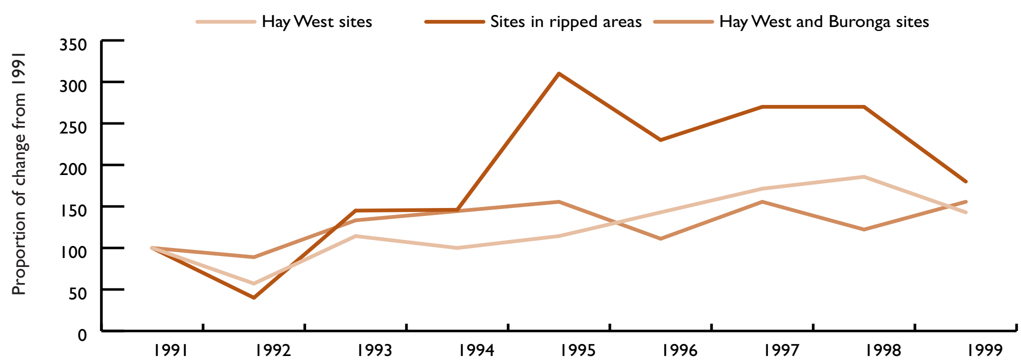
Figure A6 Correlation between the average number of species found at all Hay West sites and ripped areas, (Bluebush range type) and rainfall (1991–1999).



The average number of species found at all Hay West Bluebush sites and at those areas of rabbit ripping operations was generally the same over the 1991 to 1999 period (23.8 and 22.5 species respectively). While the maximum average number of species recorded at all sites versus sites in ripped areas was almost the same (29.37 and 29.25 respectively), the average minimum number recorded was quite different (16.1 versus 13.7 respectively). The average number of species in those areas of rabbit ripping increased by almost 10% (1995–1999) after the commencement of ripping in 1994/95. Further analysis is needed to determine the influence of other factors such as rainfall effectiveness during this period.

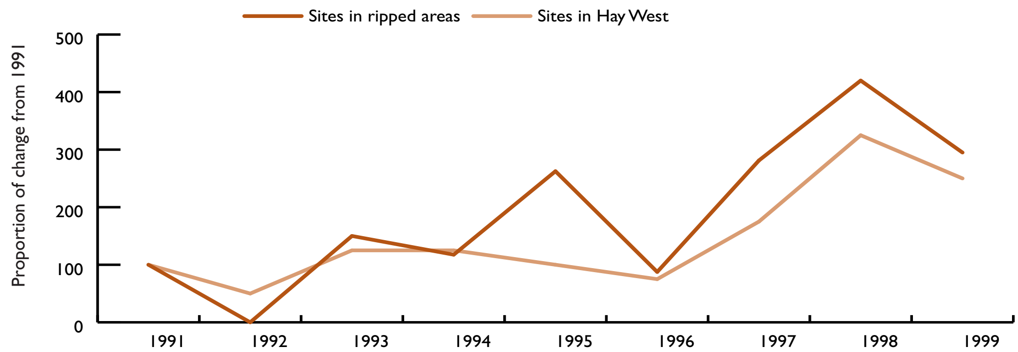
Although there has been an overall increase in average frequency of desirable pasture species at all sites in the Hay and Buronga districts (Figure A7), the increase has been much greater on those sites in the rabbit-ripped areas. Most notably an increase can be seen in the 1995 reading. This increase is just over three hundred percent from the 1991 year. The average frequency of desirable pasture species has remained elevated after the 1994/95 increase. Pasture species that were determined to be desirable included those species of high palatability and generally of a perennial nature. They included grass species (e.g. *Danthonia, Enneapogon, Eragrostis, Sporobolus*) and annual and perennial saltbush and bluebush. Many of these species have shown a decrease in abundance with increasing grazing pressure.

Figure A7 Change in the average number of desirable pasture species (1991–1999). Change is shown as a proportion of those desirable species recorded at the first reading in 1991.



Although an overall increase in perennial chenopod seedlings (a seedling or juvenile is recorded as being less than ten centimetres in height; the amount of woody thickening determines if it is a seedling or juvenile) has occurred, a particularly rapid increase occurred between 1996 and 1999 (Figure A8). Bluebush seedlings would be particularly vulnerable to rabbit grazing even in low densities. The drop in the 1999 reading is probably due to limited germination in the 1998 to 1999 period due to dry conditions.

Figure A8 Change in the average frequency of perennial chenopod seedlings and juveniles (1991–1999). Species include bluebush (*Maireana* spp.).

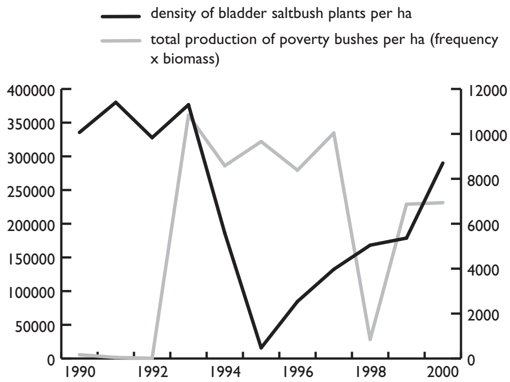


Riverina Plain

During the period 1990 to 2000 an ecological phenomenon called 'dieback' affected large areas of saltbush on the Riverina Plain. Site 8007 shows a typical ecological response to this perturbation (Figure A9). In 1990/91 the saltbush was healthy with a density of approximately 11 300 plants per hectare. In 1992 the saltbush community was hit by 'dieback' coinciding with massive defoliation from a plague of caterpillars. In 1993 saltbush plants were still struggling on with very few leaves. At the same time a large germination of poverty bushes had occurred. By 1994 the poverty bush density had replaced the struggling saltbush that declined to a low of 475 plants per hectare. Saltbush numbers then built up steadily from 1995 to 1999 with a good germination in 1999 coinciding with favourable seasonal conditions. During this phase the poverty bush has reached full maturity and has senesced reaching a low level again in 1998. It also responded to favourable seasonal conditions in 1999 but with a lower capacity to do so. A four year cycle can be observed in the poverty bush from germination to senescence.

Figure A9 Dieback on the Riverina Plain.

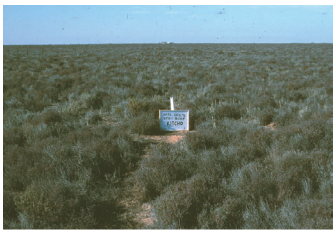

1990




1992


1994


1998


1996


2000

Queensland

- Rangelands cover most of Queensland. Throughout the central eastern and south-eastern areas, rangelands form a mosaic with cropping lands that occur mainly on fertile clay soils and originally carried brigalow forest and bluegrass grassland communities. The climate ranges from hot and dry desert in the south west of the State through to subtropical and tropical in the north where the rainfall is summer dominant. Thirteen bioregions occur wholly or partly within rangelands.

- Major river catchments include the Murray–Darling and Lake Eyre Basins. Bioregions in the north generally drain into the Gulf of Carpentaria. Some bioregions have rivers that flow to the east of the Great Dividing Range.

- Vegetation types vary from semi-arid tussock grasslands in the south west, through to Mitchell grass downs and a range of woodlands from semi-arid to tropical.

- Pastoralism is the major land use with the beef industry found throughout. The sheep industry is generally confined to the central western and south-western areas.

- The Queensland government has three agencies with responsibility for natural resource management in its rangelands:

  The Department of Natural Resources and Mines assesses and monitors Queensland's lands to ensure they are managed as effectively as possible. It is responsible for administering over 36 000 leases and other tenures over the State and are responsible for the *Land Act 1994*, *Water Resources Act 1989*, *Integrated Planning Act 1997* and the *Rural Lands Protection Act 1985*.

  The Environment Protection Agency has the key functions of environmental and biodiversity planning and along with the business group, Queensland Park and Wildlife Service, is charged with protecting Queensland's natural heritage in an ecologically sustainable way. It is responsible for the *Environmental Protection Act 1994* and the *Nature Conservation Act 1992*.

  The Department of Primary Industries is the rural economic development agency for Queensland's agriculture, forestry and fisheries industries. In rangelands it is responsible for research, development and extension to deliver economic, social and environmental benefits to Queensland.

Monitoring in Queensland's rangelands occurs in such programs as Transect Recording and Processing System (TRAPS); QGRAZE and Grass Check run by the Department of Primary Industries; and Statewide Landcover and Trees Study (SLATS) and *Aussie GRASS* run by the Department of Natural Resources and Mines.

Transect Recording and Processing System

The Transect Recording and Processing System (TRAPS) has been progressively establishing 150 sites in woodland communities since 1982 (Figure A10). Attributes assessed along permanent transects within the site area of 1 ha include:

- woody vegetation floristics;
- cover (Figure A11);
- structure and dynamics and their response to impacts of climate and fire; and
- disturbance such as clearing and grazing.

The herbaceous component is recorded in quadrats (see QGRAZE p. 140). All Transect Recording and Processing System sites have been re-recorded at least twice. Transect Recording and Processing System data has been used to show that woody plant 'thickening' is a real and significant process occurring in Queensland's grazed woodlands (Figure A12).

Figure A10 Transect Recording and Processing System and QGRAZE site distribution in Queensland.

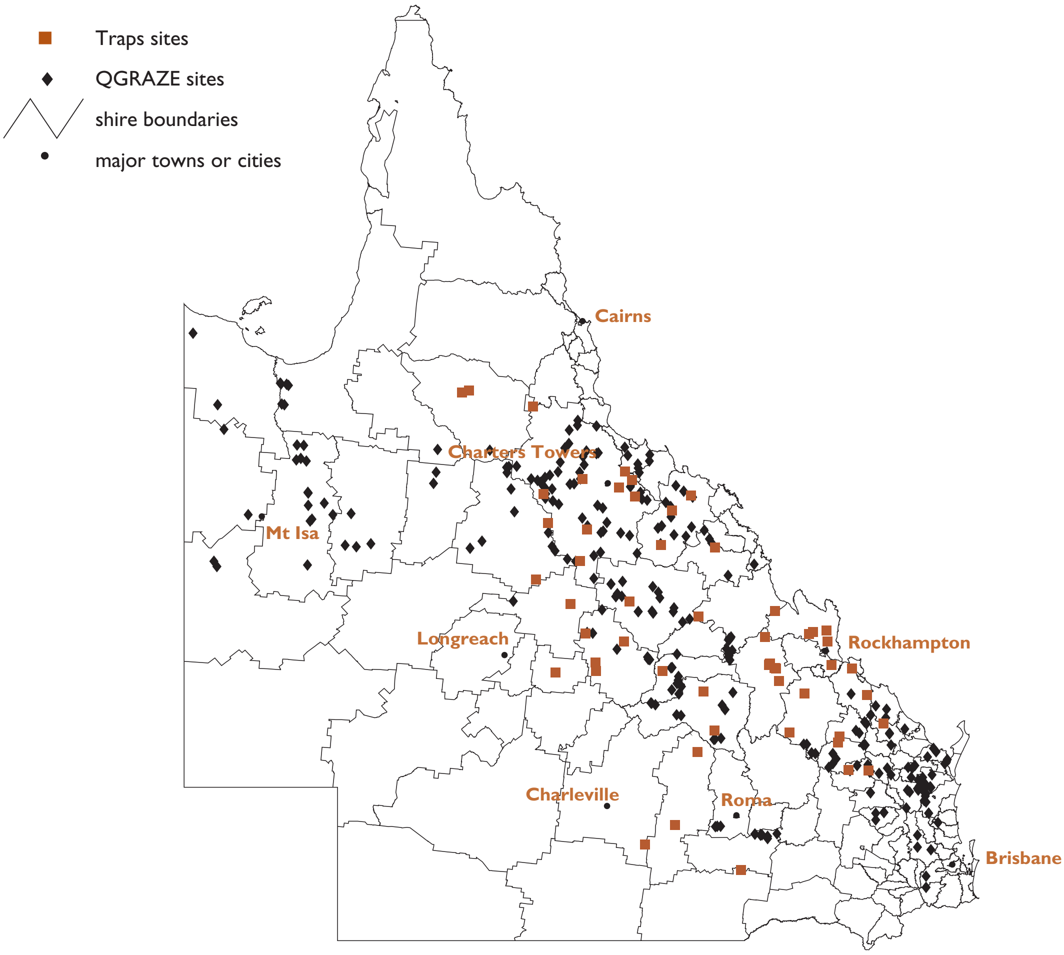


Figure A11 Graphic generated by the Transect Recording and Processing System processing package showing the reduction in area (canopy cover) along four recording lines of the shrub *Carissa ovata* following a fire.

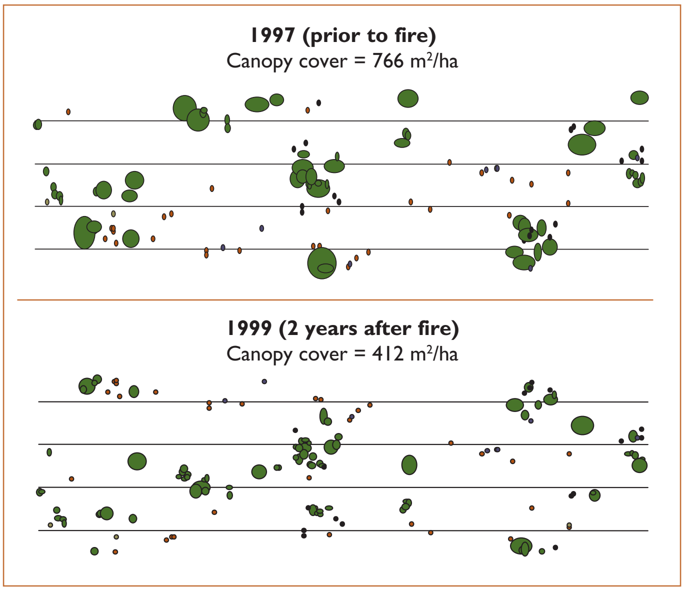


Figure A12 Transect Recording and Processing System site in narrow-leaved ironbark woodland in central Queensland (1983, 1995 & 1999) showing a thickening of the shrubby understorey.

1983

1995

1999

QGRAZE

Three hundred and fifty QGRAZE sites have been established since 1991. They are located mainly in black speargrass mesic woodlands (44%), *Aristida/Bothriochloa* xeric woodlands (25%), brigalow (9%), spinifex (4%), channel pastures (3%), bluegrass/browntop (3%), gidyea (3%) and Mitchell grass (3%). Herbaceous species frequency, frequency and size of woody species and amount of cover are measured in quadrats (Figure A13, Table A2). Pasture yield (based on photographic standards), soil surface condition and tree basal areas are assessed over the general site area of 4 ha (Figure A14). Although it is planned to re-record sites at least once every five years this has only occurred in about 70% of the sites. Mechanisms for reporting are being developed around the attributes of ground cover (a), perennial grass species (b), palatable, productive and perennial grasses (3P grasses) (c), and exotic species (d). These are being tested as surrogates for landscape function (a+b), grazing condition (a+c) and landscape health/biodiversity (a+b+c).

Figure A13 Photo pair showing ground cover change at a QGRAZE site in a narrow-leaved ironbark woodland, in the black speargrass native pasture community, approximately 150 km west of Charters Towers. Photo 1 is from 1994 during dry/drought years. Photo 2 is from 1999 following good summer rains.

1994

1999

Table A2 QGRAZE output showing changes in plant species frequency and cover on three geological units in Dalrymple Shire in North Queensland (data from 12 QGRAZE sites) (1995 to 1999/2000). The periods between 1991 and 1997 were drought years.

	Year	**Geological units**			**Average**
		Basalt	Granodiorite	Tertiary sediment	
Pasture species					
***Aristida* spp.**	**1**	4.50	7.67	39.00	**17.06**
	2	2.33	3.00	31.00	**12.11**
Bothriochloa ewartiana	**1**	30.33	3.33	t	**11.22**
	2	53.33	t	5.00	**19.44**
Bothriochloa pertusa	**1**	t	57.33	1.00	**19.44**
	2	24.00	51.00	1.00	**25.33**
Chrysopogon fallax	**1**	17.67	18.67	41.33	**25.89**
	2	15.67	2.50	29.67	**15.94**
Forbs	**1**	40.33	65.00	25.33	**43.56**
	2	25.00	4.33	31.67	**20.33**
Heteropogon contortus	**1**	6.33	23.50	12.67	**14.17**
	2	16.33	12.00	23.00	**17.11**
Native legumes	**1**	1.50	7.00	t	**2.83**
	2	1.50	t	2.33	**1.28**
***Panicum* spp.**	**1**	t	4.50	1.50	**2.00**
	2	3.67	t	10.50	**4.72**
Sedges	**1**	t	13.33	42.33	**18.56**
	2	2.50	1.00	36.67	**13.39**
***Sida* spp.**	**1**	21.00	9.33	10.00	**13.44**
	2	2.00	t	1.67	**1.22**
Cover	**1**	35.06	41.45	38.26	**38.26**
	2	83.14	72.57	56.71	**70.81**

Year 1 is 1995. Year 2 is either 1999 or 2000

t = traces

Figure A14 Rangeland officers estimating tree basal area using the Bitterlich Stick method, at a QGRAZE site, Cloncurry, north-west Queensland.

Grass Check

Land managers are encouraged to implement their own monitoring and adaptive grazing management through the Grass Check (Grazier Rangeland Assessment for Self-Sustainability) program by:

- establishing photo points;
- recording species present;
- estimating forage availability and ground cover; and
- estimating the cover of woody species where present.

Statewide Landcover and Trees Study

The Statewide Landcover and Trees Study initiative has used Landsat thematic mapper images to develop a monitoring system to report regularly the extent, condition and trend of Queensland's vegetation cover and land use, and provide estimates of greenhouse gas emissions in the land use and forestry sectors.

Aussie GRASS

The Australian Grassland and Rangeland Assessment by Spatial Simulation project (*Aussie GRASS*) is a collaborative project led by the Department of Natural Resources and Mines. It uses advanced simulation modelling techniques to assess the condition of Australia's rangelands. The *Aussie GRASS* model operates across the continent on a 5 km grid basis. The model uses inputs of daily rainfall and climate, soil functional characteristics, vegetation characteristics, tree density, and grazing pressure for each grid cell. The model simulates the processes of runoff, infiltration, deep drainage, evapotranspiration, pasture growth and senescence, litter decay, and consumption of biomass by grazing animals. Model output is often presented in percentile format, that allows users to assess current seasonal conditions relative to historical conditions (Figures 23 & 24—p. 63).

South Australia

- Rangelands cover 85% of South Australia, including all but the southern portion of the State.
- The climate varies from very hot and dry in the north with an erratic summer-dominant rainfall pattern, to a temperate climate with winter-dominant rainfall in the south.
- Distinctive geological features include the Flinders and Gawler Ranges in the south, the Musgrave Ranges in the north west, Lake Eyre in the centre, the Simpson Desert in the north and the Nullarbor Plain crossing into Western Australia along the coast.
- 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 through about 60% of the South Australian rangelands, with sheep south of the dingo-proof fence and cattle north of the fence.
- The 40% of the South Australian rangelands that are not under pastoral lease are predominantly the Great Victoria and Simpson sandy desert areas dedicated as conservation or regional reserves, or the north-west ranges forming the Pitjantjatjara lands. Products of mining activities in rangelands include oil, natural gas, iron, copper, uranium, silver and gold.
- Pastoral leasehold land is administered by the South Australian Pastoral Board, with support from Primary Industries and Resources SA which also has responsibility for the *Soil Conservation and Land Care Act* (1989) covering all tenures. Primary Industries and Resources SA has the lead responsibility for management and monitoring of rangelands. The Department for Environment and Heritage has the lead role in biodiversity conservation including management of arid zone parks.

The rangelands program also runs a number of projects specifically related to its core function of carrying out monitoring and inventory of the land resources of South Australia's rangelands. These include a long-term historic photo relocation project whereby old pastoral inspection photographs are being systematically re-located where possible and archived. The more interesting photo-sequences are being formalised into photo points as part of the current pastoral monitoring program. The photographs included here show a typical 35-year sequence on Lilydale station in the Northeast Pastoral district. Chenopod shrubs, particularly blackbush, are now colonising what was a previously bare and degraded blackoak community.

Rangeland Monitoring Program

Primary Industries and Resources SA has a comprehensive, integrated program of:

- resource inventory;
- resource condition and lease assessment;
- lease inspection; and
- rangeland monitoring.

Over the last 10 years South Australia has assessed resource condition and established a baseline monitoring system over all pastoral leases in the State. Each of the 219 pastoral properties on 328 leases and covering 409 000 km^2 of the rangelands now has:

- resource and lease inventory information;
- resource condition assessments;
- baseline monitoring sites established; and
- priority paddocks identified for management action.

Approximately 5500 photo point monitoring sites have been established, 20 000 Land Condition Index sample points have been assessed and 4500 individual paddocks have been assessed and assigned a priority for land management action and further inspection. This work and the scientific standards upon which it is based are driven by requirements under the *Pastoral Land Management and Conservation Act 1989* (SA).

The focus of future activities by the Pastoral Board and Primary Industries and Resources SA is on reporting at both lease and district scales. Lease-scale reports remain confidential to the Pastoral Board and the lessee. Although little aggregated information is currently available, a pilot project to develop district-based reporting using the photo point monitoring site network is being undertaken across the Kingoonya and Gawler Ranges Districts.

There is no firm schedule for reassessment of leases or systematic reassessment of photo point monitoring sites at present. In the short term, 10% of photo points in the Kingoonya and Gawler Ranges District will be revisited through the District Monitoring Project. The Pastoral Inspection Program will also revisit a selection of sites as well as following up on land management issues identified during the Pastoral Assessment Program.

In the longer term, an assessment is required every 14 years after the initial assessment or when the lessee accepts a new or extended term of the lease, as provided for under the Act. Thus properties that have not accepted a new or extended lease will require assessment in 2004.

There are two techniques for assessing resource condition depending on whether the land is under cattle or sheep grazing.

Grazing Gradient Assessment

The Grazing Gradient Assessment method (Pickup et al. 1994) is used on a proportion of the northern cattle leases and 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. Vegetation cover tends to increase with distance from watering points as grazing intensity decreases, producing a grazing gradient (Figure 11, p. 43). Where this cover gradient persists after high rainfall, it indicates a degree of land degradation.

The grazing gradient method is an effective tool for describing present rangeland condition. A major benefit is the ability to separate grazing effects from seasonal change in vegetation cover.

Grazing gradient analyses were conducted in areas used for extensive grazing by domestic cattle in northern South Australia for the regional assessment and reporting of landscape function (vegetation cover). Areas where vegetation cover was below optimal levels under grazing land use were identified. It also provided a benchmark from which future changes could be measured.

There is considerable potential to integrate ground-based monitoring with Grazing Gradient Assessment to better understand the actual changes occurring to the soil and vegetation. This could occur by applying the grazing gradient method at property and paddock scales. Ground-based monitoring sites could be located at distances from water where change in vegetation is indicated by the grazing gradient plots. Such sites could collect data describing landscape function (Ludwig et al. 1997). The pattern of vegetation response in grazing gradient plots would allow determination of how much the landscape function has been changed. Areas at risk could then be identified and targeted. Pastoral administrators would be able to shift to a more predictive approach that would prevent damage from inappropriate grazing.

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 (Table A3).

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 disturbance;
- moderate disturbance; and
- low disturbance.

These classes are precisely specified for each component of each pasture type within a district. Under the *Pastoral Land Management and Conservation Act 1989 (SA)*, 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 of the pasture types.

The disturbance categories are mostly based on the presence, absence and abundance of perennial plant species, the level of grazing and browsing of palatable species, and some consideration of soil surface condition. The condition classes provide an inherent assessment of the likelihood of the vegetation community to return to something like undisturbed condition (e.g. sites in Class 1 condition are unlikely to recover, while those in Class 2 have the potential to recover under sufficiently benign management).

A weighted average condition index is determined for each lease by multiplying the percentage of sample points for each condition rating by the rating. This gives a value for each lease of between 100 (all sample points severely disturbed) and 300 (all sample points assessed as low disturbance).

Table A3 Percentage of condition rating observations for pasture type communities within Gawler Ranges Soil Conservation District leases. Such tables provide data on the relative condition of different vegetation types and also indicate the relative proportion of each vegetation type sampled within each district. They do not necessarily represent the relative areas of each vegetation type within the district.

Vegetation community	**Land Condition Index rating (%)**			
	High disturbance	Moderate disturbance	Low disturbance	Total
Chenopod shrublands				
1(a) Treeless plains	0.30	0.64	5.56	**6.51**
1(c) Samphire/saltlake	0.61	1.14	6.48	**8.22**
1(d) Calcareous plains	1.88	9.11	16.17	**27.16**
1(e) Arcoona tableland	0.30	0.30	4.68	**5.29**
1(g) Blackbush watercourses	2.08	6.78	9.52	**18.38**
1(h) Gawler Range alluvial valleys	5.23	5.20	1.41	**11.85**
Total	**10.41**	**23.17**	**43.83**	**77.41**
Low woodlands				
2(a) Mulga grasslands–sandy	0.36	1.30	0.55	**2.21**
2(d) Mallee/blackoak	3.99	5.34	6.17	**15.5**
2(e) Native pine on dunes	0.33	1.14	0.28	**1.74**
2(f) Mallee/spinifex on dunes	0.00	0.39	1.16	**1.555**
Total	**4.68**	**8.17**	**8.17**	**21.02**
Hummock grasslands				
4(a) Gawler Range rhyolite hills	0.61	0.58	0.36	**1.55**
Total	**0.61**	**0.58**	**0.36**	**1.55**
Total	**15.70**	**31.92**	**52.36**	**100.00**

Northern Territory

- The whole of the Northern Territory is defined as rangelands.
- The climate ranges from hot and dry in the south to monsoonal in the north with distinct wet and dry seasons.
- Vegetation ranges from tussock grasslands, shrublands and low open woodlands in the south to tall woodland with patches of monsoon rainforest in the north.
- Pastoralism is the major land use with beef cattle being the main enterprise. Indigenous land use and conservation areas are also significant.
- World heritage areas include Kakadu and Uluru-Kata Tjuta National Parks.
- Mining for bauxite, uranium, gold, lead, and zinc is important to the economy.
- The Northern Territory government has three agencies with responsibility for natural resource management: Department of Lands, Planning and Environment; Parks and Wildlife Commission; Department of Primary Industry and Fisheries.

The Department of Lands and Planning and Environment undertakes all land resource assessment and mapping, pastoral lease monitoring and infrastructure mapping, regional land monitoring, and lease inspection activities. Monitoring of the pastoral estate involves permanent photo sites, soil and vegetation measurements, and remote sensing.

Monitoring of the pastoral estate is a two-tiered system, called Tier 1 and Tier 2.

Tier 1 is operational on a property by property basis, while Tier 2 is regionally based with current activity in the Victoria River District, Sturt Plateau, the Barkly Tablelands, the Mary River catchment and some of the Alice Springs District.

Tier 1

The Tier 1 system consists of permanent photo sites located in each of the major paddocks (or grazing areas) on pastoral leases. Pastoral Officers record soil and vegetation observations though lessees are encouraged to photograph sites annually and record their own observations.

Regional Rangeland Monitoring Program (Tier 2)

The Regional Rangeland Monitoring Program (Tier 2) uses two different (but related) satellite-based methods to account for variation. Landscape Cover Change Analysis is used in the tropical savannas in the north and Grazing Gradient is used in the arid interior to the south.

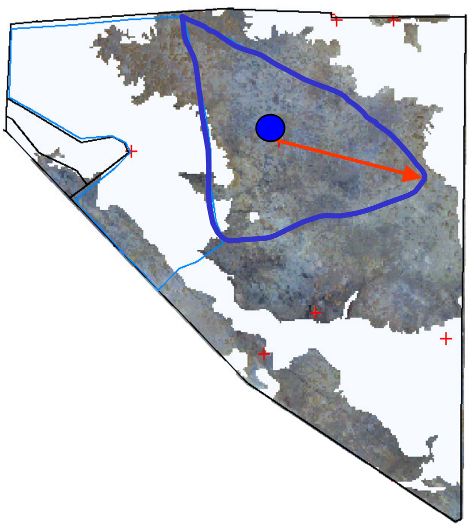
Remote sensing is seen as the major means of broadscale monitoring, augmented by ground-based sites. This system is the most sophisticated system in Australia and includes an explicit focus on landscape processes rather than vegetation species composition.

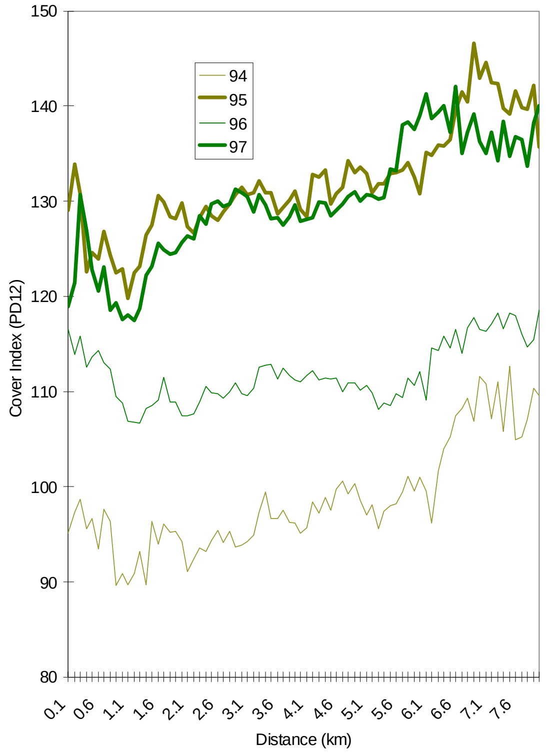
Land administration is focused on conservation of the base resource for pastoral purposes. Lease conditions in the *Pastoral Land Act* 1992 (NT) do not include the need to manage for biodiversity. Nor is there an explicit requirement to monitor biodiversity. However, monitoring of landscape processes has relevance to maintenance of biodiversity.

Grazing gradient: a single watering point

Grazing gradients at individual water points can be examined to provide information at the basic management unit level (Figure A15). The comparison of two seasonal gradients demonstrates not only the extent of use, but also the subsequent response that occurred following rain.

Figure A15 Grazing gradient for a single watering point on the Barkly Tableland. The blue circle in the image on the left is the watering point. Grazing in 1994 (dry) was somewhat heavier than in 1996 (dry), indicated by the lower two gradients (thin lines). However, the pasture responses after rains in 1995 (wet) and 1997 (wet) were to essentially the same levels, indicated by the upper two gradients (thick lines). The positive gradients in both wet years suggest that a permanent effect present around this particular watering point is inhibiting its production potential (i.e. cover is increasing at distance from water).





Source: McGregor 2000.

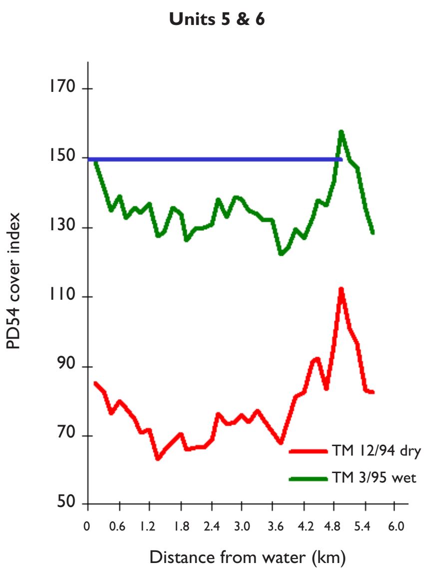
Grazing gradient: landscape types at the paddock scale

Grazing gradients for one landscape type in a paddock were calculated from Landsat TM-derived data for December 1994 and March 1995 (Figure A16). Each gradient shows average cover levels present at increasing distance from water before (red line) and after (green line) a moderate rainfall event. The Y axis is scaled in units of PD54 cover between 0 and 254: values below 60 equate with bare ground while values above 240 represent 100% cover. The horizontal blue line indicates the expected cover level if vegetation close to water had fully recovered from the effects of grazing following the rainfall received.

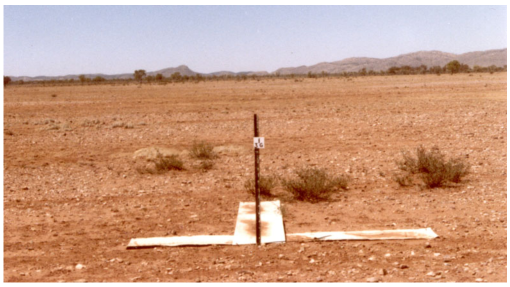
Dams, or surface catchments, constructed adjacent to tree-lined creeks are the usual closest water source in this floodplain unit. Tree canopies thus contribute to the relatively high cover levels immediately adjacent to water. Average cover levels decline with increasing distance from water as progressively more of the low-cover floodplain (i.e. ephemeral herb land unit) is included in the calculation of average cover levels. Cover levels increase beyond about 4 km from water due to the presence of perennial tussock grasses on riparian areas and patches of timber on the floodplains.

The majority of this floodplain unit appears to be grazed fairly uniformly. There is no distinct pattern of increasing average cover with distance from water until the area at 4 km from water is reached. If there were areas further than 6 km from water, we would expect average cover levels to continue to increase before levelling off. The wet-period data indicate that there was considerable growth of herbage across the floodplain unit following the January 1995 rains. This suggests that the floodplain unit has a considerable potential to recover from grazing following substantial summer rain (even though maximum cover levels are not uniformly restored at all distances from water across the vegetation unit).

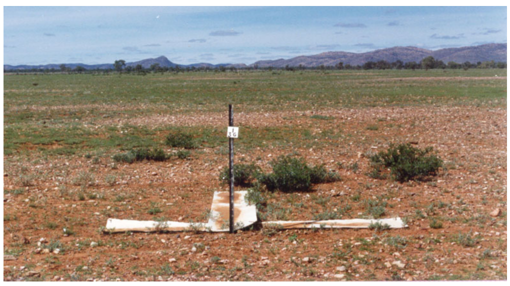
Figure A16 Grazing gradients for ephemeral herb land before and after a moderate rainfall event.



Source: Chewings et al. 1998.



Ephemeral herb land in dry conditions



Ephemeral herb land in wet conditions

Grazing gradient: resilience of vegetation at the paddock scale

Response of vegetation cover to rainfall can be assessed on a pixel by pixel basis for determining whether it is above or below what might be expected given little or no grazing impact. Below-expected response often results from desertification and can indicate areas with reduced pasture productivity. Above-expected response indicates a resilient landscape that:

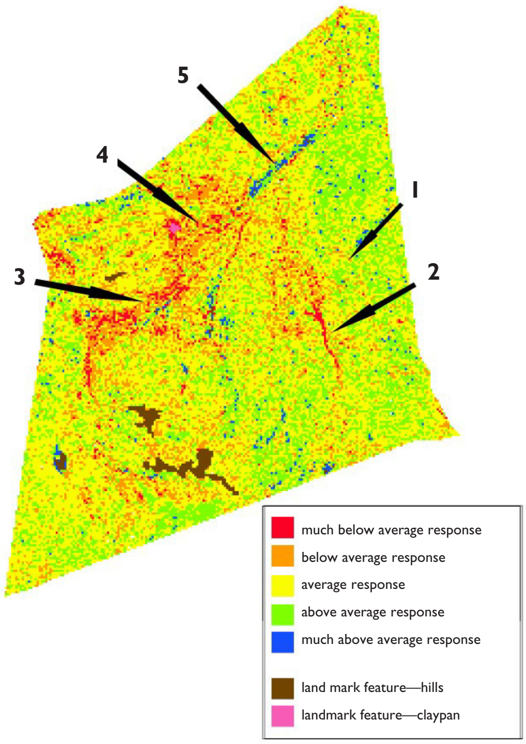
- may be in good condition;
- recovers well from removal of plant matter by grazing; and
- is likely to be productive.

In this type of assessment landscape features are numbered image and described (Figure A17).

Following initial assessment and in the longer term, further images can be produced in a repeatable manner following future good rains. The output can be used to assist in judging the range of trend under continued, or changed, grazing management.

Figure A17 Vegetation response in a paddock following 350 mm of rainfall in March 1989. Much of the paddock had an average to above-average vegetation response. The best response was in a broad watercourse where alluvial soils and water running off higher ground combined to produce ideal conditions for annual plant growth. Below-average vegetation response occurred on eroded areas surrounding a long-established watering point and in a heavily shrubbed watercourse.

Management options include piping water to lightly grazed country in the eastern part of the paddock and closing access to waters associated with below-average plant response except when required for mustering.



Landscape descriptions

1 **lightly grazed country**
Stable soils, good infiltration and abundant annual grasses combine to produce above average pasture response.

2 **heavily shrubbed watercourse**
Shrubs compete with pasture for available moisture and nutrients.

3 **semi-saline drainage line**
Moderate cover of samphire, oldman saltbush & other shrubs prior to rain. Large flood dislodged much of this growth giving rise to apparent poor response.

4 **eroded slopes**
Poor growth because of increased runoff, exposed subsoil and depleted seed reserves.

5 **watercourse**
Alluvial soils & run-on water combine to produce ideal conditions for pasture growth.

Source: Chewings et al. 1998

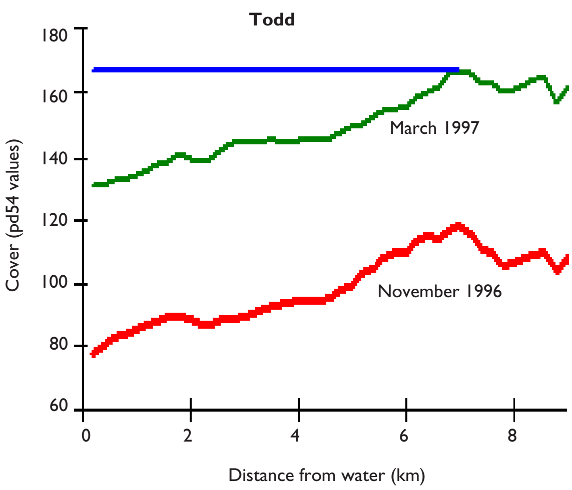
Grazing gradient: regional summaries

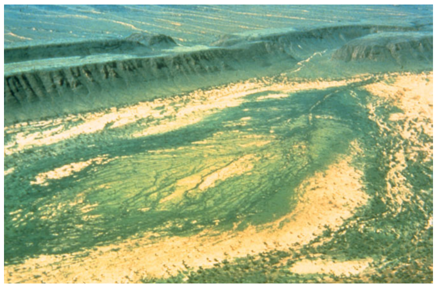
Analysis of 26 land systems covering 38 000 km^2 indicated that those land systems containing a high proportion of palatable forage had the most persistent wet-period grazing gradients and were the most affected by grazing. Each land system was analysed separately and ranged in area from 67 km^2 to 3137 km^2. Assessment of one of these land systems is represented in Figure A18 showing average cover levels present at increasing distance from water before (red line) and after (green line) a moderate rainfall event. The Y axis is scaled in units of pd54 cover between 0 and 254: values below 60 equate with bare ground while values above 240 represent 100% cover. The horizontal blue (or black) line indicates the expected cover level if vegetation close to water had fully recovered from the effects of grazing following the rainfall.

This land system is made up of alluvial plains and other major creeks in the northern part of the region. The major vegetation type is an open woodland over annual and perennial forage species though smaller areas of perennial grassland on clay loam soils also occur. An aerial photograph shows a typical landscape. The graphs show a moderate cover level. Strong wet and dry period normal grazing gradients persist to 7 km from water and although cover levels increased after rain, there is minimal recovery from the effects of grazing closer to water.

Management techniques that encourage the regeneration of palatable forage species, including perennial grasses, would seem necessary in some areas to allow vegetation closer to water to respond to rainfall in a similar manner to that on more distant areas.

Figure A18 Assessment of a land system showing average cover levels present at increasing distance from water before and after a moderate rainfall event.





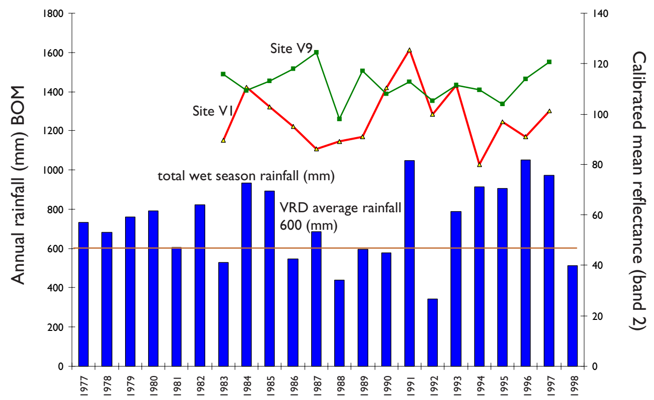
Source: Chewings et al. 1998.

Land Cover Change Analysis: long-term time trace of monitoring sites in the Victoria River District.

The time-trace of monitoring sites allows comparison of monitoring data in the context of long-term change in the landscape (Figure A19). The time trace of two monitoring sites, one in good condition (V9—green line) and one in poor condition (V1—red line) are compared over a fifteen-year period from 1983 to 1997. Bureau of Meteorology rainfall data is displayed as an indication of seasonality. Lower mean reflectance corresponds to lower vegetation cover. Dissimilarity between time traces is evident as the trace for site V1 has greater fluctuations, generally following seasonal trends, compared to site V9, that has been relatively stable.

Successive good seasons from 1993 to 1997 (rainfall data) are reflected by upward trends in both time traces. Time traces also respond to specific events (e.g. Site V9 was affected by fire in 1988 and exhibited a downward trend; in 1994 heavy grazing left site V1 virtually bare, that was expressed as a downward trend and low mean reflectance. The time trace analysis suggests Site V1 has been in a poor state dominated by annuals and herbaceous cover for a considerable period, in contrast to site V9).

Figure A19 Long-term time trace of monitoring sites in the Victoria River District.



Poor condition site (V1)

Good condition site (V9)

Source: Karfs 1999.

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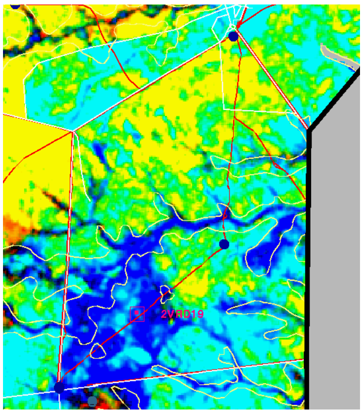
Land Cover Change Analysis: multiple temporal satellite sequences at the paddock scale

Trend summary imagery can be used at the paddock scale and over varying time sequences (Figure A20). By comparing the same areas over time, changes to cover can be detected.

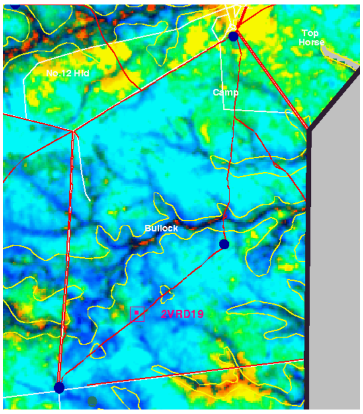
Colours indicate good vegetative cover (cyan and green), good cover with decreasing trend (yellow) and poor cover (blue and red). Watering points are shown as solid blue circles, fencelines in white and roads in red. Continuous high cover indices detected over the ten-year period indicate good condition grassland dominated by perennials, that ground truthing has confirmed. Drainage lines having a dense tree canopy display low cover indices (blue and red), due to absorption in Landsat MSS band 2. This response is similar to exposed, dark coloured soil on the adjacent plains, requiring stratification of these systems. Recovery is evident in pastures near the bore in the lower left, following grazing impact in 1987.

In this example, the spatial extents of under utilised perennial pastures provide landholders with baseline information on land condition to help develop management options. Most of the area has been in good condition for some time. The few areas adjacent to riparian corridors (that often provide refuge for stock and native wildlife) having lower cover values may indicate preferential patch grazing. By developing a management regime with more even utilisation of pastures over the broad landscape, the focus on other areas may be reduced.

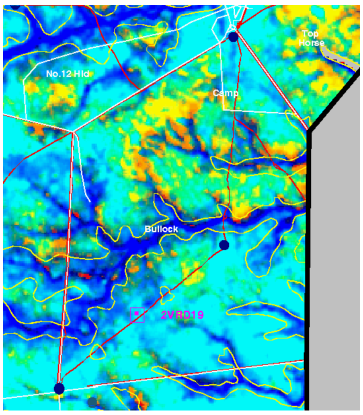
Figure A20 Examples of trend summary imagery at the paddock scale over three time sequences.



1987–92



1991–94



1994–97

Source: Karfs et al. 2000.

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Land Cover Change Analysis: regional summaries

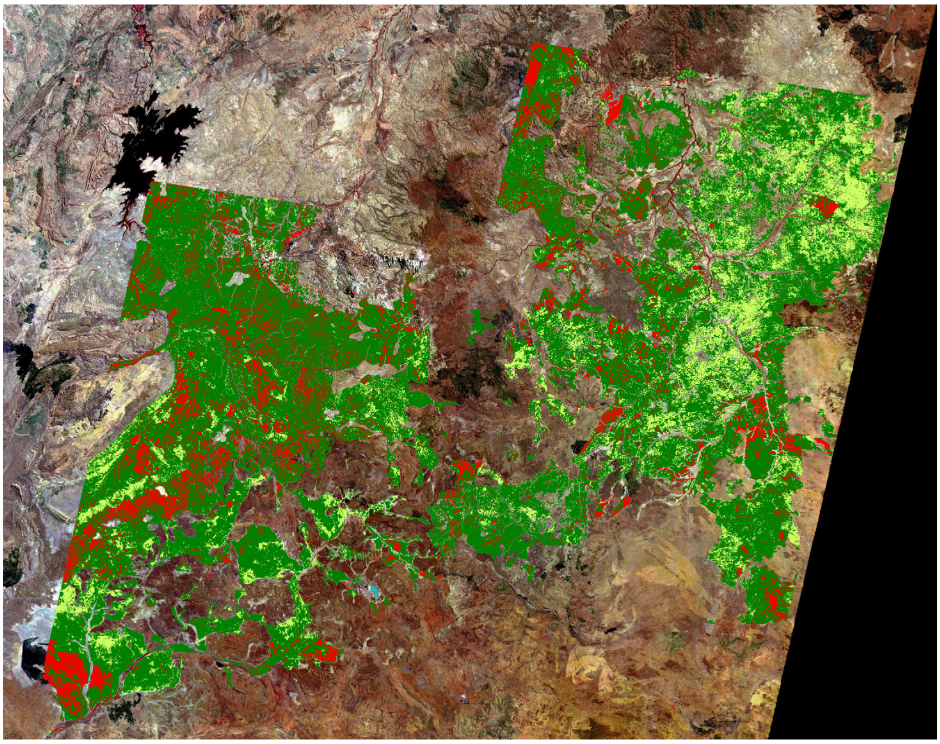
Analysing three land types separately then combining them into a contiguous coverage created a regional trend product from 1992 to 1997 (Figure A21). The area analysed is 66 550 km^2 of 126 000 km^2 within four mosaic Landsat scenes.

Light green represents areas where cover increased and dark green represents areas with stable cover over the period. Areas shown in red represent a decreasing trend in cover. In this example, fire scars have not been removed and much of the red is attributed to burnt country. Fire history maps overlain on this image would aid in identifying areas affected by fire.

Clearly these data show that over most of the region cover has increased or remained stable. This regional trend can be attributed to an exceptional run of good seasons from 1993 to 1997. It is also consistent with the interpretation of ground data collected at monitoring sites over the same period.

Regional information products are beneficial to statutory agencies to report on differences within their jurisdiction. There is also considerable potential for examining the cover trends to make comparisons of current and past management with regard to seasonal variation over large tracks of rangelands.

Figure A21 A regional trend product from 1992 to 1997.



Source: Karfs et al. 2000.

Western Australia

- Rangelands make up about 87% of Western Australia and include all but the south-west of the State.

- The climate varies from hot dry desert throughout the inland parts of the State, to semi-arid and more temperate areas with winter-predominant rainfall in the south, to subtropical and tropical areas in the north with a distinct monsoonal wet and dry season.

- In the savannas of the Kimberley, vegetation types are typically hummock (i.e. hard and soft spinifex) grasslands, curly spinifex, tussock (e.g. Mitchell) grasslands, and tropical tall grass communities. Tree and shrub cover is generally sparse, although there are isolated monsoonal forests in the North Kimberley and areas dominated by pindan wattle in the west. The Pilbara is dominated by hummock grasslands with scattered eucalypt and acacia overstoreys. Short grass vegetation is found on alluvial plains and deltas, while many of the valleys contain mulga woodland. From south of the Pilbara through to the Nullarbor, the arid shrublands are dominated by mulga communities; chenopods (i.e. saltbush and bluebush); and sandplain or dunes, carrying shrubby vegetation, spinifex or wanderrie grasses.

- Livestock grazing on pastoral leasehold is the dominant commercial land use across about 45% of the Western Australian rangelands (Figure A23). Cattle are run in the Kimberley and almost all of the Pilbara. To the south, sheep dominate, although the proportion of leases on which cattle production is the major enterprise is increasing. There is some relatively small, although intensive horticultural and crop production using irrigation from the Gascoyne (Gascoyne Region) and Ord (East Kimberley Region) Rivers.

- The remainder of the rangelands consists of unallocated Crown land (37%), land held for the use or benefit of Indigenous people (9%), land held for conservation (7%) and minor areas for other uses (2%). Mining (e.g. iron ore, gold, and diamonds) dominates the economic output of the Western Australian rangelands.

- There is substantial overlap between the pastoral areas and 12 bioregions (Figure A22). A further 10 bioregions are either inland of the pastoral areas or are partly contained within rangelands along the margins of the wheatbelt in the south west.

- A number of State government agencies play some role in managing Western Australia's rangelands. However, the Department of Land Administration has the greatest responsibility, administering those rangelands held as either unallocated Crown lands, or as pastoral lands.

The Pastoral Lands Board of Western Australia is responsible for administering the *Land Administration Act 1997* (WA) for the 504 pastoral leases in Western Australia. The Department of Agriculture provides rangeland monitoring, condition assessment and lease inspection services to the board under a memorandum of understanding, as well as providing advice to the Commissioner for Soil Conservation (based within the Department of Agriculture).

Range inventory and monitoring activities

A range of activities are being used in Western Australia to track trend over time and report on condition of the pastoral rangelands. Elements of all the activities described below can be collated and used for Australia wide reporting on a commissioned basis.

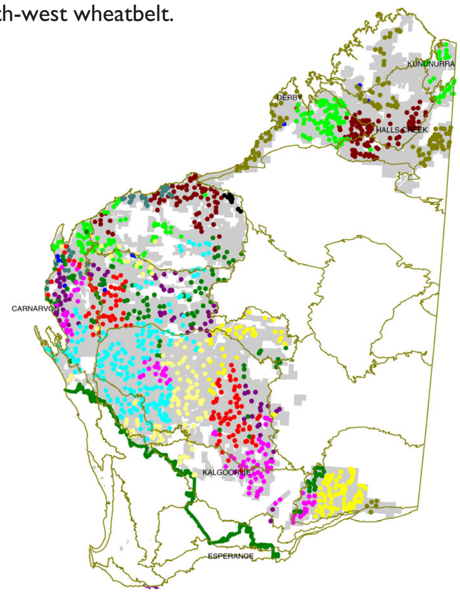
Regional scale resource inventory and range condition survey

The Departments of Land Administration and Agriculture conduct a joint Range Survey program that maps rangelands to the land system level and combines soil and vegetation condition assessments into an assessment of range condition at the lease and land system scale. Severely degraded and eroded areas are also mapped. About 87% of the pastoral rangelands have been included in these surveys. In the Kimberley, land systems were mapped by CSIRO. Range condition was assessed by the Department of Agriculture in the mid-1970s (in the west Kimberley) and throughout the Kimberley Region in the early 1990s, but on a lease by lease rather than regional basis. South of the Kimberley, the Regional Surveys are one-off assessments and no repeat surveys have been scheduled. However, over 6000 inventory and condition sites were sampled during the Range Surveys and the potential remains to re-visit these sites if required and resourced.

Regional scale range monitoring

The Western Australian Rangeland Monitoring System (WARMS) consists of almost 1600 fixed sites, located on representative areas of specific pasture/vegetation communities. While most leases, of viable size, have at least one Western Australian Rangeland Monitoring System site and on average there are about three sites per lease, the Western Australian Rangeland Monitoring System is designed to report at the vegetation type or regional/district scale, not at the lease scale.

Figure A22 The location of WARMS sites, coloured by year of assessment. The greyed areas denote pastoral leases and the khaki line work denotes Interim Biogeographic Regionalisation of Australia (version 4) boundaries. The heavy green line in the southwest shows the demarcation between rangelands and the south-west wheatbelt.



There are two different types of Western Australian Rangeland Monitoring System sites. Throughout the Kimberley, the Pilbara and some areas south of the Pilbara, grassland sites are used. Shrubland sites are used throughout the area south of the Kimberley, particularly south of the Pilbara. Attributes related to perennial vegetation dynamics and landscape function are recorded on both grassland and shrubland sites. On grassland sites, the frequency of all perennial species is assessed in quadrats and an estimate is made of crown cover of woody perennials. On shrubland sites, the demography and maximum crown dimensions of all shrubs are recorded using complete census techniques. On both grassland and shrubland sites standard Landscape Function Analysis techniques developed by CSIRO are used to assess soil surface and other attributes related to landscape function. Standard photographs are taken at both types of sites. Grassland sites are reassessed on a three-yearly cycle, shrubland sites on a six-yearly cycle. The system in its current form was begun in 1992, although many old monitoring sites were incorporated and some data and photo records go back to the 1970s.

Lease level range condition assessment

The Department of Agriculture, on behalf of the Pastoral Lands Board, maintains a regular program of individual lease inspection, on a maximum cycle of six years. Range Condition Assessment uses similar techniques to the Range Survey program and over time will enable regional assessments to be made of condition, and change in condition, at the sublease scale. While reports for individual leases are confidential to the lessee and the Pastoral Lands Board, outputs could be aggregated on a regional/district or vegetation type level.

Lease level monitoring by pastoralists

Many pastoral managers maintain their own systems of range monitoring, using photo or other techniques. While government does not formally maintain data, many pastoralists' sites overlap with Western Australian Rangeland Monitoring System sites and their photos are assessed by pastoral lease inspectors during their lease inspection activities. At least 3000 of these sites have been installed. Recently, the Department of Agriculture and the Department of Conservation and Land Management have begun supporting the monitoring by pastoralists of a range of attributes related to pastoral productivity and nature conservation. This monitoring is a component of the Ecosystem Management Unit Project.

Other monitoring activities

While not currently part of a formal system, the Western Australian Rangeland Monitoring System activity maintains photos and/or data records for about 3800 other monitoring sites on pastoral leases. Many of these overlap with individual lessee sites. These sites were put in for a range of purposes. However, the majority were installed using techniques similar to Western Australian Rangeland Monitoring System but pre-date the current Western Australian Rangeland Monitoring System activity. Although these photos and records are used in an ad hoc manner (e.g. by pastoral lease inspectors), the potential remains for their more formal use either within a better resourced program, or in more intensive studies of specific areas.

The Department of Agriculture helped develop the Land Cover Change Analysis technique of remote sensing as used by the Northern Territory Department of Lands Planning and Environment. While there is no scheduled program of State-wide coverage in Western Australia, analysis is complete for much of the east Kimberley and for several areas in the

Pilbara and the shrublands. The technique is now being field tested on a district-level scale in the East Kimberley. The outputs are used for a range of purposes, including the identification of leases, or parts of leases, where the change in perennial cover over time is poor in relation to neighbouring areas. Changes in cover since 1982 can be produced for a range of stratifications within those areas for which processed imagery exists.

Range Survey Program

Almost 75 000 traverse assessments of range condition were made at 1 km intervals during the Range Survey Program. These allow a snapshot to be produced of range condition at the regional scale (Table A4). Range Condition Assessment during pastoral lease inspections will enable contemporary updates of these regional assessments for an Australia-wide information system. Summaries can also be produced for other stratifications, such as vegetation type.

Table A4 Summary of condition assessment outputs from the Range Survey Program, a joint initiative of the Departments of Land Administration and of Agriculture.

Region surveyed (and year commenced)	Total area (km^2)	No. of traverse assessments	Severely degraded and eroded area (as mapped)		Resource condition classes (% of traverse assessments)		
			km^2	%	Good	Fair	Poor
Gascoyne (1969)	63 400	2 426	1 205*	1.9*	32	53	15
West Kimberley (1972)	89 600	4 532	2 000*	2.2*	20	50	30
Eastern Nullarbor (1974)	47 400	1 273	0	0	50	10	40
Ashburton (1976)	93 600	8 608	534	0.6	50	34	16
Carnarvon Basin (1980)	74 500	10 952	647	0.9	45	32	23
Murchison (1985)	88 360	13 441	1 560	1.8	21	37	42
Roebourne Plains (1987)	10 216	1 172	233	2.3	51	27	22
North-eastern Goldfields (1988)	100 570	10 470	452	0.4	39	32	29
Sandstone-Yalgoo-Paynes Find (1992)	94 710	9 435	145	0.2	45	32	23
Pilbara (1995)	181 736	12 518	322	0.2	77	11	12
All areas surveyed	**843 576**	**74 827**	**7 098**	**0.8**	**46**	**30**	**24**

* Not mapped, estimate only

Western Australian Rangeland Monitoring System

The Western Australian Rangeland Monitoring System set of grassland sites was installed during 1994 to 1996, and a complete reassessment was finished in 1999. Shrubland sites were installed from 1993 to 1999. The first round of shrubland reassessments began in 2000 and is due to finish in 2004.

In the Kimberley, perennial grass frequency remained constant or increased on 69% of sites between the period 1994 to 1996 (installation) and 1997–1999 (first reassessment). Figure A23 provides an example output for three vegetation types. Overall, 10% of sites were judged to have improved, and 5% declined (Table A5). Across all sites, the average frequency of perennial grasses increased (Table A6), while the crown cover of woody perennials decreased on limestone grass and black soil plain vegetation groups during the same period.

Preparation of these summaries was based on stratifications that meet the needs of the Department of Agriculture and the Pastoral Lands Board. Other stratifications (e.g. using different combinations of species or on a district by district basis) can be used to prepare specific outputs for an Australia-wide system to meet commissioned needs.

Figure A23 Change in perennial grass frequency, and judgement of change, for three vegetation types (Mitchell grass, curly spinifex, southern ribbon grass) on Kimberley WARMS sites between installation (1994–1996) and reassessment (1997–1999).

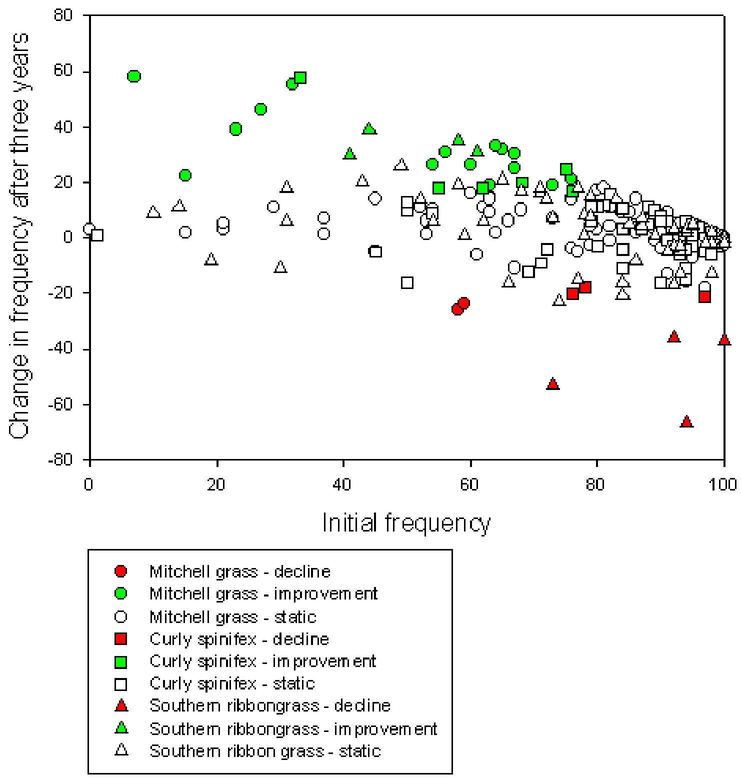


Table A5 Summary of trend assessment for Western Australian Rangeland Monitoring System grassland sites in the Kimberley, by vegetation group and Land Conservation District over the period from 1994–1996 (installation) to 1997–1999 (reassessment). The analysis was based on perennial grass frequency, all species pooled.

Land Conservation District	Vegetation group	No. of sites	Improved	Static	Declined
Broome	Curly spinifex	19	2	16	1
	Coastal vegetation	12	2	9	1
	Northern ribbon grass	2		2	
	Southern ribbon grass	1		1	
	Soft spinifex	9		8	1
Subtotal		**43**	**4**	**36**	**3**
Derby West Kimberley	Black soil plains	63	11	51	1
	Curly spinifex	31	3	26	2
	Frontage grass	11	1	9	1
	Southern ribbon grass	59	3	52	4
	Soft spinifex	1			1
Subtotal		**165**	**18**	**138**	**9**
Halls Creek – East Kimberley	Black soil plains	46	4	41	1
	Curly spinifex	6		6	
	Limestone grass	12	3	9	
	Northern ribbon grass	5	1	4	
	Southern ribbon grass	3	1	2	
	Soft spinifex	13	1	11	1
Subtotal		**85**	**10**	**73**	**2**
North Kimberley	Black soil plains	4		4	
	Curly spinifex	13	1	12	
	Frontage grass	2		2	
	Northern ribbon grass	25		22	3
	Southern ribbon grass	1		1	
Subtotal		**45**	**1**	**41**	**3**
Total		**340**	**33**	**290**	**17**

Table A6 Average change in perennial grass frequency and average change in crown cover estimates (%) for all woody species >1 m, by vegetation groups for Kimberley Western Australian Rangeland Monitoring System sites assessed and reassessed between 1994 and 1999.

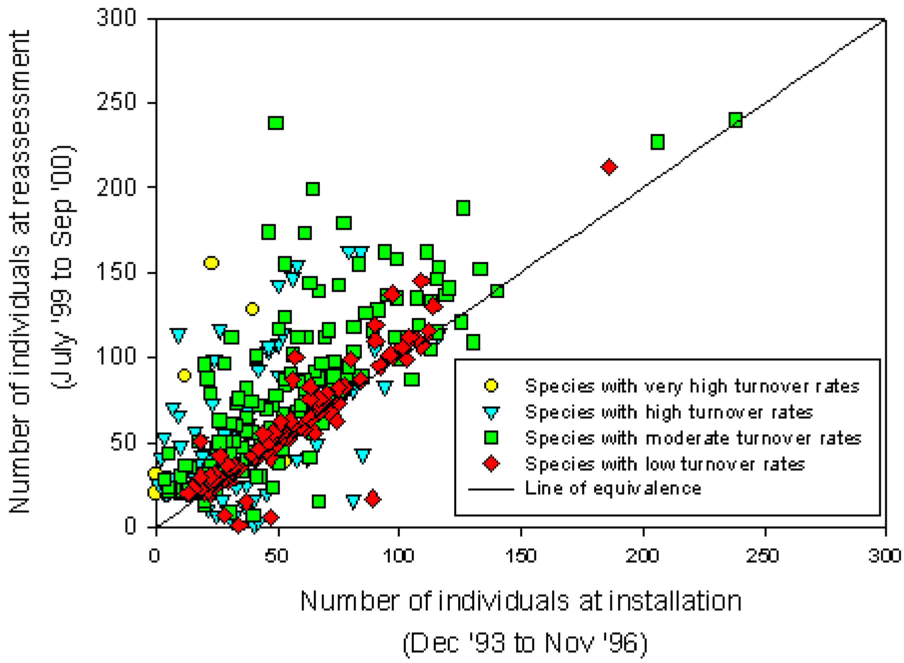
Vegetation group	No. of sites	Mean frequency 1994–1996	Mean frequency 1997–1999	Significant change
Average change in perennial grass frequency (%)				
Black soil plains	113	74.4	80.7	*
Curly spinifex	69	83.7	85.7	
Coastal vegetation	12	86.2	89.2	
Frontage grass	13	70.0	75.4	
Limestone grass	14	39.9	47.1	
Northern ribbon grass	32	88.5	85.7	
Southern ribbon grass	64	75.0	76.6	
Soft spinifex	23	84.9	86.5	
Average crown cover (%)				
Black soil plains	113	1.8	1.4	*
Curly spinifex	69	13.2	13.8	
Coastal vegetation	12	1.0	0.5	
Frontage grass	13	7.9	9.3	
Limestone grass	14	6.7	4.8	*
Northern ribbon grass	32	12.5	12.5	
Southern ribbon grass	64	6.1	5.6	
Soft spinifex	23	5.0	7.7	

Significance was tested using the two tailed paired t-test.
not significant = P>0.05

In the shrublands, most sites appear stable or are showing improvement, based on analysis of shrub dynamics. An increase in shrub populations, in most vegetation types, is seen as desirable. Furthermore, species with low turnover rates (essentially longer-lived species) are more reliable indicators of range health, being less subject to demographic fluctuations caused by recent seasonal conditions. During the period between installation (1993–1996) and reassessment (1999–2000), only 19% of shrub populations, when considered by turnover rate category, declined (Figure A24). Only a few sites showed catastrophic decline and many of these were in areas that had been uncharacteristically inundated by sequential cyclonic rains.

Outputs from the Land Cover Change Analysis technique are identical to those produced by the Northern Territory Department of Lands Planning and Environment (see Northern Territory section). These include time traces by vegetation group—either for individual leases or for entire land systems—as well as images showing change over time for specific areas and images, and which areas are performing better or worse than neighbouring areas (see Land Cover Change Analysis section for the Northern Territory).

Figure A24 Change in shrub populations from all 214 WARMS shrubland sites reassessed to end of 2000. After combining individual species into categories based on turnover rates, 351 turnover rate by site combinations were produced. Populations were filtered to include only those where either the initial or final number was greater than 20 individuals.



APPENDIX 2. TOTAL CATTLE AND SHEEP NUMBERS

Total cattle and sheep numbers for Australia's rangelands by jurisdiction ('000).

Year	Queensland		New South Wales		Western Australia		South Australia		Northern Territory		Total	
	Cattle	Sheep	Cattle	Sheep	Cattle	Sheep	Cattle	Sheep	Cattle	Sheep	Cattle	Sheep
1956	7 064	21 893	81	8 456	517	3 215	na	na	1 028	33	nc	nc
1957	7 193	23 011	100	9 086	551	3 108	187	2 524	1 176	30	9 207	37 759
1958	6 927	22 051	88	8 225	568	3 084	173	2 357	1 244	27	8 999	35 744
1959	6 626	21 923	89	8 381	569	3 211	159	2 531	1 099	19	8 542	36 064
1960	6 743	23 118	90	8 835	578	3 091	138	2 447	1 111	15	8 660	37 506
1961	6 733	21 987	99	8 344	588	3 297	115	2 206	1 154	16	8 688	35 849
1962	6 819	21 995	113	8 690	618	3 453	98	2 246	1 063	10	8 712	36 395
1963	6 950	22 709	113	9 388	661	3 417	102	2 145	1 086	9	8 911	37 669
1964	7 107	24 224	137	9 634	659	3 665	121	2 434	1 105	10	9 130	39 967
1965	7 095	23 908	115	8 416	631	3 843	132	2 368	1 067	9	9 040	38 543
1966	6 599	18 288	83	5 728	614	3 872	100	2 365	1 032	9	8 428	30 262
1967	6 626	19 211	68	5 790	629	3 984	105	2 294	1 097	8	8 525	31 288
1968	7 053	19 860	83	6 612	643	3 934	128	2 198	1 130	9	9 038	32 613
1969	7 338	20 244	110	7 936	708	4 226	153	2 485	1 185	7	9 494	34 897
1970	7 157	16 380	104	7 195	767	4 004	143	2 638	1 179	8	9 350	30 225
1971	7 550	14 723	130	7 146	746	3 796	129	2 386	1 145	9	9 701	28 060
1972	8 604	14 557	181	7 393	756	3 560	160	2 444	1 166	7	10 867	27 961
1973	9 377	13 310	169	5 030	797	3 304	176	2 381	1 237	3	11 756	24 028
1974	9 868	13 086	219	4 846	819	3 188	201	2 429	1 321	1	12 427	23 551
1975	10 425	13 878	271	5 209	867	3 199	267	2 578	1 434	1	13 265	24 865
1976	10 906	13 570	302	5 455	945	3 427	238	2 531	1 603	1	13 994	24 984
1977	11 121	13 279	314	5 399	993	3 143	271	2 375	1 664	1	14 362	24 198
1978	11 119	13 416	240	4 817	978	2 357	243	1 943	1 681	1	14 261	22 534
1979	10 514	13 568	185	4 659	954	2 191	241	2 009	1 785	1	13 680	22 427
1980	9 962	12 139	137	4 309	957	1 858	211	2 197	1 730	1	12 998	20 503
1981	9 555	10 597	119	3 761	941	1 923	182	2 256	1 675	1	12 471	18 538
1982	9 419	12 318	131	4 318	930	2 137	166	2 155	1 624	1	12 269	20 929

Year	Queensland		New South Wales		Western Australia		South Australia		Northern Territory		Total	
	Cattle	Sheep	Cattle	Sheep	Cattle	Sheep	Cattle	Sheep	Cattle	Sheep	Cattle	Sheep
1983	9 008	12 188	82	4 459	869	2 315	111	1 414	1 548	1	11 619	20 377
1984	8 844	13 003	96	5 240	898	2 237	90	1 453	1 390	1	11 318	21 935
1985	9 093	14 012	105	5 989	843	2 430	111	1 765	1 484	1	11 635	24 198
1986	9 317	14 282	108	6 094	838	2 679	143	1 838	1 458	1	11 864	24 895
1987	8 729	14 603	112	6 117	864	2 736	167	1 920	1 439	1	11 311	25 377
1988	8 501	14 340	124	6 504	859	2 443	183	1 918	1 345	0	11 012	25 205
1989	8 661	14 845	156	7 231	899	2 389	198	2 022	1 388	0	11 302	26 488
1990	8 968	16 637	165	7 387	876	2 601	217	2 231	1 327	0	11 552	28 855
1991	9 480	17 401	169	7 198	751	2 568	205	2 237	1 353	0	11 957	29 404
1992	9 636	15 238	142	5 526	767	2 393	162	1 968	1 334	0	12 041	25 124
1993	9 493	13 380	164	4 896	716	2 287	189	1 953	1 347	0	11 910	22 516
1994	9 495	11 528	210	5 208	740	2 464	193	1 909	1 435	0	12 074	21 109
1995	9 367	11 460	210	4 909	803	2 360	190	1 914	1 421	0	11 990	20 643
1996	9 574	10 586	204	5 152	793	2 356	179	1 978	1 503	0	12 252	20 072
1997	10 422	10 528	200	4 932	800	2 381	191	1 736	1 609	0	13 222	19 577
1998	10 867	10 992	188	4 613	906	2 682	224	1 790	1 567	0	13 753	20 077
1999	10 748	10 556	190	3 952	844	2 049	217	1 780	1 567	0	13 566	18 337

na = not available

nc = not calculated

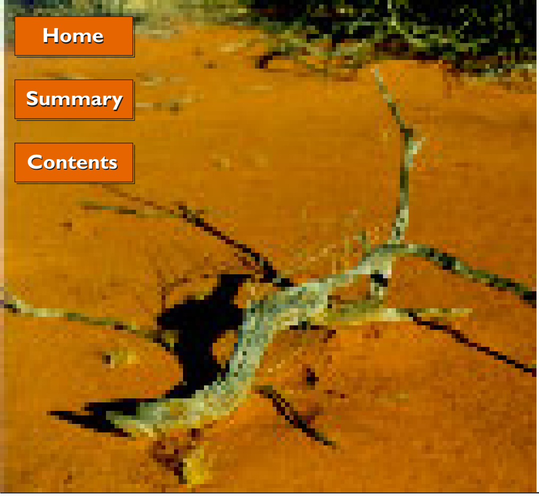
APPENDIX 3. LAND TENURE CHANGES

Land tenure changes in Australia's rangelands since 1955 (km^2). Total area of rangelands on which these figures are based is 5 545 314 km^2

Classes of tenure	1955	1965	1975	1985	1995	1999
State-owned crown land with assigned uses (transport corridor, stock routes)	72 314	72 345	68 407	60 712	58 686	58 236
State-owned crown land with no assigned uses	1 622 623	1 217 053	1 103 368	938 075	807 460	804 167
Defence reserve	225 404	257 431	124 339	129 685	129 617	129 617
Freehold land (non-Indigenous)	539 615	538 998	538 322	532 370	525 296	525 272
Non-Indigenous pastoral lease**	2 709 187	2 895 721	2 931 060	2 844 063	2 698 722	2 661 706
Indigenous pastoral lease**	2 754	17 041	55 590	46 635	102 130	109 347
Indigenous land*	344 409	437 571	584 276	708 130	815 516	815 857
National parks (proclaimed and gazetted)	1 399	10 529	27 909	80 174	143 413	156 982
Conservation lands (not gazetted)	22 341	91 995	100 138	184 136	225 268	244 905
Forested areas (State forest, forest reserve)	4 075	5 409	10 511	19 349	32 787	32 787
Other reserves (hunting, historical, heritage)	759	786	835	877	2 454	2 473
Water reserves (wetlands, storages)	309	309	432	981	3 759	3 759
Marine reserves	254	254	254	254	334	334

* This broad class incorporates a range of tenure types including Indigenous land that was administered by the Crown (States) until the 1970s for Western Australia, South Australia, and Northern Territory, the 1980s for New South Wales and the 1990s for Queensland. Although instances of Crown administration still exist, most are now administered or owned by Indigenous land trusts, land councils or Indigenous local governments. In some instances, historical data erroneously referred to large areas as Indigenous freehold land.

** Indigenous pastoral lease and non-Indigenous pastoral lease are the same tenure. These have been subdivided as requested by the Indigenous Land Council to fully display the scope of Indigenous holdings and management in Australia's rangelands.



GLOSSARY

Biodiversity
Variety of life forms including the different plants, animals and microorganisms, the genes they contain, and the ecosystems they form. Biodiversity is usually considered at three levels: genetic, species and ecosystem.

Biogeographic region, bioregion, IBRA
Based on an Interim Biogeographic Regionalisation for Australia. A complex land area composed of a cluster of interacting ecosystems that are repeated in similar form. Region descriptions seek to describe the dominant landscape scale attributes of climate, lithology, geology, landforms and vegetation. Biogeographic regions vary in size with larger regions found where areas have more subdued terrain and arid and semi-arid climates.

Dryland salinity
The salinisation of land and water resources due to land use impacts by people. It results from rising watertables mobilising salt in the soil from dryland management systems as distinct from irrigated systems.

Ecosystem
Community of organisms (that may include people) interacting with one another. Incorporates the physical, chemical and biological processes inherent in that interaction and the environment in which they live.

Environmental water provisions
Water allocated to support the ecological functioning of aquatic and other dependent habitats based on environmental, social and economic considerations. Includes existing user rights and is broadly specified under the Council of Australian Governments Water Reform Initiative.

Environmental water requirements
Descriptions of the flow regimes (e.g. volume, timing, seasonality, duration) needed to sustain the ecological values of aquatic ecosystems including their processes and biological diversity.

Freehold
Tenure where land is held for life and owned by individuals or entities.

Gigalitre (GL)
1000 megalitres (ML).

Grazing gradient
The varying intensity of grazing on the landscape at increasing distance from water.

Ground-based monitoring point
Data collected at a defined site (quadrats or transects) using specified methods.

Groundwater
Water naturally stored underground in rock fractures and pores.

Groundwater dependent ecosystems
Ecosystems that are dependent on groundwater for their existence and health (e.g. mound springs).

Groundwater management unit
A hydraulically connected groundwater system that is defined and recognised by State and Territory agencies. This definition allows for management of the groundwater resource at an appropriate scale at which resource issues and intensity of use can be incorporated into local groundwater management practices.

Hundreds and Counties
In South Australia, land holdings were divided and identified using a system of Hundreds and finer resolution Counties. This system was replaced in 1983 with statistical local areas.

Landsat
The US Landsat 7 satellite that gathers remotely sensed images of the Earth's land surface and coastal regions.

Landscape condition
A value judgement related to the worth of a landscape for a particular land use. Condition is not necessarily equivalent to function. This judgement may depend on the presence of species considered important for a particular land use and may be influenced by cultural or social views or values.

Landscape Cover Change Analysis
The name given to the Tier 2 rangeland monitoring method in tropical savannas. It involves the integration of time-series Landsat satellite data with ground monitoring, land resource and infrastructure spatial data sets to infer land condition and trend.

Landscape function
The ability of a landscape to conserve and use scarce water and nutrients.

Leasehold
Tenure where land is occupied by individuals or entities under a lease agreement with a State or Territory government. Often conditions of the lease include the use to which the land can be allocated.

Megalitre (ML)
1 000 000 litres.

Monitoring (ground) point
Permanently located area (point) at which repeated recordings are made.

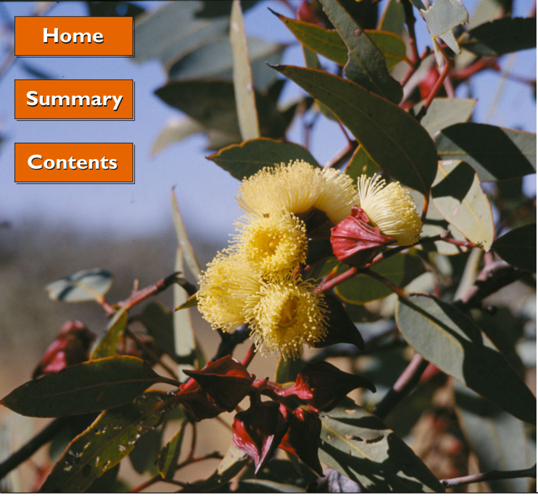
NOAA
National Oceanic and Atmospheric Administration satellites designed for observing weather systems and with a resolution of up to 1 km. Advanced High Resolution Radiometer (AVHRR) is an imaging instrument aboard the NOAA Polar orbiting satellites. The instrument detects radiation in five channels including visible, near infrared, shortwave infrared, and thermal infrared.

Normalised Difference Vegetation Index (NDVI)
A measure of the response of vegetation to rainfall, or an estimate of vegetation greenness. Greenness depends on the amount, structure and composition of vegetation in each 1 km by 1 km pixel. Normalised Difference Vegetation Index data are compiled every two weeks throughout the year and provide continental coverage.

Rainfall effectiveness
A measure of the productivity of vegetation measured in terms of leaf area, vigour or biomass. Rainfall effectiveness does not provide a measure of water balance it does not include rainfall lost as run-off to percolation or evaporation.

Statistical local area
A general purpose spatial unit based on the boundaries of incorporated bodies of local government where these exist. In aggregate, statistical local areas cover the whole of Australia without gaps or overlaps.

Time trace
Repeated measurements over a period of time.



Eucalyptus pachyphylla: mallee tree from spinifex sand dune country

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Grass tree on sandy plain at the base of the Peterman Ranges

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We would like to acknowledge the contribution of those involved in completing rangelands Monitoring theme projects. To the real unsung heroes of these projects, the project teams, we extend our sincere thanks.

Project 1. An assessment of change in ecosystem function, trends in intensity of use and history of climate and fire that impact on the ecosystem

1.1 Ecosystem function analysis of rangeland monitoring data – David Tongway, CSIRO Sustainable Ecosystems

1.2 Indices of change in ecosystem function (cover) for northern South Australia using Landsat Thematic Mapper satellite data – Amanda Brook, Rodger Tynan, Department for Environment and Heritage South Australia

1.3 Indices of change in ecosystem function at the national scale using Advanced High Resolution Radiometer Normalised Difference Vegetation Index data – Shane Cridland, Nikki Fitzgerald, Environmental Resources Information Network

1.4 Incidence of extreme climatic events – Shane Cridland, Nikki Fitzgerald, Environmental Resources Information Network

1.5 Intensity of land use – Wayne Hall, Michael Gutteridge, Queensland Centre for Climate Applications, Department of Natural Resources and Mines

1.6 Implementation project: Regional land condition and trend assessment in tropical savannas – Robert Karfs, Rod Applegate, Rohan Fisher, Dominique Lynch, Deborah Mullin, Paul Novelly, Luke Peel, Kathleen Richardson, Philip Thomas, Jeremy Wallace, Department of Lands, Planning and Environment, Northern Territory

Project 2. Determining trends in economic, social and institutional factors that influence land use and management in rangelands

2.1 Indicators within a decision framework – Jenny Gordon, Centre for International Economics; Mark Stafford-Smith, CSIRO Sustainable Ecosystems; Gerald Haberkorn, Bureau of Rural Sciences

2.2 Change in land tenure/land use – Wayne Hall, Michael Gutteridge, Queensland Centre for Climate Applications, Department of Natural Resources and Mines

2.3 Compiling a database of socioeconomic indicators for rangelands – Gerald Haberkorn, Colin MacGregor, Shannon Kelson, Con Charalambou, Bureau of Rural Sciences

Project 3. Developing an adaptive framework for monitoring biodiversity in rangelands

John Childs, Peter Whitehead, John Woinarski, Alaric Fisher, Carmen Verhagan, Cooperative Research Centre for Tropical Savannas Management

Project 4. Developing information and decision aids to help decision makers reach their management decisions

4.1 Collation of State monitoring activities – Ian Watson, Department of Agriculture

4.2 National reporting framework – Alec Holm, Alec Holm and Associates

4.3 Plain English summaries of regional information – Roland Breckwoldt, Rob Thorman, Jenny Andrew, Resource Policy and Management Pty Ltd

4.4 Web reporting system – Peter Fox, Dave Johnson, EarthWare Systems (Australia) Pty Ltd

Project 5. Coordination and reporting

Ian Watson, Department of Agriculture

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Department of Agriculture (Western Australia)
inside cover, pages 39, 58, 70, 72, 74, 76, 78, 96, 101, 103, 104, 115, 118, 122

Department of Land and Water Conservation (New South Wales)
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NATIONAL LAND AND WATER RESOURCES AUDIT

Who is the Audit responsible to?

The Minister for Agriculture, Fisheries and Forestry – Australia has overall responsibility for the Audit as a program of the Natural Heritage Trust. The Audit reports through Minister Truss to the Natural Heritage Board comprising both Minister Truss and Senator the Hon. Robert Hill, Minister for the Environment and Heritage.

How is the Audit managed?

An Advisory Council manages the implementation of the Audit. Dr Roy Green, with a background in research, science policy and management chairs the Advisory Council. Members of the Advisory Council and the organisations they represent in August 2001 are: Alex Campbell (L&WA), Geoff Gorrie (AFFA), Stephen Hunter (EA), Bryan Jenkins (SCEP), John Radcliffe (CSIRO), Peter Sutherland (SCARM), Jon Womersley (SCC), Roger Wickes (SCARM) and Colin Creighton (Audit).

What is the role of the Audit Management Unit?

The Audit Management Unit's role has evolved over its five-year life. Phases of activity include:

Phase 1. Strategic planning and work plan formulation—specifying (in partnership with Commonwealth, States and Territories, industry and community) the activities and outputs of the Audit—completed in 1998–99.

Phase 2. Project management—letting contracts, negotiating partnerships and then managing all the component projects and consultancies that will deliver Audit outputs—a major component of Unit activities from 1998–99 onwards.

Phase 3. Reporting—combining outputs from projects in each theme to detail Audit findings and formulate recommendations—an increasingly important task in 2000–2001 and the early part of 2001–02.

Phase 4. Integration and implementation—combining theme outputs in a final report, working towards the implementation of recommendations across government, industry and community, and the application of information products as tools to improve natural resource management—the major focus for 2001–2002.

Phase 5. Developing long term arrangements for continuing Audit-type activities—developing and advocating a strategic approach for the continuation of Audit-type activities—complete in 2001–2002.

The Audit Management Unit has been maintained over the Audit's period of operations as an eight-person multidisciplinary team. This team as at August 2001 comprises Colin Creighton, Warwick McDonald, Stewart Noble, Maria Cofinas, Jim Tait, Rochelle Lawson, Sylvia Graham and Drusilla Patkin.

How are Audit activities undertaken?

As work plans were agreed by clients and approved by the Advisory Council, component projects in these work plans were contracted out. Contracting involves negotiation by the Audit to develop partnerships with key clients or a competitive tender process.

Facts and figures

• Total Audit worth, including all partnerships	in excess of $52 m
• Audit allocation from Natural Heritage Trust	$34.19 m
• % funds allocated to contracts	~ 92%
• Total number of contracts	130

RANGELANDS

This CD contains

• rangeland atlas (CD version) •

• an introductory video on Australia's rangelands •

• photographic sequences since 1920 •

• link to Australian Natural Resources Atlas online •

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