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Extract from Rangelands 2008 — Taking the Pulse
3. Change in the rangelands

Assistant Secretary
Biodiversity Conservation Branch
Department of the Environment, Water, Heritage and the Arts
GPO Box 787
Canberra ACT 2601
Australia

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3 Change in the rangelands

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

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

Climate variability

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

Table 3.1 Themes and information types

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

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

October 1983

September 1984

October 1987

September 1988

Photo: WA Department of Agriculture and Food

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

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

Climate variability information

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

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[6] http://www.bom.gov.au/climate

[7] http://www.longpaddock.qld.gov.au

[8] http://www.nrw.qld.gov.au/silo

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

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

Seasonal quality

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

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

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

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

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

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

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

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

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

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

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

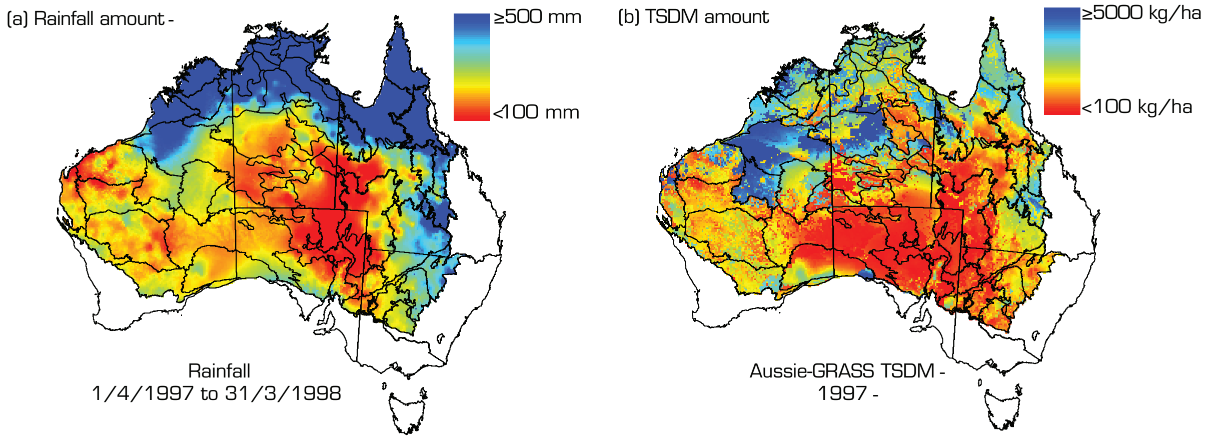
IBRA = Interim Biogeographic Regionalisation for Australia; TSDM = total standing dry matter

Seasonal quality for a selected year

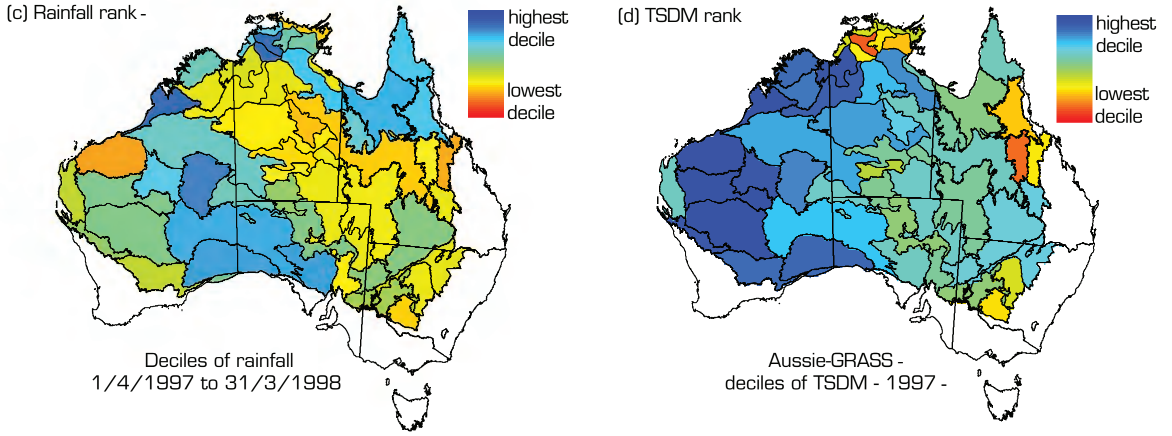
For one rainfall year (1 April 1997 to 31 March 1998) across all rangeland IBRA bioregions, *seasonal quality* was indicated by both rainfall and TSDM. Rainfall patterns were derived from SILO gridded data; TSDM data were simulated by the AussieGRASS model. These *seasonal quality* patterns (Figure 3.2)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

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

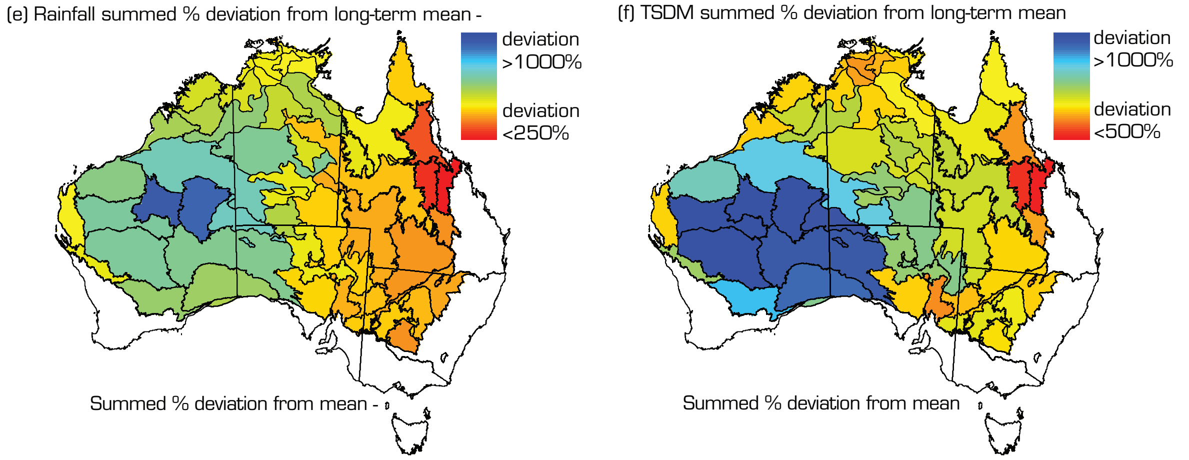
Figure 3.2 ***Seasonal quality*, all rangeland bioregions**


(a) Rainfall amount -

(b) TSDM amount


(c) Rainfall rank -

(d) TSDM rank


(e) Rainfall summed % deviation from long-term mean -

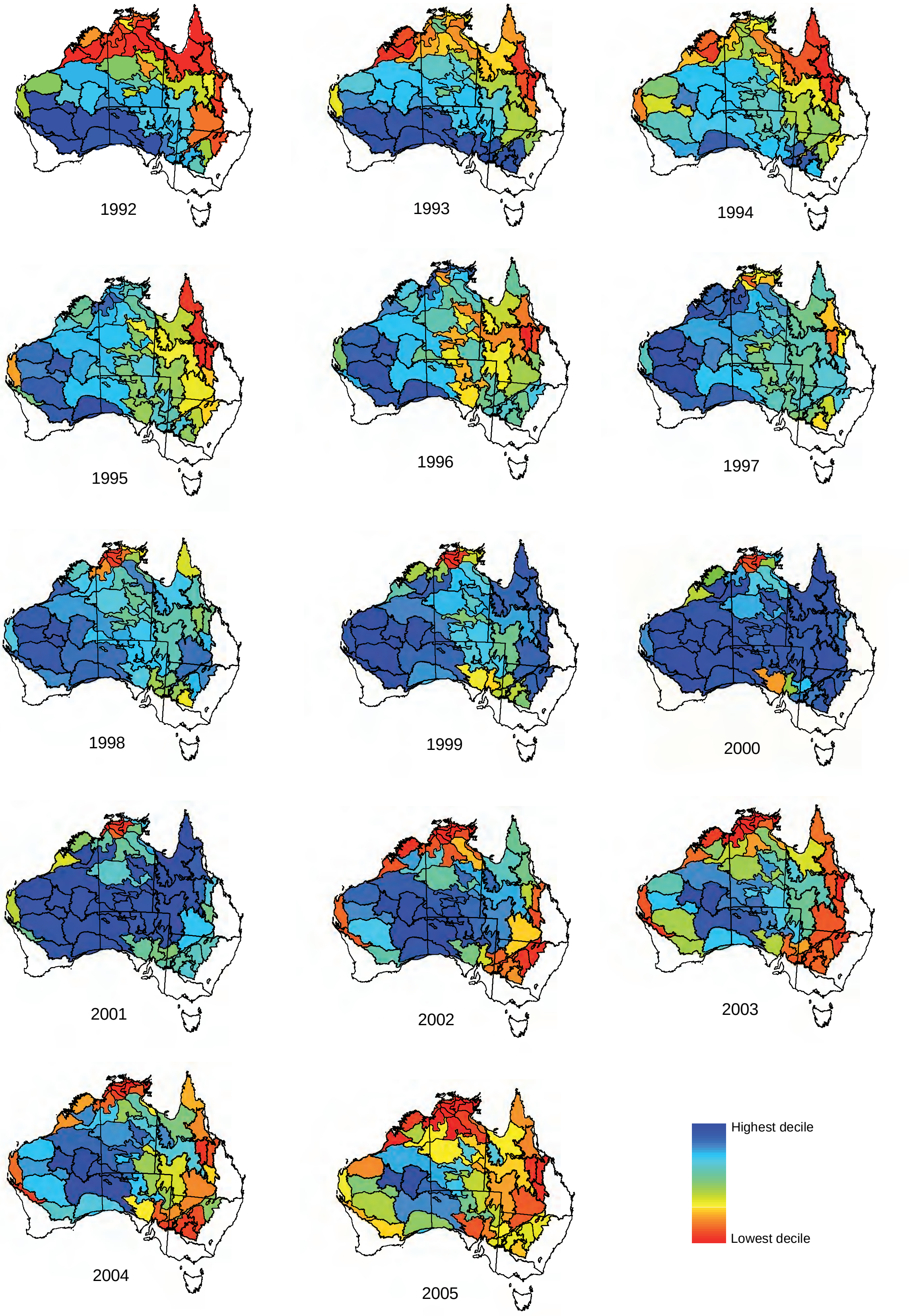
(f) TSDM summed % deviation from long-term mean

Rainfall

Simulated pasture biomass (TSDM)

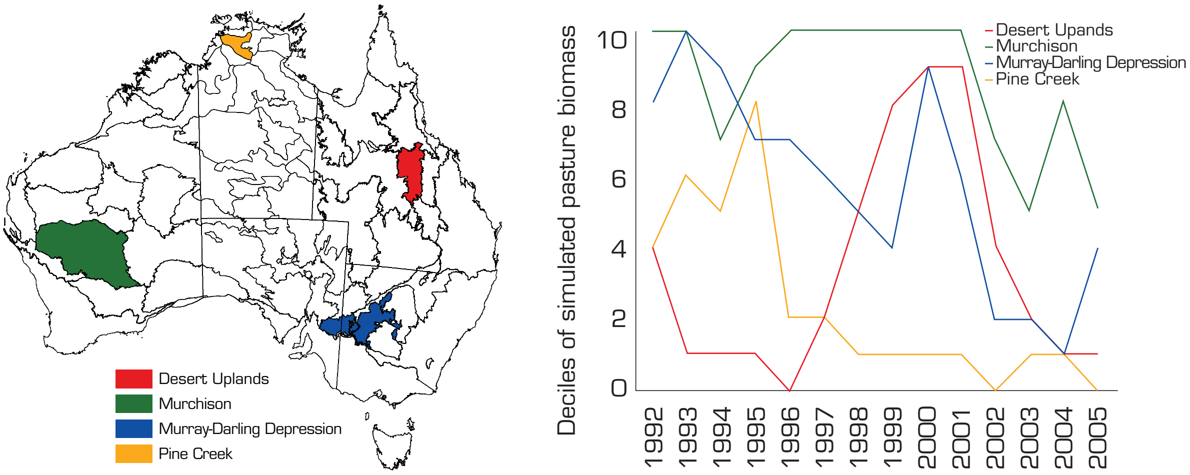
Data source: http://www.bom.gov.au/silo (accessed 23 April 2006). Maps compiled by the ACRIS-MU.

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



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

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



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

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

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

Pasture biomass by IBRA bioregion, 1992–2005

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

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

Time traces of changes in pasture biomass

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

These time traces indicate the following:

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

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

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

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

Key points

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

Landscape function

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

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

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

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

Figure 3.5 Functional and dysfunctional landscapes in central Australia

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

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

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

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

Changes in landscape function

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

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

1965

1996

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

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

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

Gross change — all seasons

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

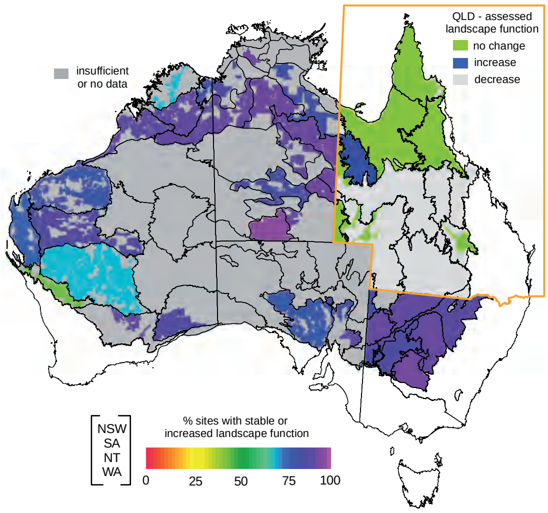
An estimate of the reliability of these scores to accurately report change in landscape function is also mapped (Figure 3.7, bottom). The reliability scores are based on a composite of:

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

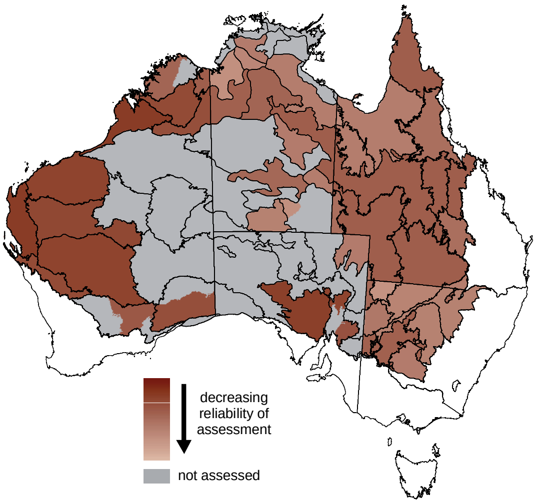
At most monitoring sites within pastoral bioregions in NSW, SA, the NT and WA, landscape function was either stable or had increased (Figure 3.7, top). These findings had moderate to high reliability (Figure 3.7, bottom), except for some subregions in central Australia, the northern Kimberley and the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

In Queensland, landscape function did not change in northern bioregions (ie Cape York Peninsula, much of the Einasleigh Uplands and the Gulf Plains) but increased across the Mount Isa Inlier (Figure 3.7, top). Landscape function was also stable in parts of the Brigalow Belt South (two sub-IBRAs), Simpson–Strzelecki Desert (two sub-IBRAs) and Channel Country (one sub-IBRA). Reliability was generally moderate for all bioregions reported (Figure 3.7, bottom).

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



Stable or improved landscape function



Reliability - landscape function

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

Bottom: Reliability estimates for those changes.

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

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

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

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

Seasonally adjusted change

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

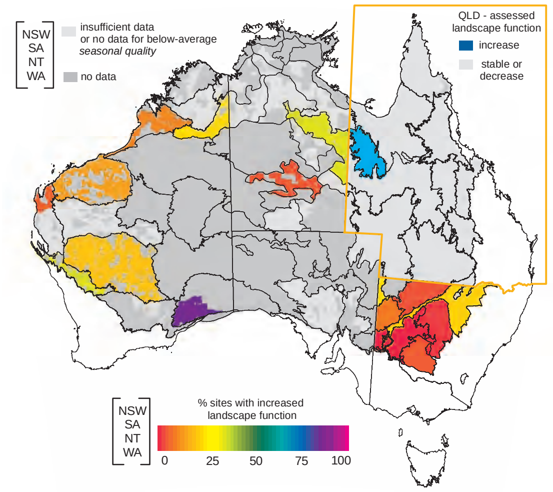
For NSW, SA, the NT and WA, maps illustrating seasonally adjusted changes in landscape function are based on monitoring data from field sites, whereas for Queensland maps are based on a combination of field observations and AussieGRASS simulations.

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

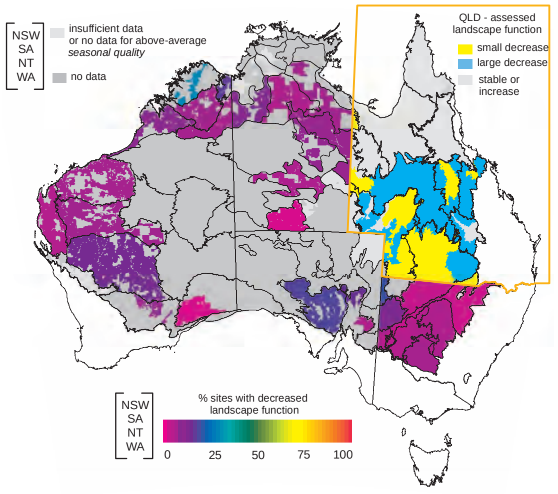
There were seven pastorally important bioregions where 20% or more of monitoring sites assessed following poor *seasonal quality* showed increased landscape function instead of the expected decrease (Figure 3.8, top panel). Notable examples were the Nullarbor 2 sub-IBRA and Yalgoo IBRA. Lesser increases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

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

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



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



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

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

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

Box 3.1 Rangeland monitoring of landscape function

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

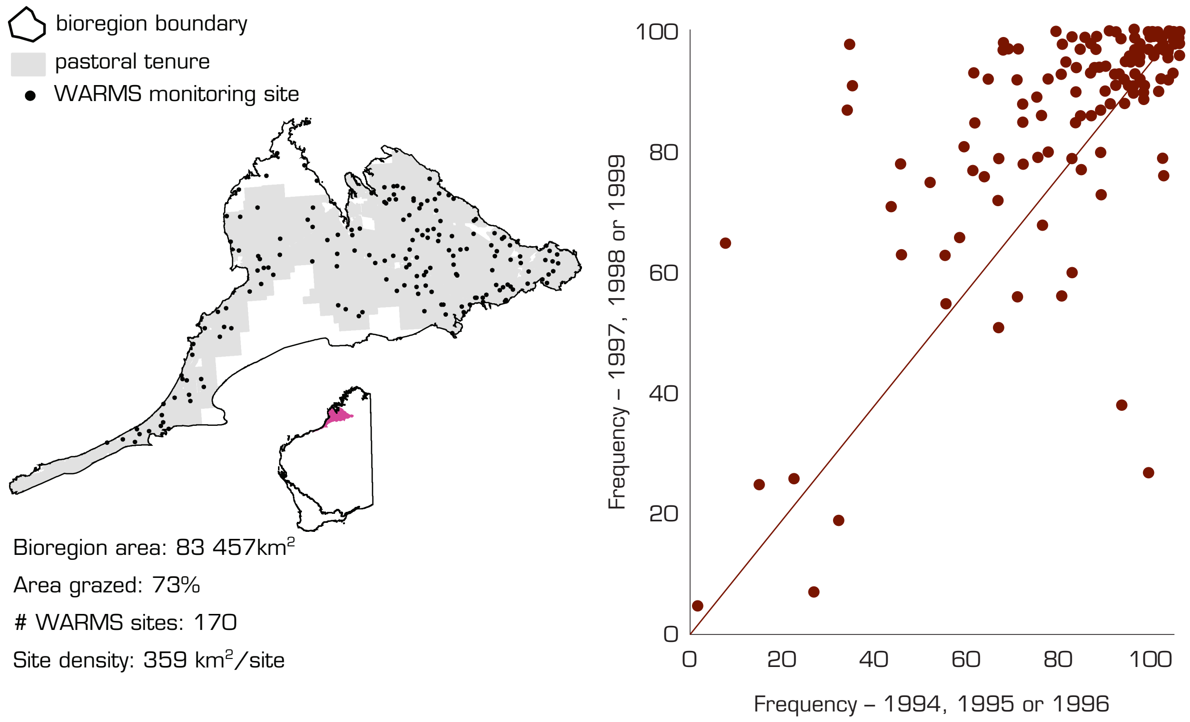
Reliability in reporting change in landscape function is indicated for each region.

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

Dampierland IBRA: a regional example of change in landscape function

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

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



Left: WARMS sites in the Dampierland bioregion

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

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

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

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

Source: see WARMS in Box 3.1.

Key points

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

Sustainable management

Sustainable management can be evaluated by assessing changes in:

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

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

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

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

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

Photo: NSW Department of Environment and Climate Change

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

Critical stock forage

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

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

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

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

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

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

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

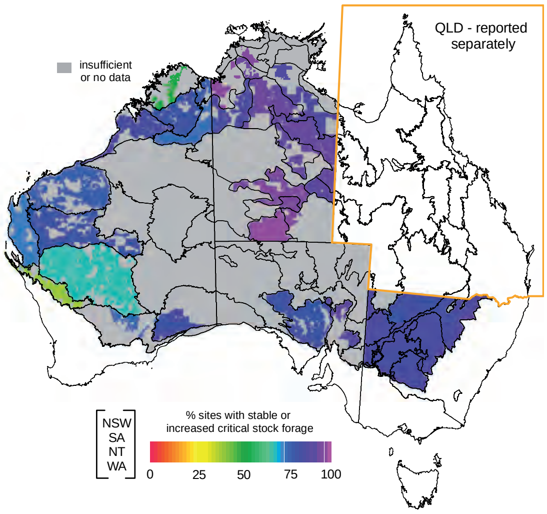
Changes in stock forage: site-based monitoring

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

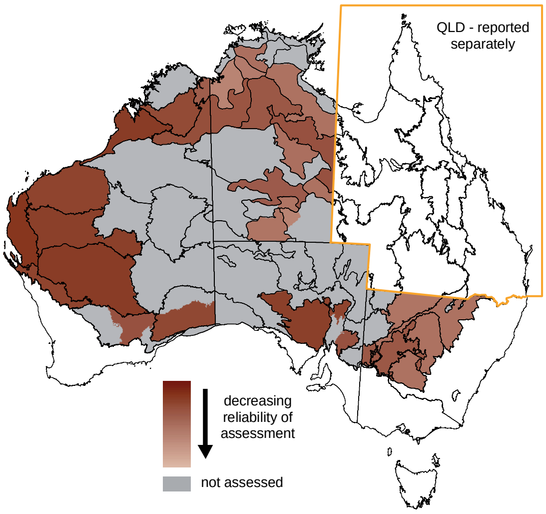
Gross change — all seasons

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

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



Stable or improved critical stock forage, 1992 to 2005



Reliability - critical stock forage

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

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

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

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

Box 3.2 Rangeland monitoring of stock forage

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

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

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

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

Seasonally adjusted change

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

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

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

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

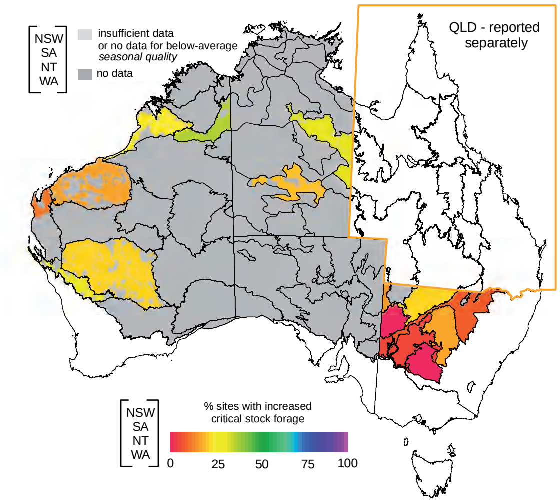
Changes in stock forage: AussieGRASS simulations

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

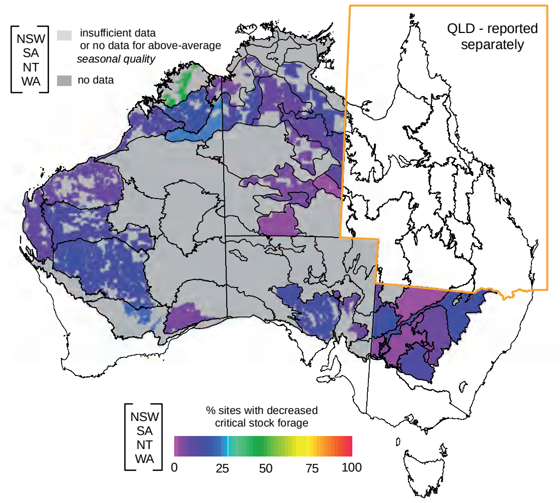
Sustainability of pasture utilisation, 1991–2005

Most of the Brigalow Belt North and South, Cape York Peninsula and Einasleigh Uplands bioregions had utilisation levels below the specified safe threshold (Figure 3.14), which suggests that levels of stock forage were being sustained. Three sub-IBRAs in the Mitchell Grass Downs (Barkly Tableland, Georgina Limestone and Northern Downs), the Simpson Desert and Dieri sub-IBRAs of the Simpson–Strzelecki Dunefields, and the Wellesley Islands (Gulf Plains bioregion) also appeared to have sustainable levels of pasture utilisation. The reliability of those assessments is presented in Figure 3.15.

Figure 3.13 Seasonally adjusted changes in forage species across rangeland regions



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



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

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

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

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

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

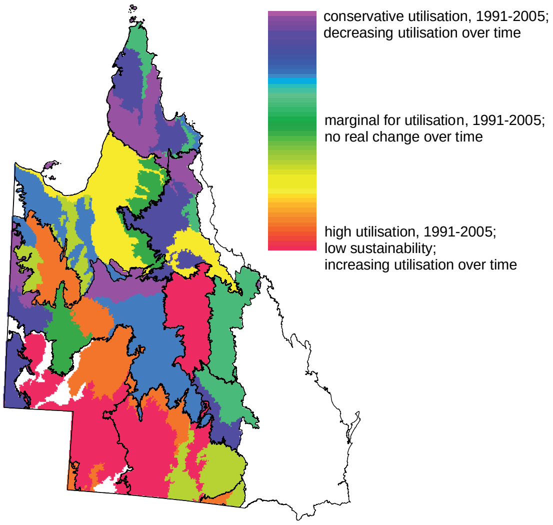
Spatial averaging of utilisation levels across sub-IBRAs conceals local variability. Within sub-IBRAs there were undoubtedly areas (paddocks and properties) with lower (more conservative) and higher (less sustainable) levels of pasture utilisation than that reported as an average over the sub-IBRA.

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

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

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

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



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

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

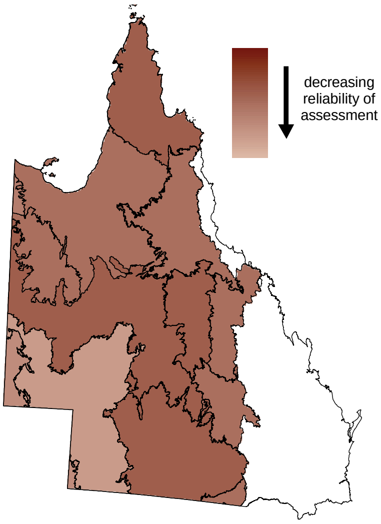
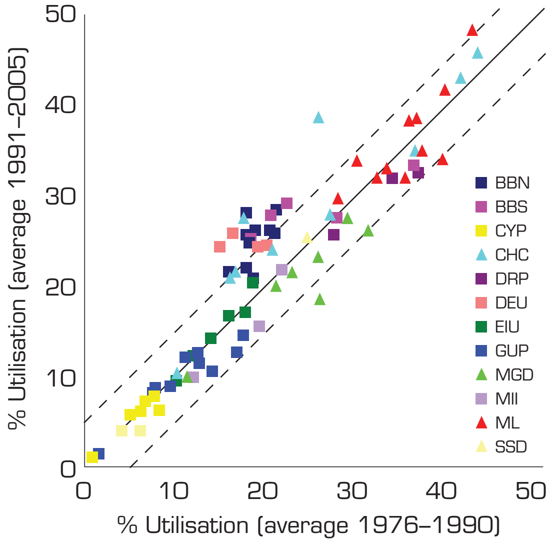


Figure 3.16 Spatially averaged levels of pasture utilisation for Queensland sub-IBRAs, grouped by bioregion



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

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

Caveats on reporting change based on AussieGRASS simulations of pasture utilisation

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

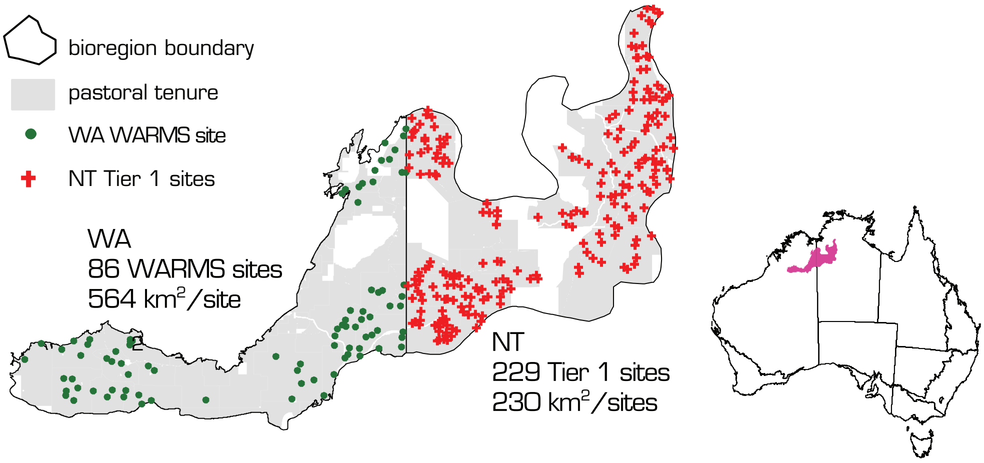
- Survey data on stock numbers sourced from the Australian Bureau of Statistics (ABS), which are essential to AussieGRASS simulations, are possibly inadequate in some areas, especially in the far west and on Cape York Peninsula, where there are few pastoral holdings.
- The safe utilisation level for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

Regional reporting of change in critical stock forage

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

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

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



Data sources: see Box 3.2.

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

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

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

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

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

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

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

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

Key points

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

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

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

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

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

Pastoral plant species richness

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

Changes in pastoral plant species richness

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

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

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

Photo: CSIRO, Alice Springs

Gross change — all seasons

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

Seasonally adjusted change

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

Box 3.3 Rangeland monitoring of plant species richness

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

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

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

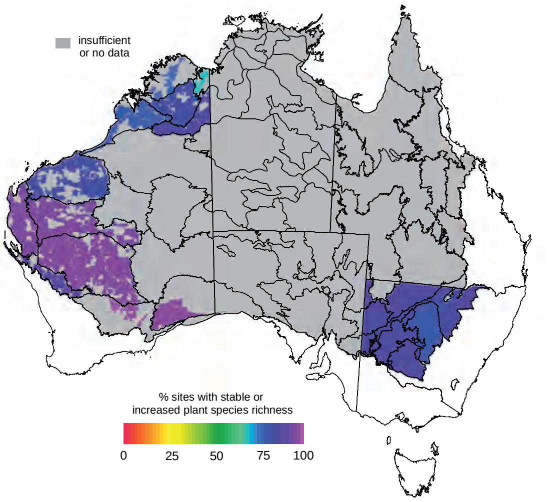
In WA, only perennial plant species are recorded on WARMS sites in order to dampen the effects of seasonal quality. For this analysis, only native plant species were included, so an increase in richness represents an increase only in that component of sustainable management, except in cases where contributing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

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

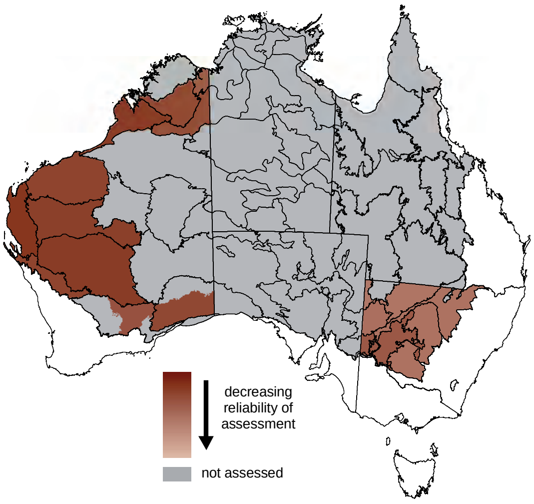
Although species richness is recorded somewhat differently on WA and NSW monitoring sites, changes were reported by presenting the percentage of sites that had changed beyond a specified threshold value. Bioregions were excluded from reporting if they did not have at least 12 sites that had been reassessed.

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

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



Stable or improved species richness of native plant species



Reliability - species richness of native plants

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

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

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

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

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

Key points

An analysis of pasture species richness data revealed that:

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

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

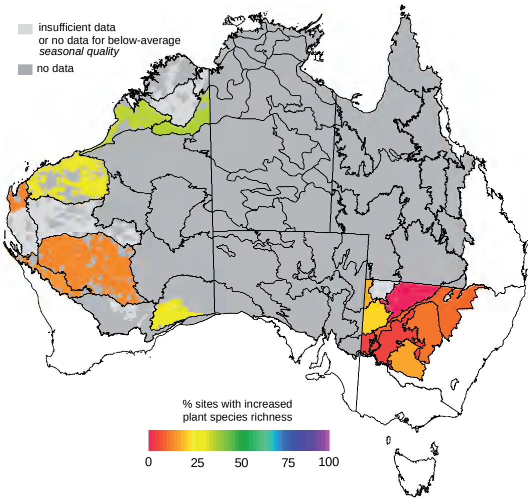
Distance from water for stock

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

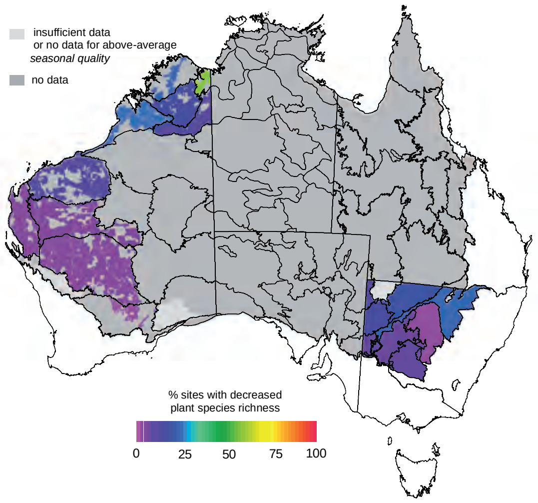
Background

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

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



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



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

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

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

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

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

Figure 3.21 Liquid gold

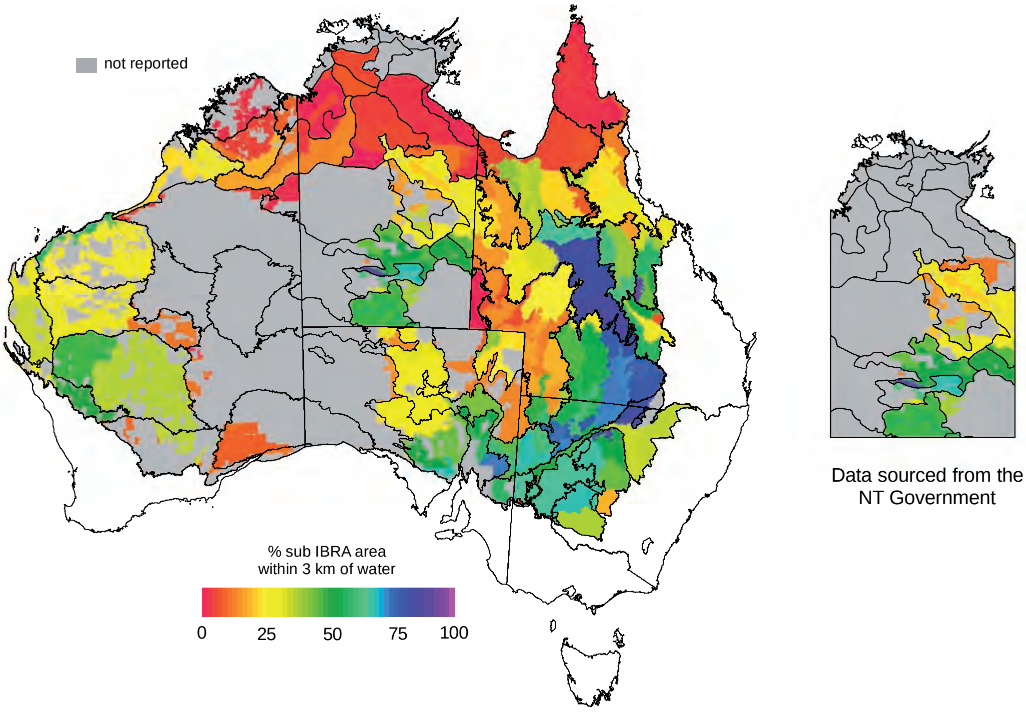
Adding waterpoints brings water closer to better feed and increases animal production but can be detrimental to biodiversity.

Photo: Jonathan Condon

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

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

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



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

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

Box 3.4 Water in the rangelands

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

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

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

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

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

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

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

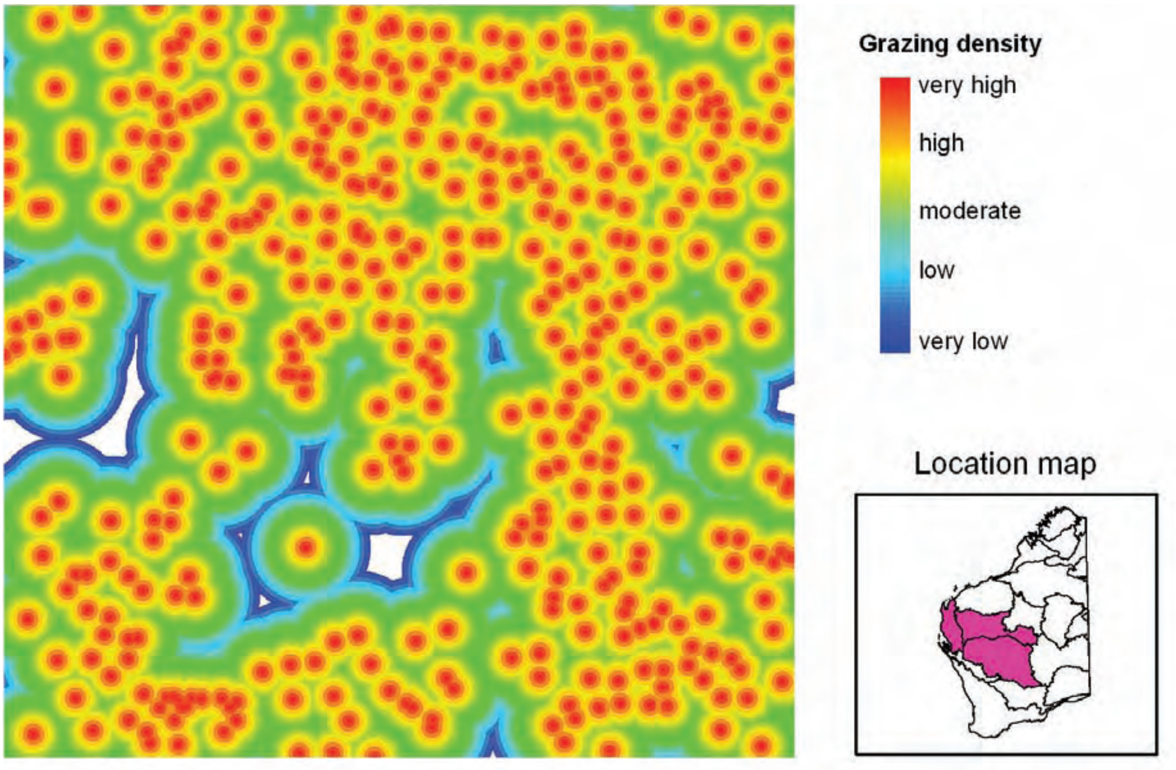
Ready access to water creates both winners and losers in terms of biodiversity. Biodiversity is generally better protected in areas remote from water and, from this perspective, increased density of waterpoints poses a threat to biodiversity (see the Biodiversity theme in this section of the report).

Water for stock: current status

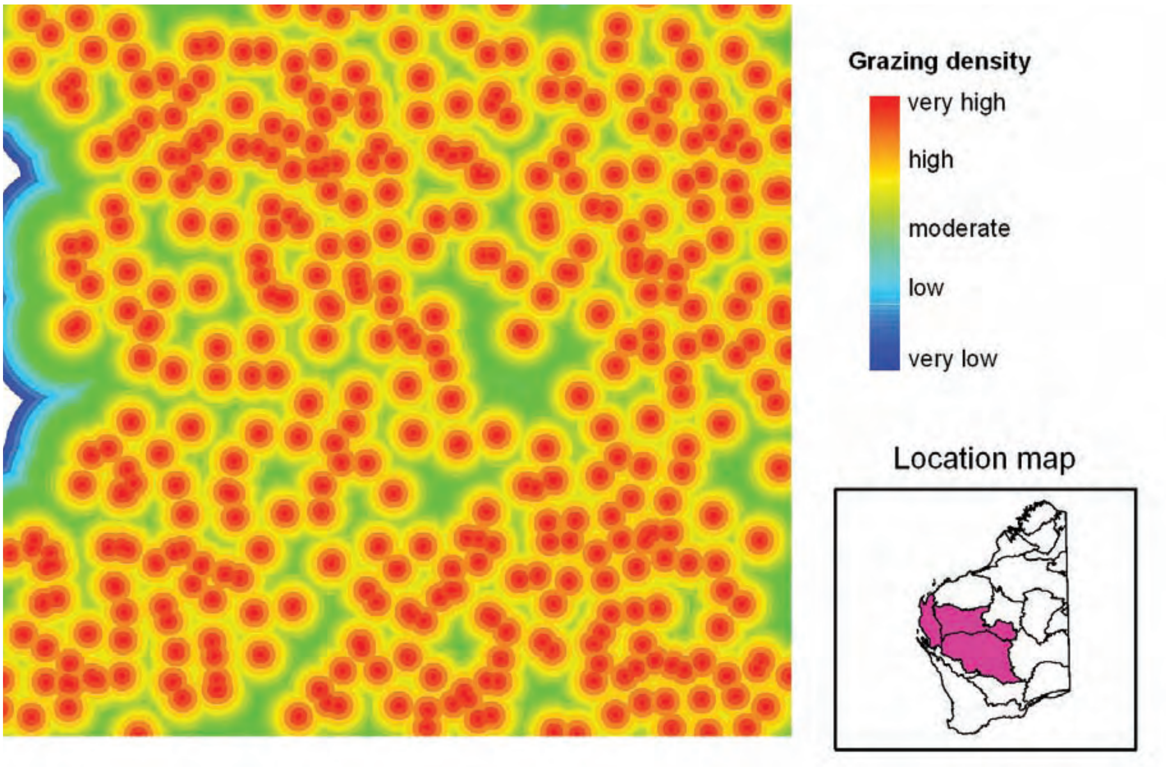
Across Australia's rangelands, there are regional differences in the proportional area within 3 km of stock waterpoints (Figure 3.22). In SA, sub-IBRAs in the southern rangelands (ie the Riverina, Flinders

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

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



Distance from permanent water circa 1990 for the area shown above



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

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

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

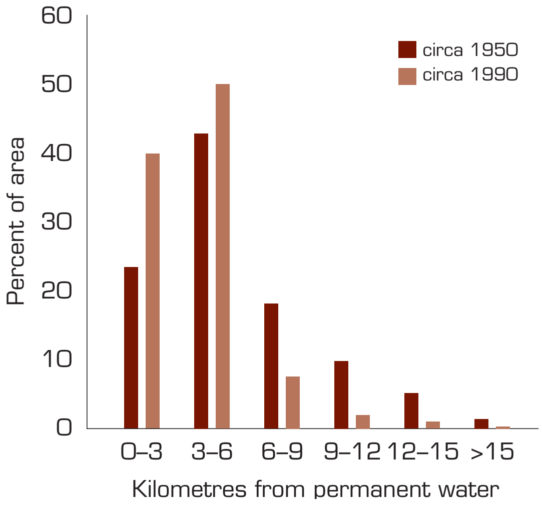
In WA, sub-IBRAs with the highest percentage area within 3 km of water include Roebourne (Pilbara IBRA, 59%), Tallering (Yalgoo IBRA, 51%) and Western Murchison (Murchison IBRA, 49%). The percentage of sub-IBRA area within 3 km of artificial water sources decreases from west to east towards the deserts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

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

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

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

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



Data and graph: Watson et al (2005a)

Change in the availability of water for stock

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

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

In the sample area (Figure 3.24), there was less land at greater distances from water and more land close to water in the 1990s than in the 1950s. This pattern was found across all land types, although the change was most pronounced in the more highly productive and fragile systems. On only one land type (the resilient and low-productivity 'Sandplains and occasional dunes

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

with spinifex grasslands' type) was stock waterpoint distribution largely unchanged since the 1950s (Watson et al 2005a).

Key points

An analysis of waterpoint data found the following:

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

These findings raised important issues:

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

Invasive weeds

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

Background

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

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

Sources of information

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

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

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

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

Examples of invasive weeds

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

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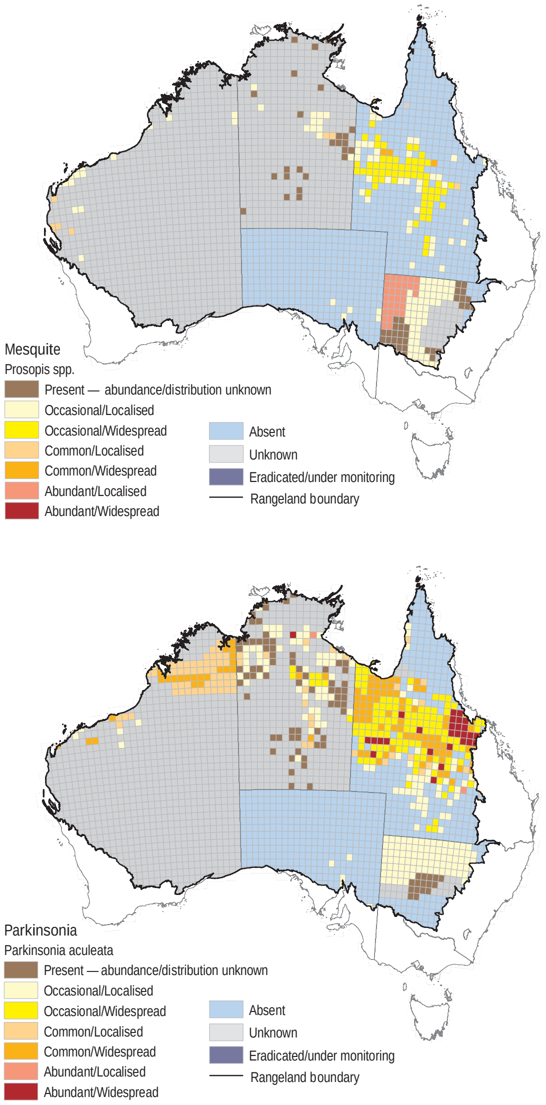
[14] NLWRA website: http://www.anra.gov.au (accessed 3 July 2007); Weeds of National Significance website: http://www.weeds.org.au/natsig.htm (accessed 3 July 2007).

Figure 3.25 Parkinsonia (*Parkinsonia aculeata*) infestation

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

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

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



Top: Mesquite

Bottom: Parkinsonia

Source: NLWRA, July 2007

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

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

Invasive weed management

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

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

Key points

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

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

Total grazing pressure

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

Livestock densities

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

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

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

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

Change in livestock density

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

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

Box 3.5 Data on livestock numbers

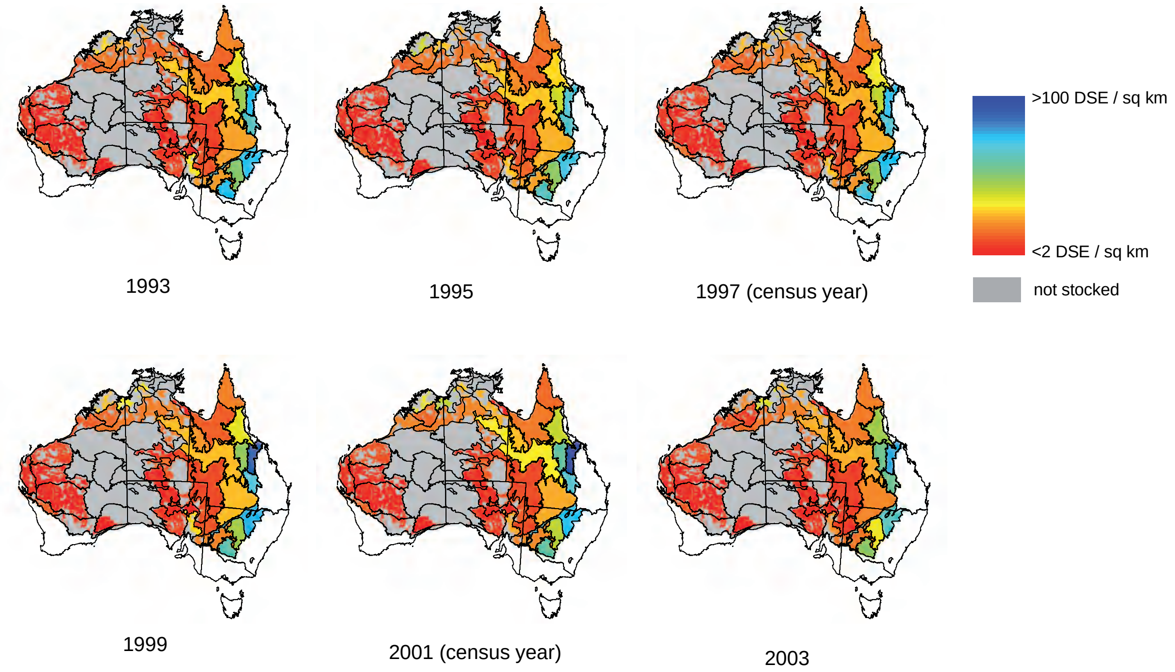
The ABS conducts annual assessments of domestic stock (sheep and beef cattle) numbers on pastoral leases, with a complete Agricultural Census every five years and sample surveys in intervening years. The ABS compiles and reports survey data by statistical local area (SLA).

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

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

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

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



1993

1995

1997 (census year)

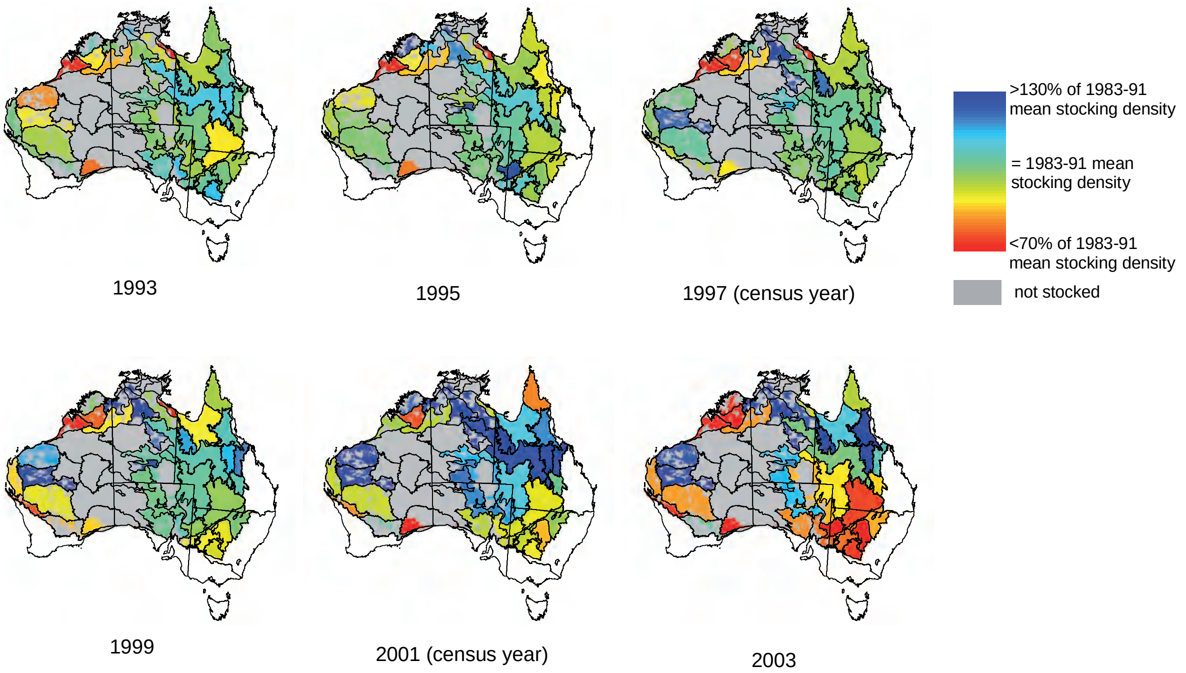
1999

2001 (census year)

2003

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

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



1993

1995

1997 (census year)

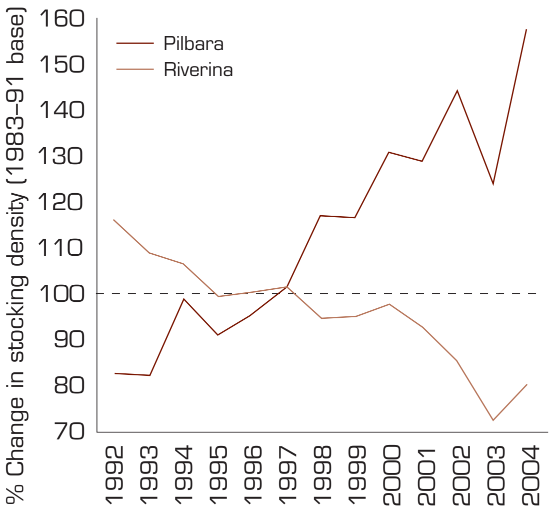
1999

2001 (census year)

2003

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

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



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

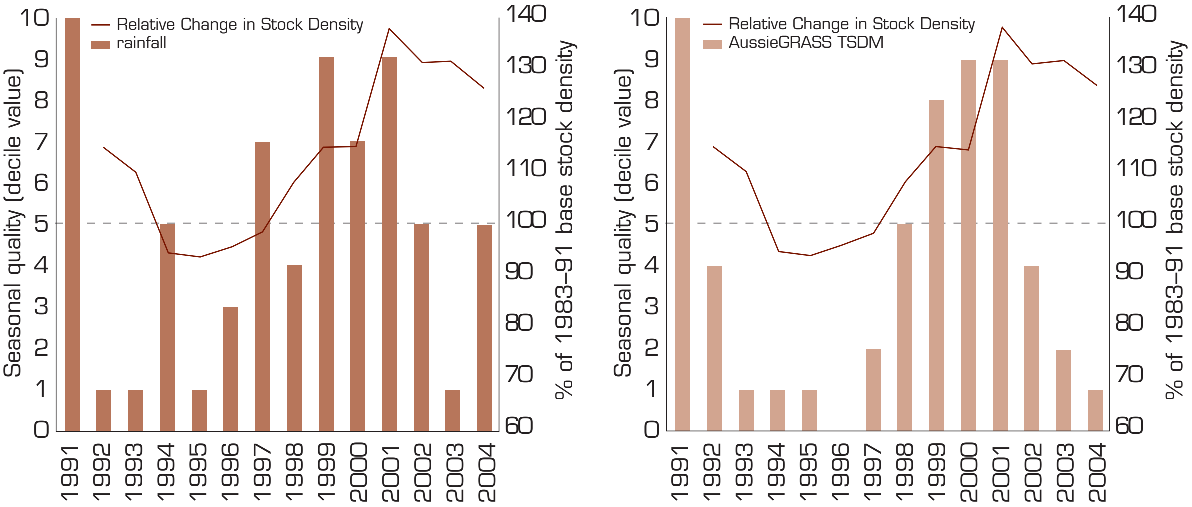
Graph compiled by the ACRIS-MU from ABS and QDNRW data.

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

Livestock density adjusted for *seasonal quality*

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

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



Indices are deciles of rainfall.

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

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

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

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

Key points

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

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

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

Photo: Arthur Mostead

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

Kangaroo densities in rangelands

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

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

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

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

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

Change in kangaroo density

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

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

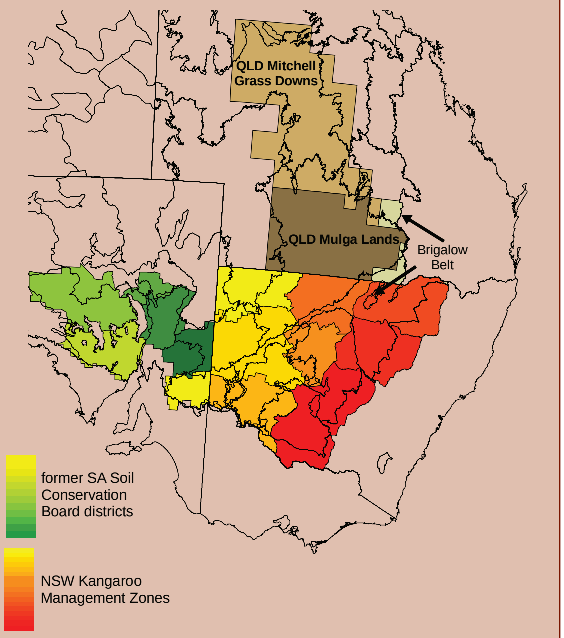
Box 3.6 Data on kangaroo numbers

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

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

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

Regions surveyed for kangaroo numbers



Source: Pople (2006)

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

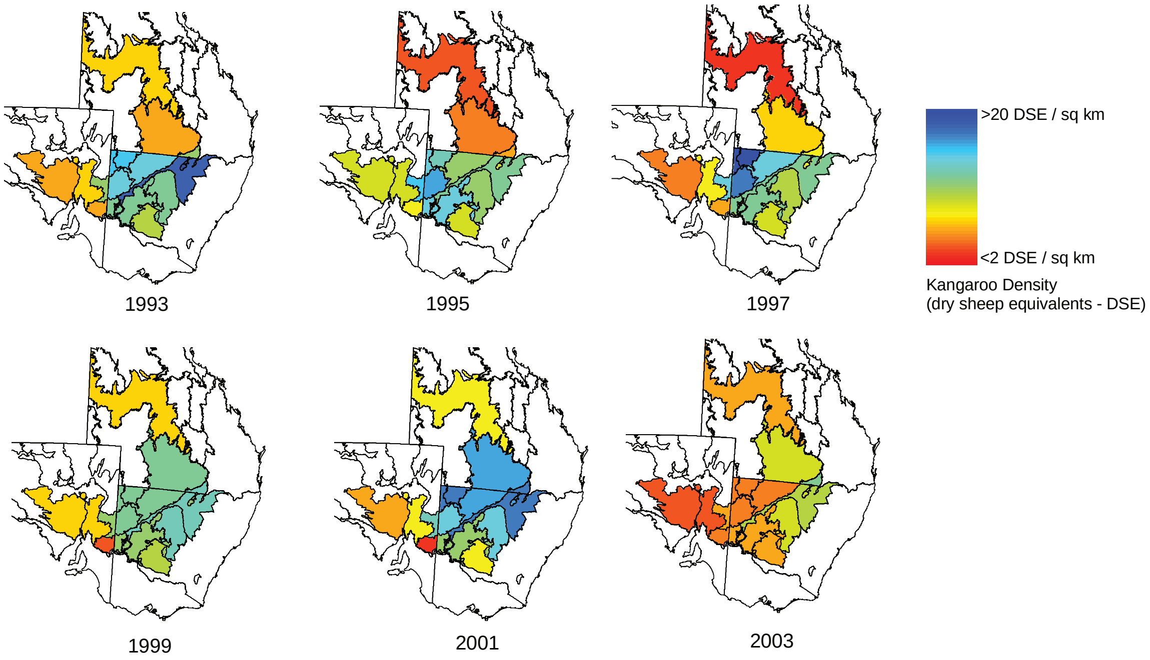
Kangaroo density adjusted for *seasonal quality*

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

Key points

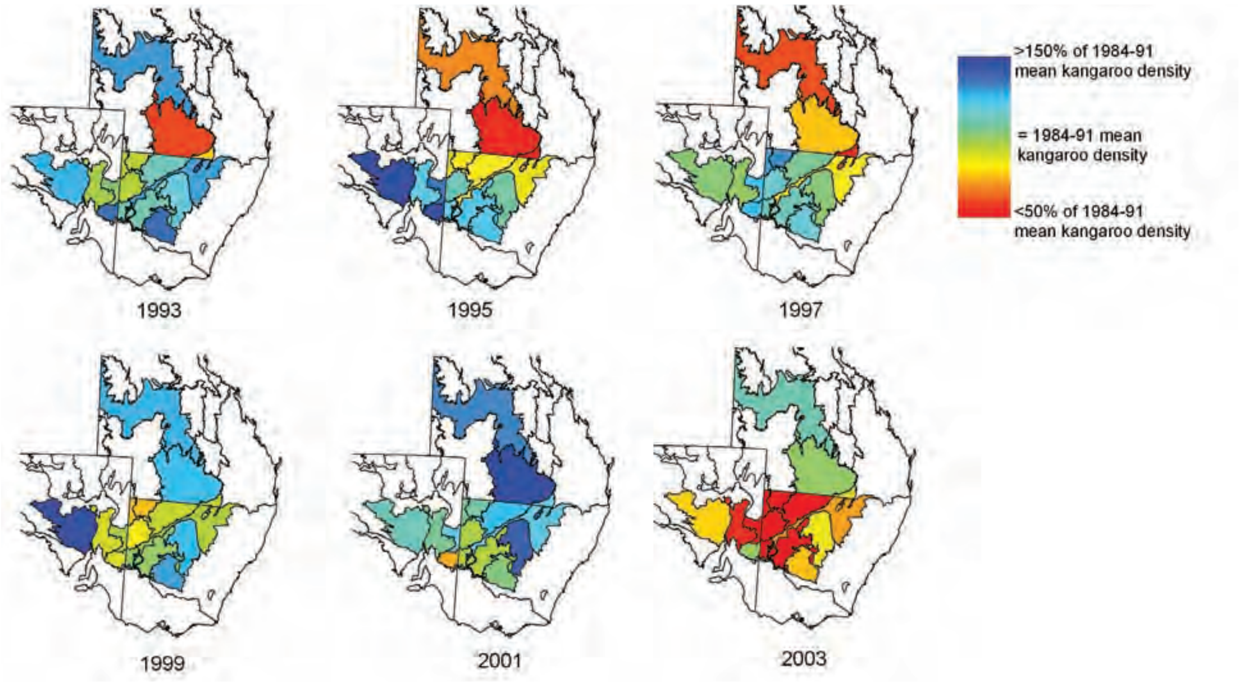
Systematic surveys of kangaroo numbers have been conducted across much of the sheep-grazed eastern rangelands (SA, NSW and southwest Queensland) for more than 20 years. These data have been comprehensively analysed (Pople 2006), and the report was kindly made available to the ACRIS Management Committee.

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



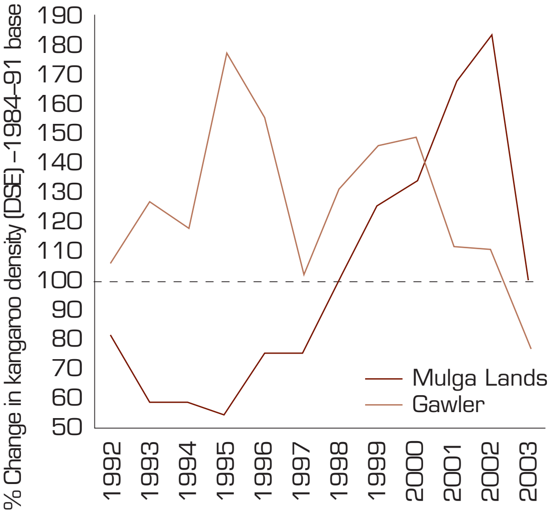
Source: compiled by the ACRIS-MU using data from Pople (2006)

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



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

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

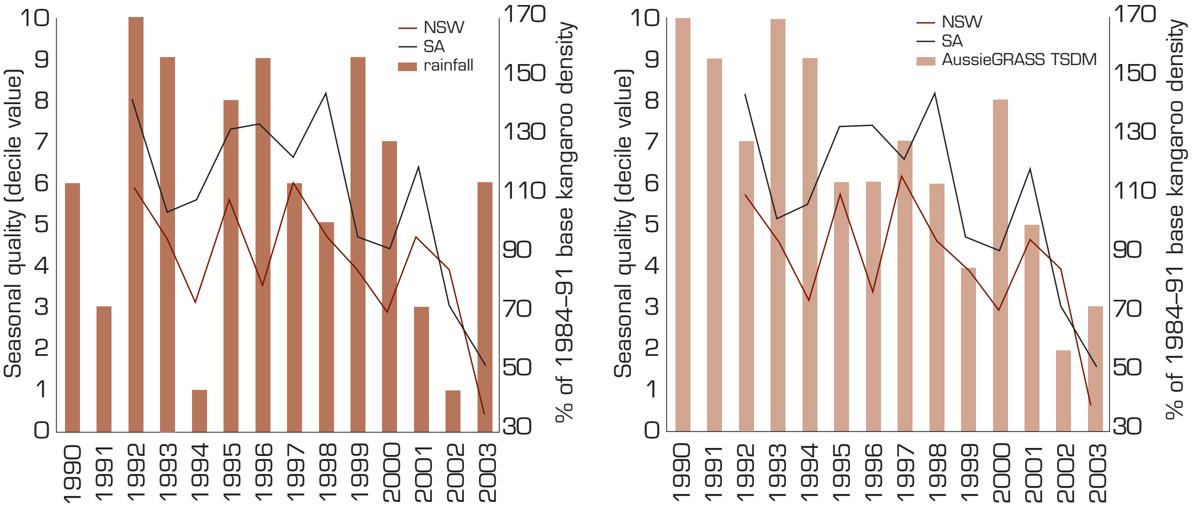


Note: Change is expressed relative to the average density for each region for 1984–1991.

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

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

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



Indices are deciles of rainfall.

Indices are deciles of AussieGRASS simulated pasture biomass.

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

Feral animals

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

Background

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

Sources of feral animal information

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

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

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

Feral animal management

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

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

Figure 3.37 Feral goats (*Capra hircus*)

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

Key points

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

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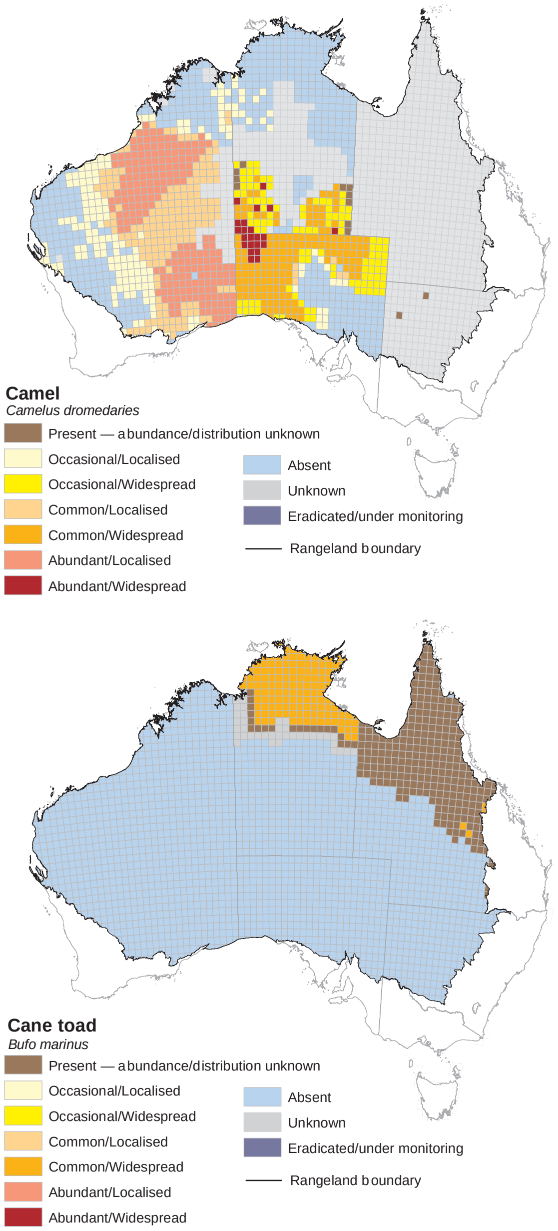
[15] http://www.anra.gov.au (accessed 3 July 2007)

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



Top: Distribution of camels

Bottom: Distribution of cane toads

Source: NLWRA, July 2007

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

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

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

Fire and dust

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

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

Figure 3.39 Burning in the Top End, NT

Photo: CSIRO Sustainable Ecosystems

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

Fire

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

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

Figure 3.40 Burning in central Australia

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

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

Box 3.7 Monitoring fire scars in the rangelands

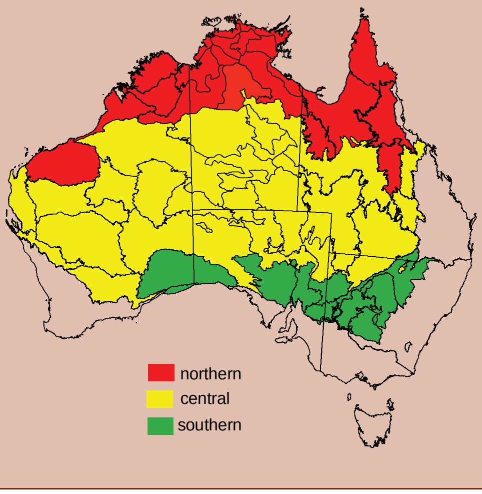
The extent of fire scars has been mapped on a monthly basis using satellite imagery covering most of Australia's rangelands. The satellite data have been acquired by the WA Land Information Authority (Landgate), and fire-scar maps are available on its website. Landgate provided statistics on the monthly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

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

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

Geographic grouping of bioregions for categorising fire intensity

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



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

Fire records in the rangelands

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

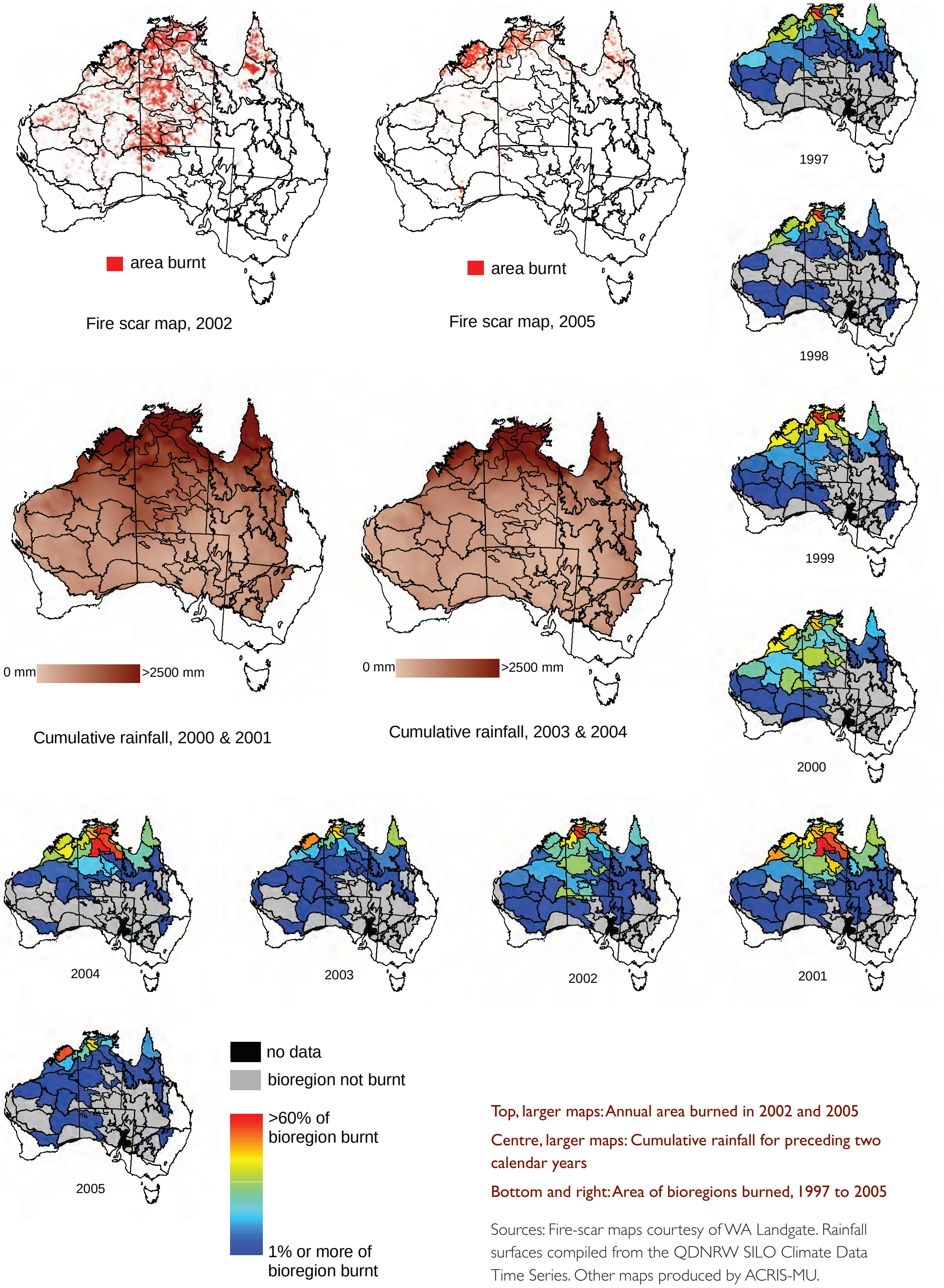
When intense or 'hot' fires sweep across the rangelands, they leave blackened landscapes (fire scars), which can be identified and mapped from satellite imagery (Box 3.7).

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

Fire extent

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

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



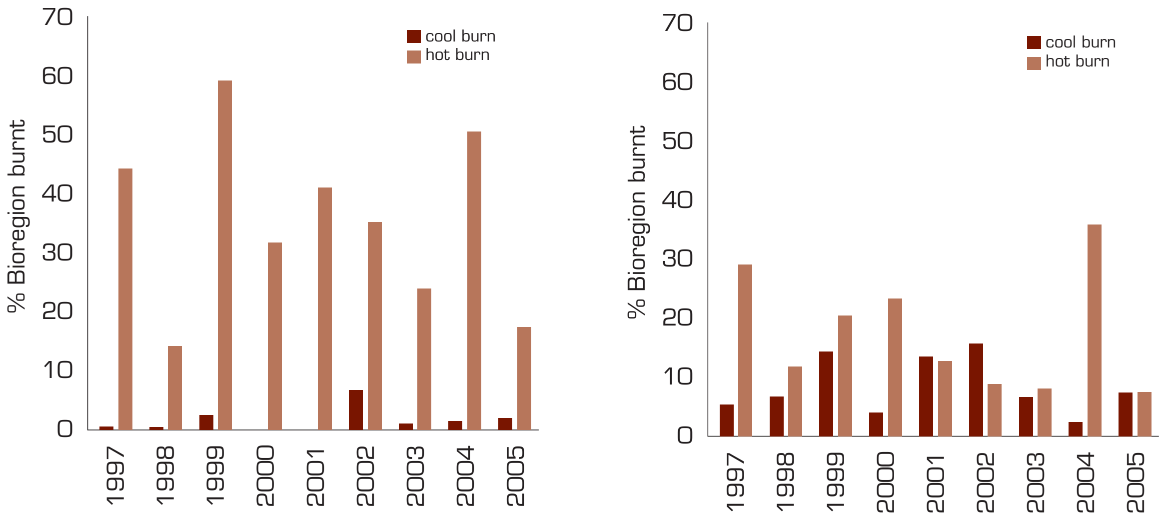
Top, larger maps: Annual area burned in 2002 and 2005

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

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

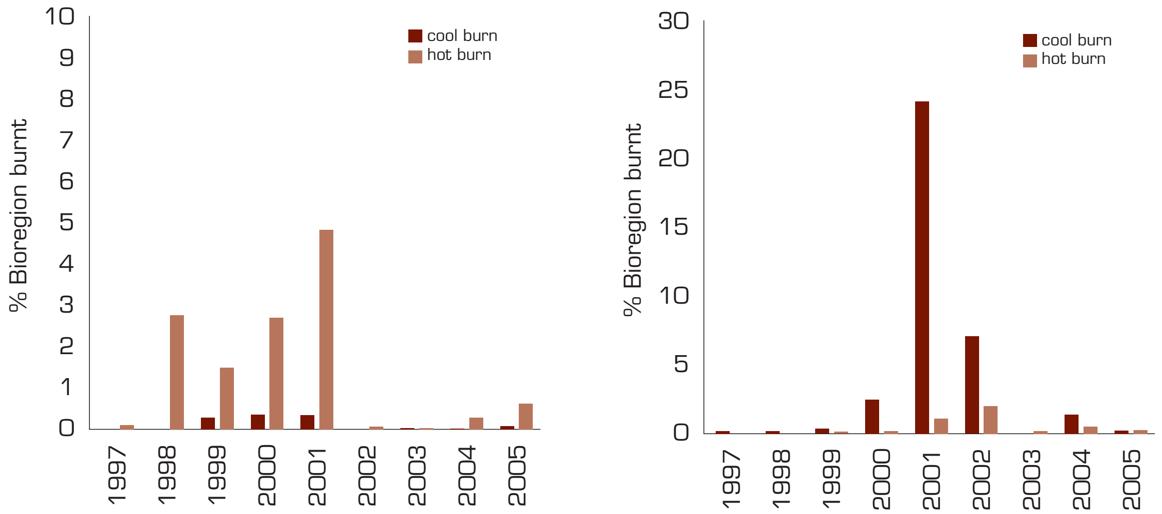
Sources: Fire-scar maps courtesy of WA Landgate. Rainfall surfaces compiled from the QDNRW SILO Climate Data Time Series. Other maps produced by ACRIS-MU.

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



Central Arnhem bioregion

Central Kimberley bioregion



Desert Uplands bioregion

Burt Plain bioregion

Data: WA Landgate. Graphs: ACRIS-MU.

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

Fire intensity

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

Box 3.8 Fire frequency in the rangelands

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

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

Year 1999		
0	1	1
0	1	1
0	1	1

Year 2000		
0	0	0
0	1	1
0	1	1

Fire Frequency		
0	1	1
0	2	2
0	2	2

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

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

0	1	1
0	2	2
0	2	2

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

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

0	1	1
0	2	2
0	2	2

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

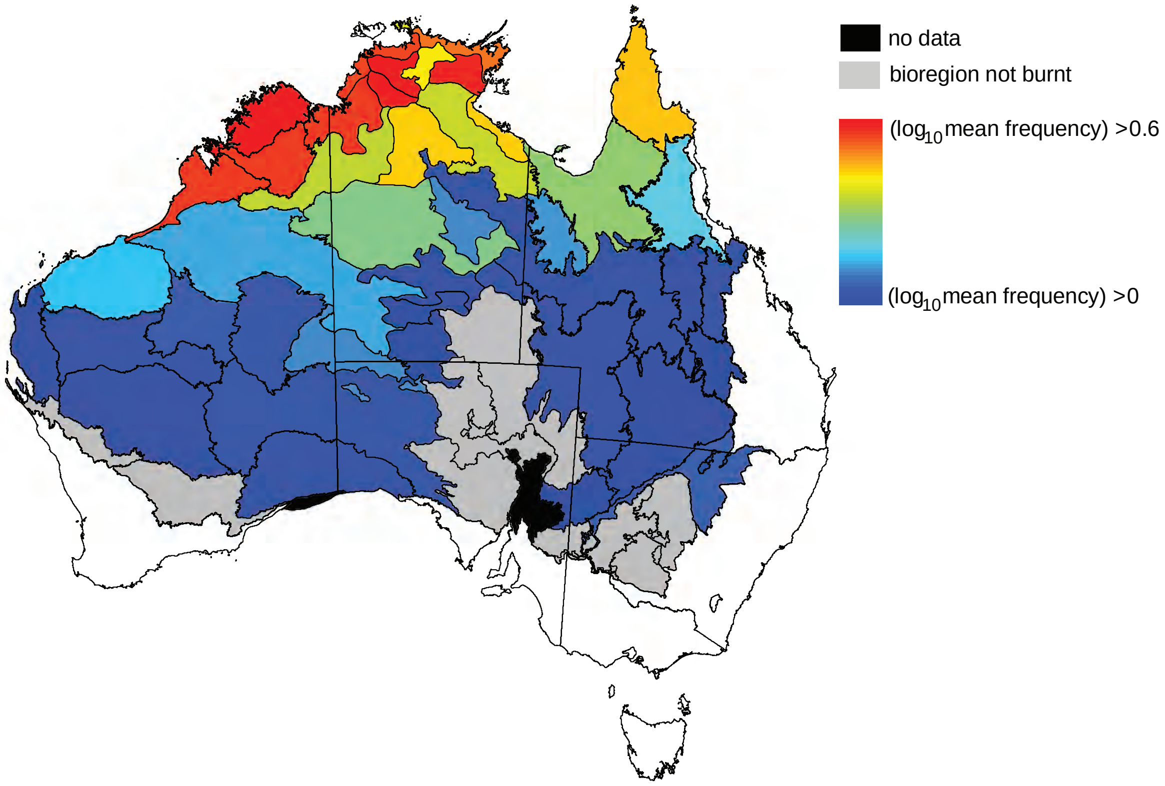
The spatially averaged fire frequency data for bioregions have a large and skewed range. Average fire frequency is relatively high in the north and very low in the south. To improve mapping detail for northern bioregions, where very large areas were burned in most years, the frequency data were $\log_{10}$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

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

Fire frequency

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

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



Data: WA Landgate. Maps: ACRIS-MU.

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

Key points

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

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

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

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

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

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

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

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

Dust

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

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

Dust records in the rangelands

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

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

Dust Storm Index maps

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

Figure 3.44 Approaching dust storm

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

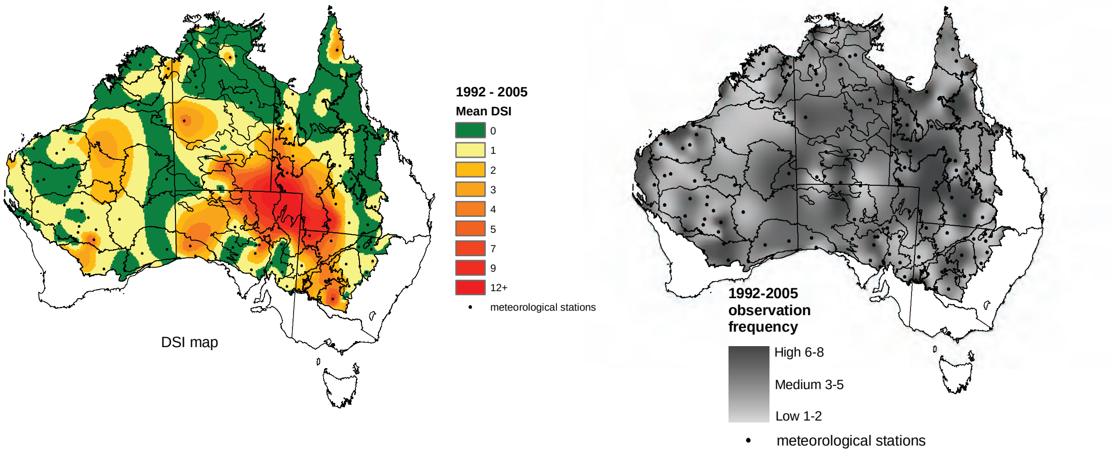
Photo: Hans Bossem

Box 3.9 Dust Storm Index data and calculation

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

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

Figure 3.45 Mean DSI_3 values, 1992 to 2005



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

Data and maps: G McTainsh, Griffith University, Queensland

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

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

Dust Storm Index and *seasonal quality*

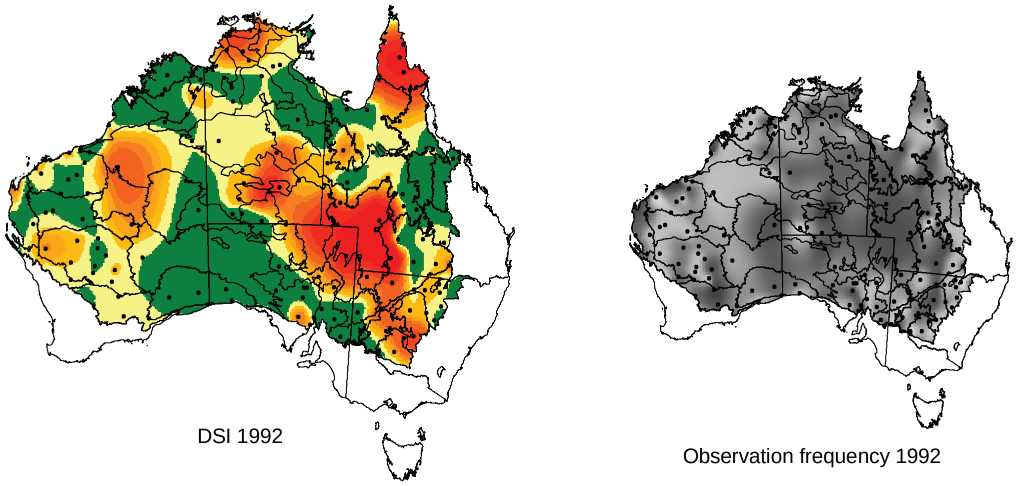
As expected, dust storms markedly increased in bioregions in years with rainfalls well below the long-term (1890–2005) average, for example, in the Channel Country and Mulga Lands bioregions (Figure 3.47). DSI_3 values increased abruptly in the driest years (1994 and 2002) and progressively declined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

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

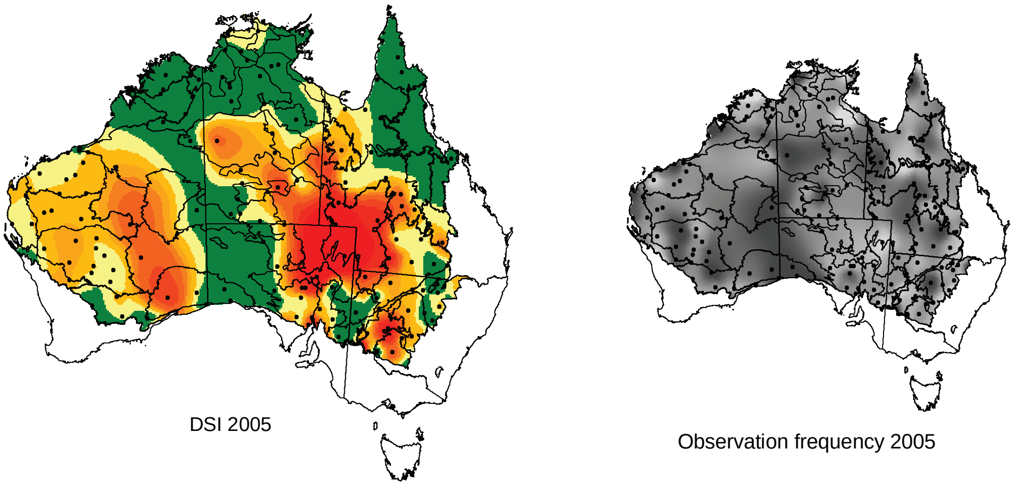
Key points

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

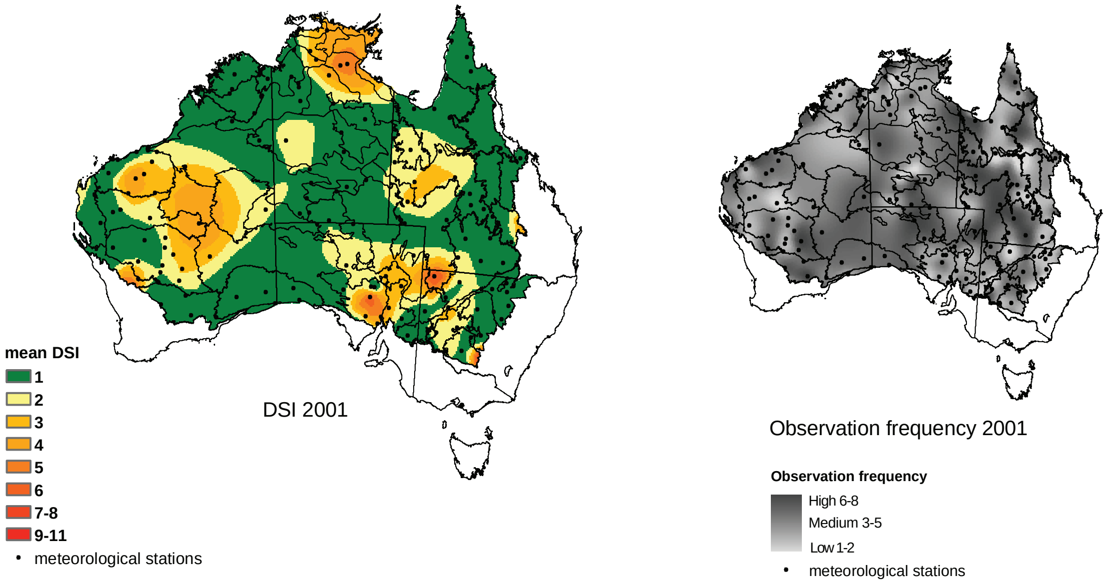
Figure 3.46 Selected years with relatively high and low levels of DSI$_3$


DSI 1992

Observation frequency 1992


DSI 2005

Observation frequency 2005

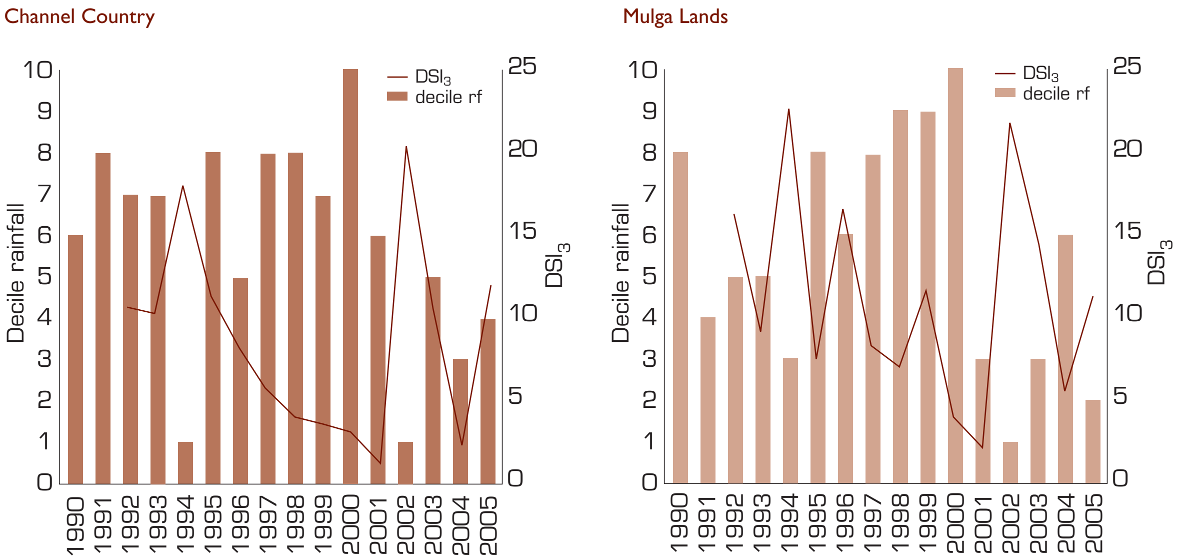

DSI 2001

Observation frequency 2001

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

Data and maps: G McTainsh, Griffith University, Queensland

Figure 3.47 Annual DSI$_3$ values and decile rainfalls, Channel Country and Mulga Lands bioregions, 1990 to 2005



Note: Rainfall deciles were calculated for each bioregion by spatially averaging yearly rainfalls estimated by SILO (http://www.bom.gov.au/climate/silo) compared to the long-term (1890–2005) record. Rainfalls in 1990 and 1991 are included to allow for any temporal lag in DSI$_3$ values in following years.

DSI$_3$ data: G McTainsh, Griffith University, Queensland. Graphs: ACRIS-MU.

- Medium-term (10+ year) changes in dust levels in relation to climate, vegetation change and management across broad regions of the rangelands need to be better understood. Future work by McTainsh and colleagues to relate DSI$_3$ values over a longer period to seasonal conditions and known changes in vegetation has the potential to improve reporting capacity.

Water resources

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

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

Reporting boundaries

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

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

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

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

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

Photo: Arthur Mostead

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

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

Key points

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

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

Figure 3.49 Water for cotton, Bourke, NSW

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

Photo: Liz Poon

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

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

Photo: Graeme Chapman

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

Biodiversity

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

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

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

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

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

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

Photo: Liz Poon

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

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

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

Protected areas

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

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

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

IA *Strict Nature Reserve* — managed mainly for science

IB *Wilderness Area* — managed mainly for wilderness protection

II *National Park* — managed mainly for ecosystem conservation

III *Natural Monument* — managed for specific natural features

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

V *Protected Landscape/Seascape* — managed for conservation

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

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

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

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

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

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

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

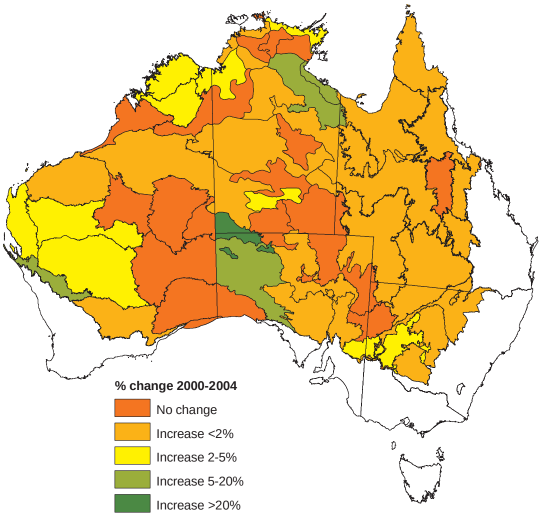
[a] See indicator subsections below for details.

[b] See subsections for additional recommended developments.

Progress on adding protected areas: 2000–2004

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

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



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

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

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

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

Key points

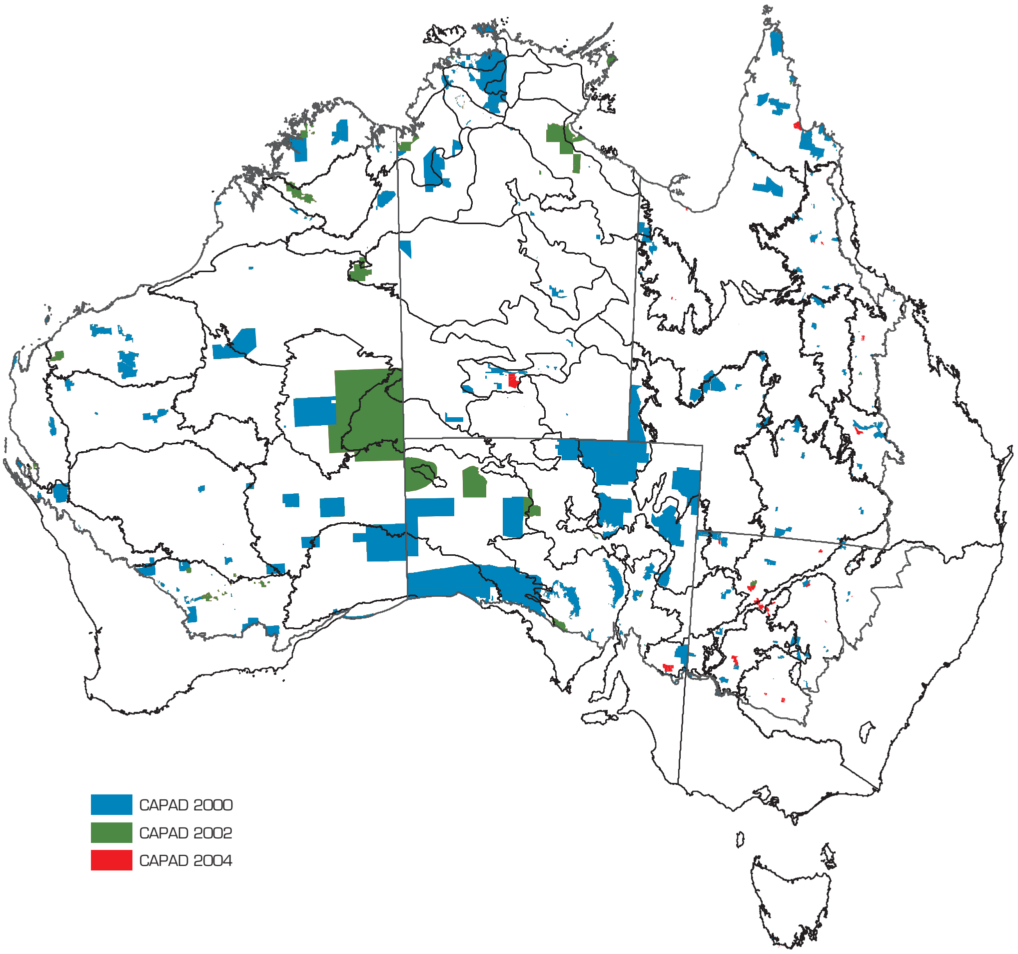
- Analyses of the CAPAD information and separate data for WA showed that most rangeland bioregions increased their percentage of protected area; in central Australia, some made notable additions.
- A number of concerns were identified:
  - Once protected areas are acquired, their locations are fixed,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

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

Location: Anne Beadell Highway, Mamungari Conservation Park

Photo: Jeff Foulkes, SA Department for Environment and Heritage

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



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

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

Number and status of threatened species/communities

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

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

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

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

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

Box 3.10 Sources of information on threatened species and communities

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

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

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

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

Listings and data sources

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

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

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

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

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

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

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

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

Numbers of threatened species, by bioregion

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

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

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

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

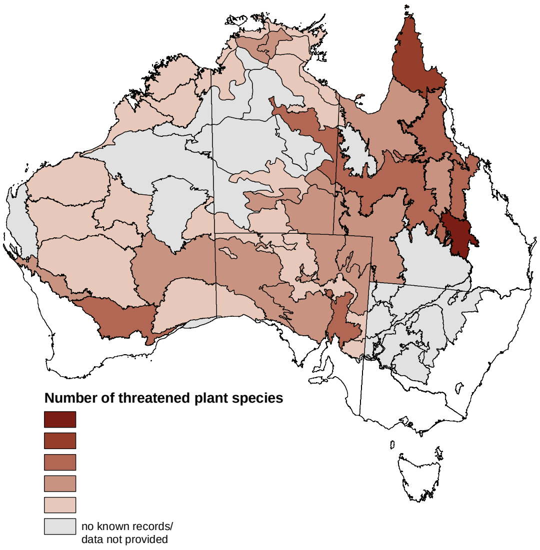
Comparison of the 2006 data with those from the 2001 rangelands report (NLWRA 2001a, p 46, Figure 13) shows that important changes have occurred (although the data for 2001 were by IBRA subregion, so numbers mapped will tend to be lower, making direct comparison difficult). Information was far more extensive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

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

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

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

Figure 3.55 Numbers of threatened vascular plant species across rangeland bioregions



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

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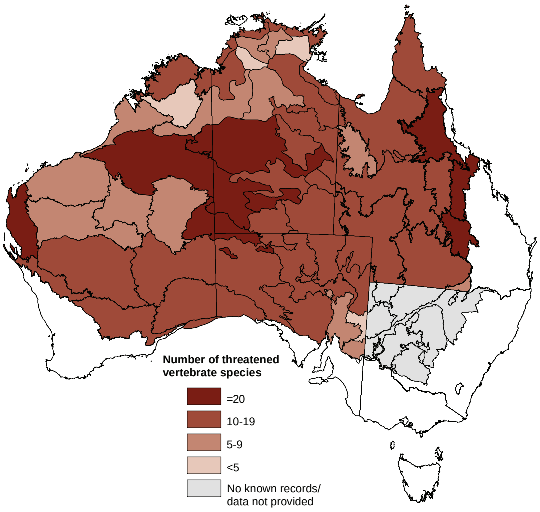
[22] http://www.environment.gov.au/biodiversity/threatened/committee.html (accessed 19 March 08)

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

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

Figure 3.56 Numbers of threatened vertebrate species across rangeland bioregions



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

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

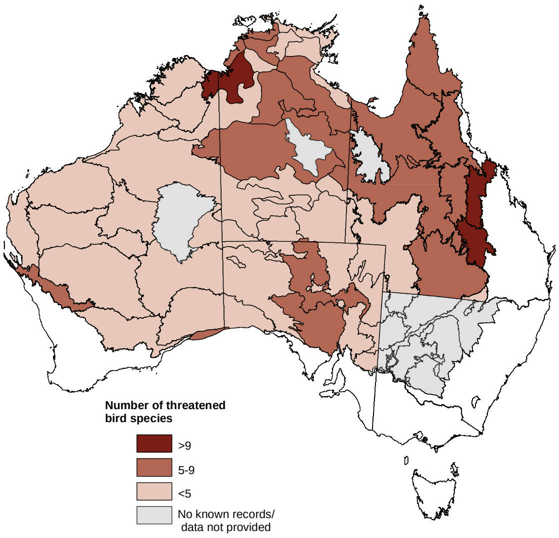
Photo: Queensland Environmental Protection Agency / Queensland Parks and Wildlife Service

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

Numbers of threatened ecological communities

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

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



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

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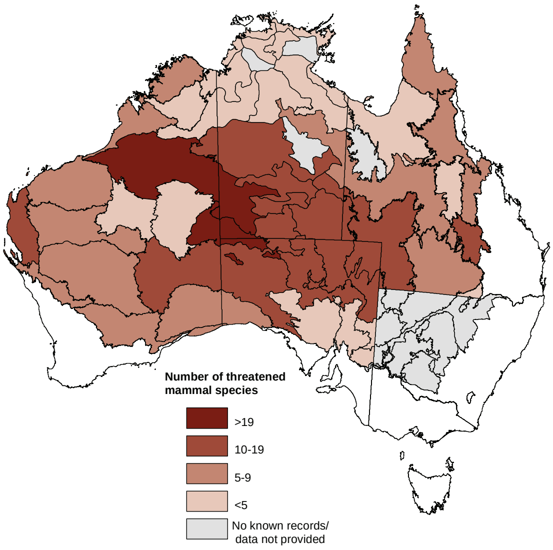
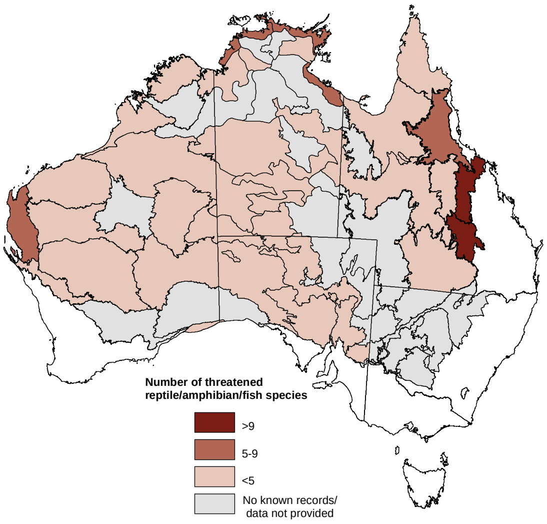
[23] http://www.epa.qld.gov.au/wetlandinfo/site/factsfigures/SummaryInformation/springs.html (accessed 24 March 2007)

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



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

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



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

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

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

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

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

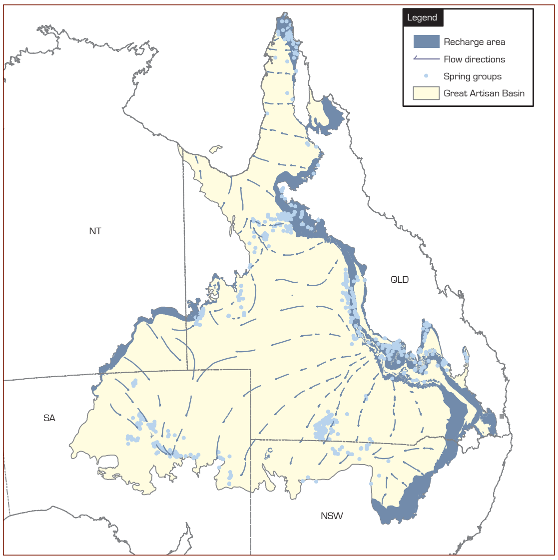
Artesian or free-flowing springs are rare and unusual environments, and therefore have significant ecological and social values. In Australia, the GAB underlies much of Queensland and parts of the NT, SA and NSW (Figure 3.62), or about one-fifth of the continent. Clustered in the GAB are a number of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

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

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

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

Figure 3.62 Great Artesian Basin, free-flowing springs



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

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

Key points

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

Habitat loss by clearing

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

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

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

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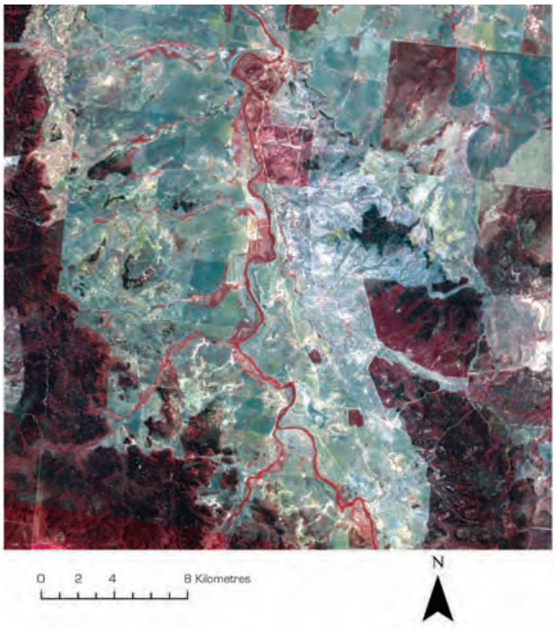
[24] http://www.nrw.qld.gov.au/water/gab/gabsi.html (accessed 24 March 2007)

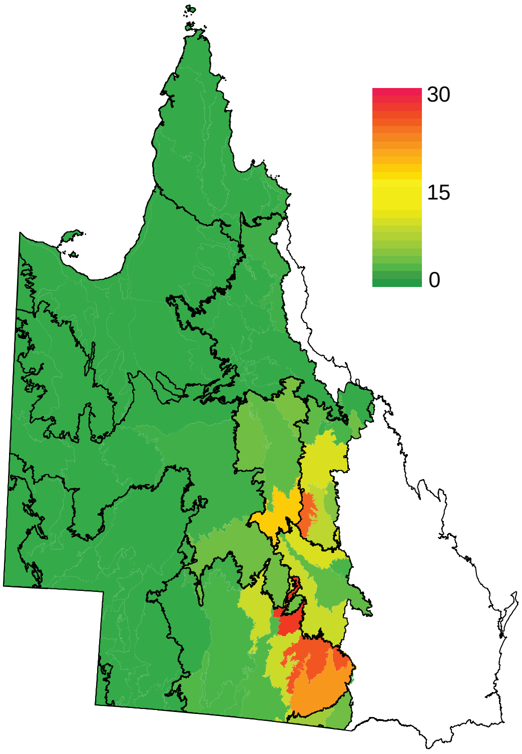
Figure 3.63 Landsat TM image showing clearing of woody vegetation south of Alpha, central Queensland, 2002



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

Source: Geoscience Australia. Map: ACRIS-MU

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



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

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

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

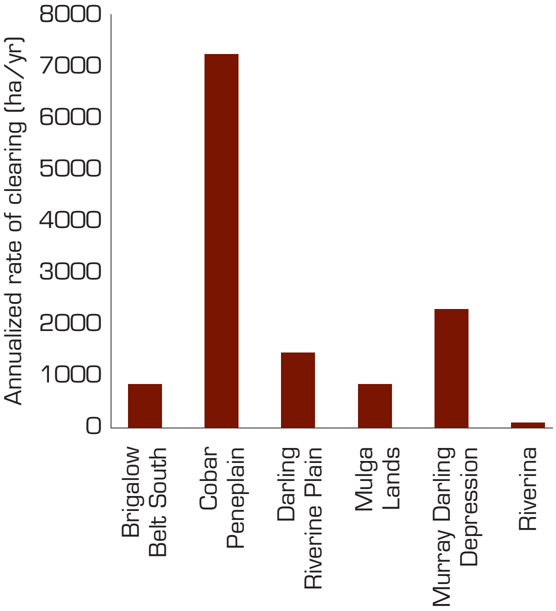
> … people living on country and harvesting wildlife [defined to include trees and bush materials such as fibre, fruit and seed] produce important sources of foods with associated economic and health benefits … Where Indigenous people live on their country, ecological and wider benefits are generated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

Because woodlands and forests typically occur in landscapes with higher and more reliable rainfall, areas with substantial tree and shrub cover tend to occur around the boundaries defining the more arid and semiarid rangelands, notably in eastern Queensland and eastern NSW. In SA and most of WA, habitat loss due to clearing is a minor issue because only a few rangeland areas have high tree cover. In the NT, tree clearing is only an issue for a few bioregions in the Top End.

Data sources and definitions

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

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



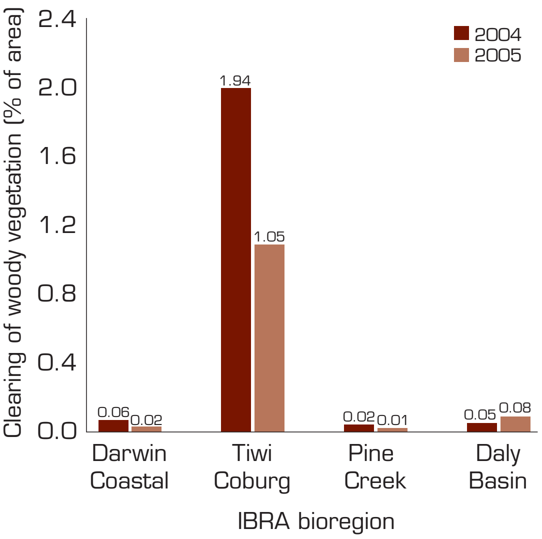
Source: Science Services Division, NSW Department of Environment and Climate Change

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

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

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

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



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

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

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

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

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

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

Key points

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

Stock waterpoint effects on biota

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

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

Effects of distance from waterpoints on biodiversity

Distance from waterpoints is known to affect rangeland biodiversity:

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

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

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

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

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

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

Figure 3.68 Crested pigeon (*Ocyphaps lophotes*)

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

Photo: Geoffrey Dabb

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

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

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

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

Data on water-remote land

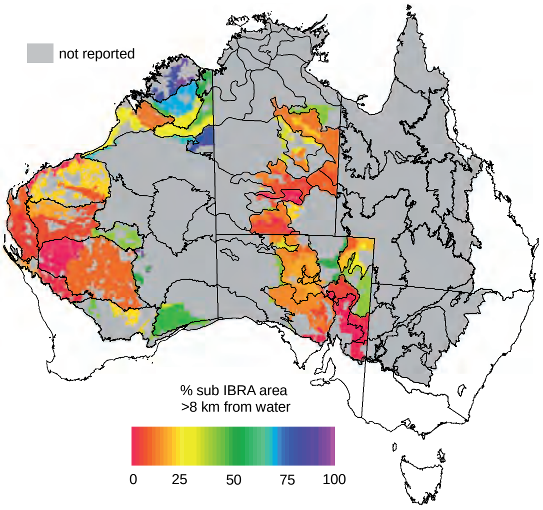
Based on available data on the distribution of stock waterpoints across the rangelands (see Box 3.4), the area remote (>8 km) from water was calculated as a proportion of the area of each rangeland sub-IBRA region.

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

Changes in water-remoteness

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

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

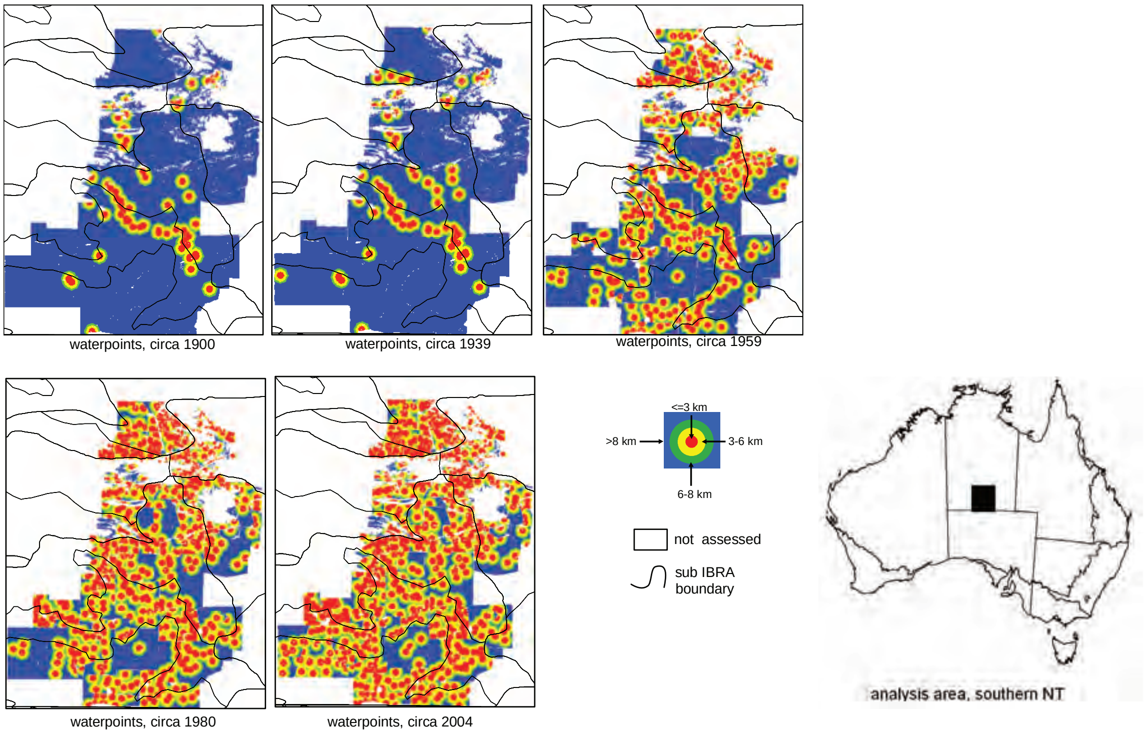


Note: Areas outside pastoral leases are not included.

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

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

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



waterpoints, circa 1900

waterpoints, circa 1939

waterpoints, circa 1959

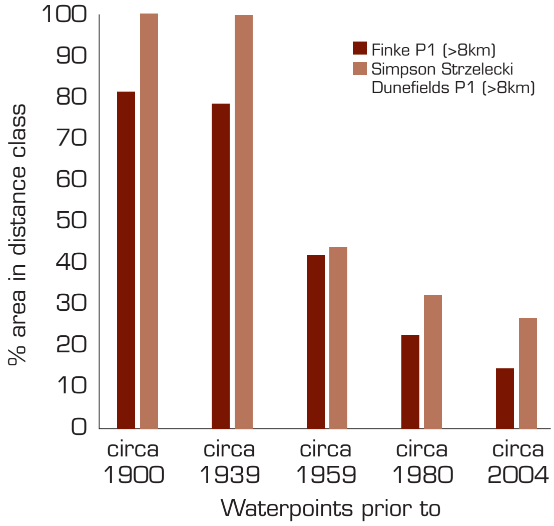
waterpoints, circa 1980

waterpoints, circa 2004

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

Data and maps: CSIRO, Alice Springs.

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



Data and graph: CSIRO, Alice Springs.

Key points

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

Fauna surveys and records in rangelands

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

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

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

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

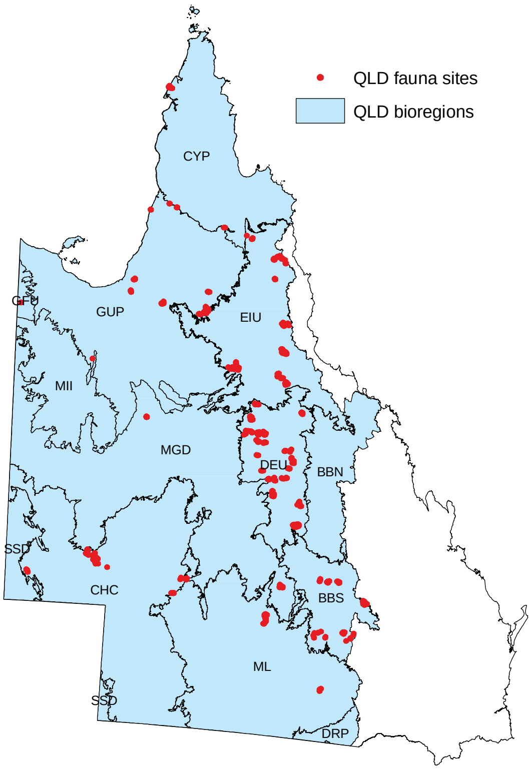
Photo: CSIRO, Alice Springs

Fauna surveys

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

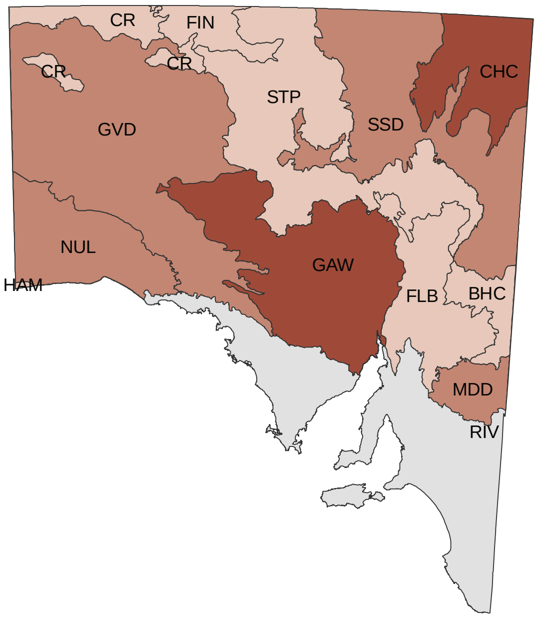
If the date of a fauna site survey is known, it can be used to track changes in the numbers of sites surveyed over time. For example, in South Australia, few sites had been surveyed for fauna before 1992 (Figure 3.74, top panel); by 2006, many more had been surveyed (Figure 3.74, bottom panel), although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

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

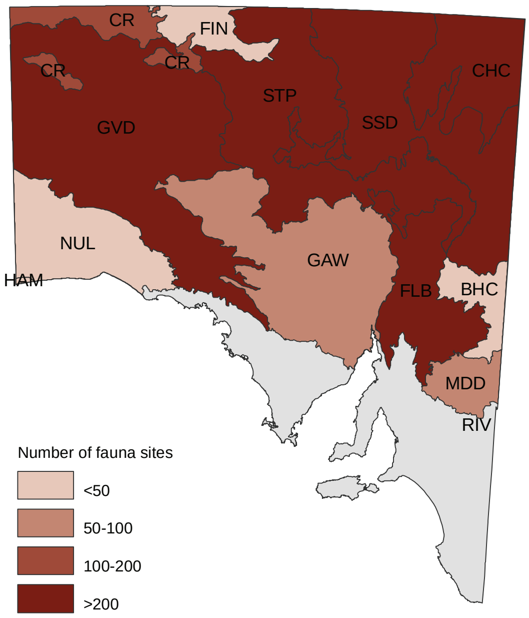


Source: Teresa Eyre, Biodiversity Sciences Unit, Queensland Environmental Protection Agency, and Alex Kutt, CSIRO Sustainable Ecosystems.

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



Before 1992



1992 to 2006

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

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

Photo: Michael Mathieson, Queensland Environmental Protection Agency

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

Fauna records

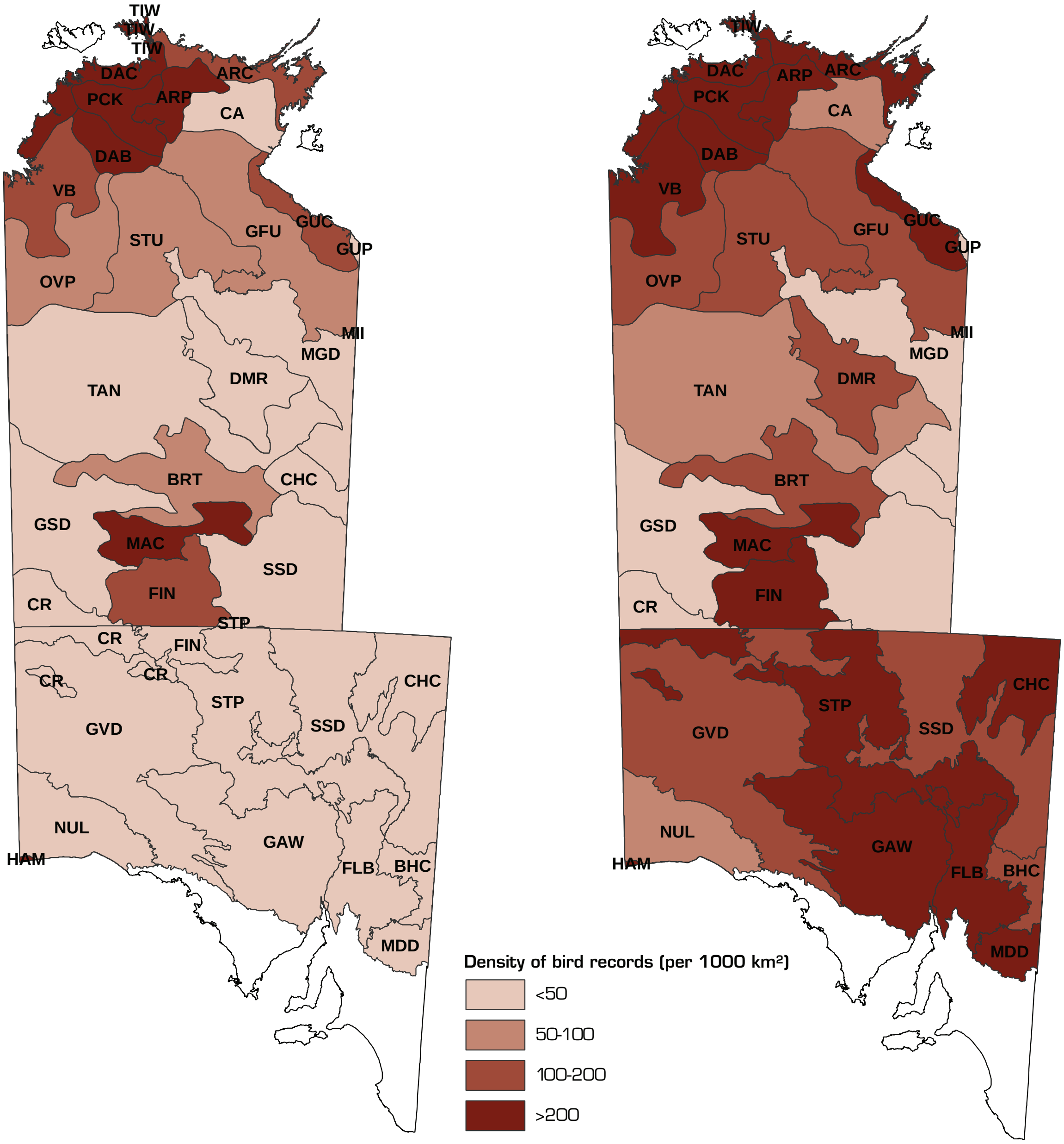
Another useful indicator of effort to conserve biodiversity is the number of records for different taxa across rangeland bioregions, such as the fat-tailed dunnart (*Sminthopsis crassicaudata*; Figure 3.75) and the Spencers goanna (*Varanus spenceri*; Figure 3.76). These records are currently incomplete,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

Figure 3.76 Spencers goanna (*Varanus spenceri*)

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

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

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

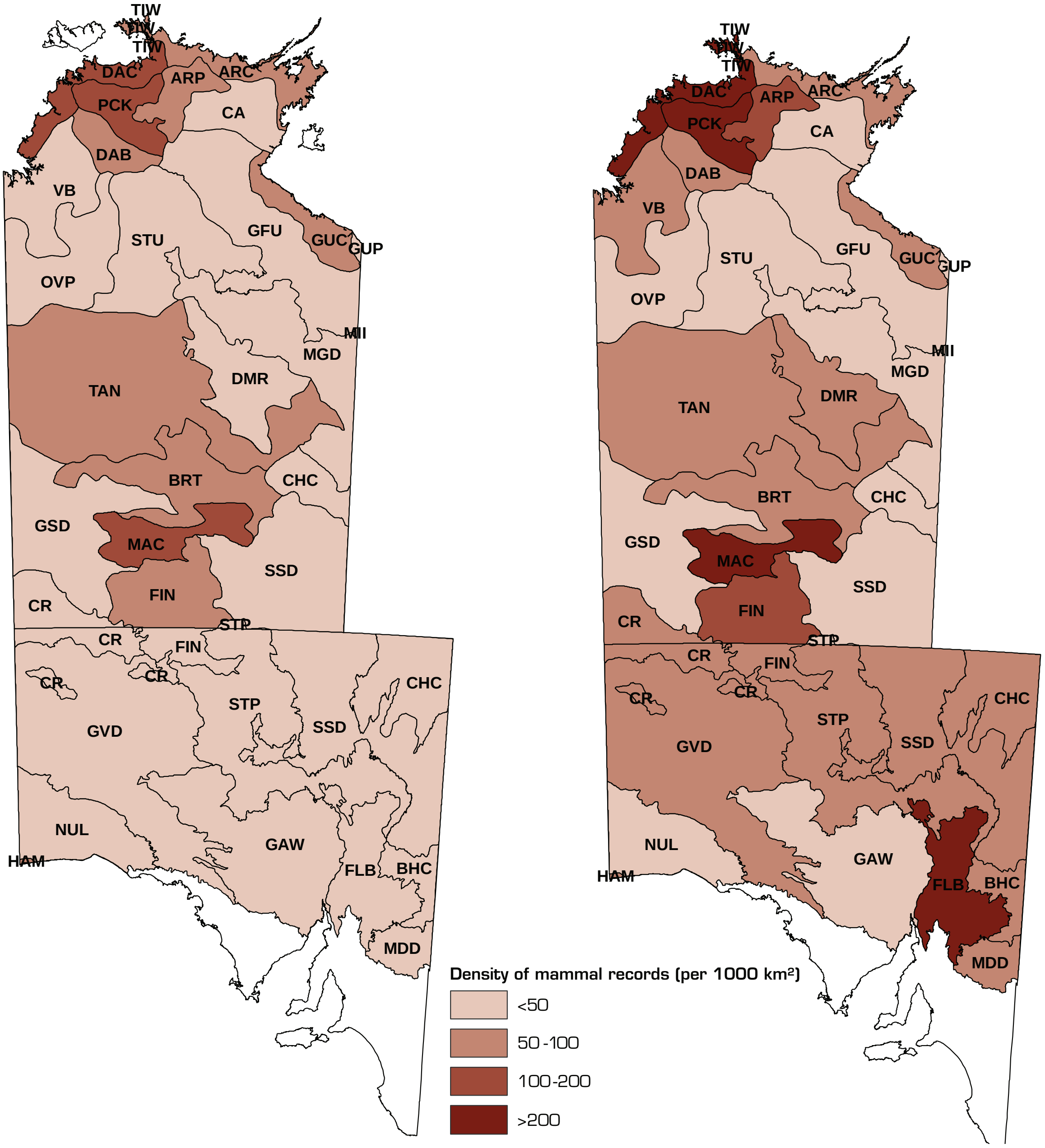


Before 1992

End of 2005

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

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

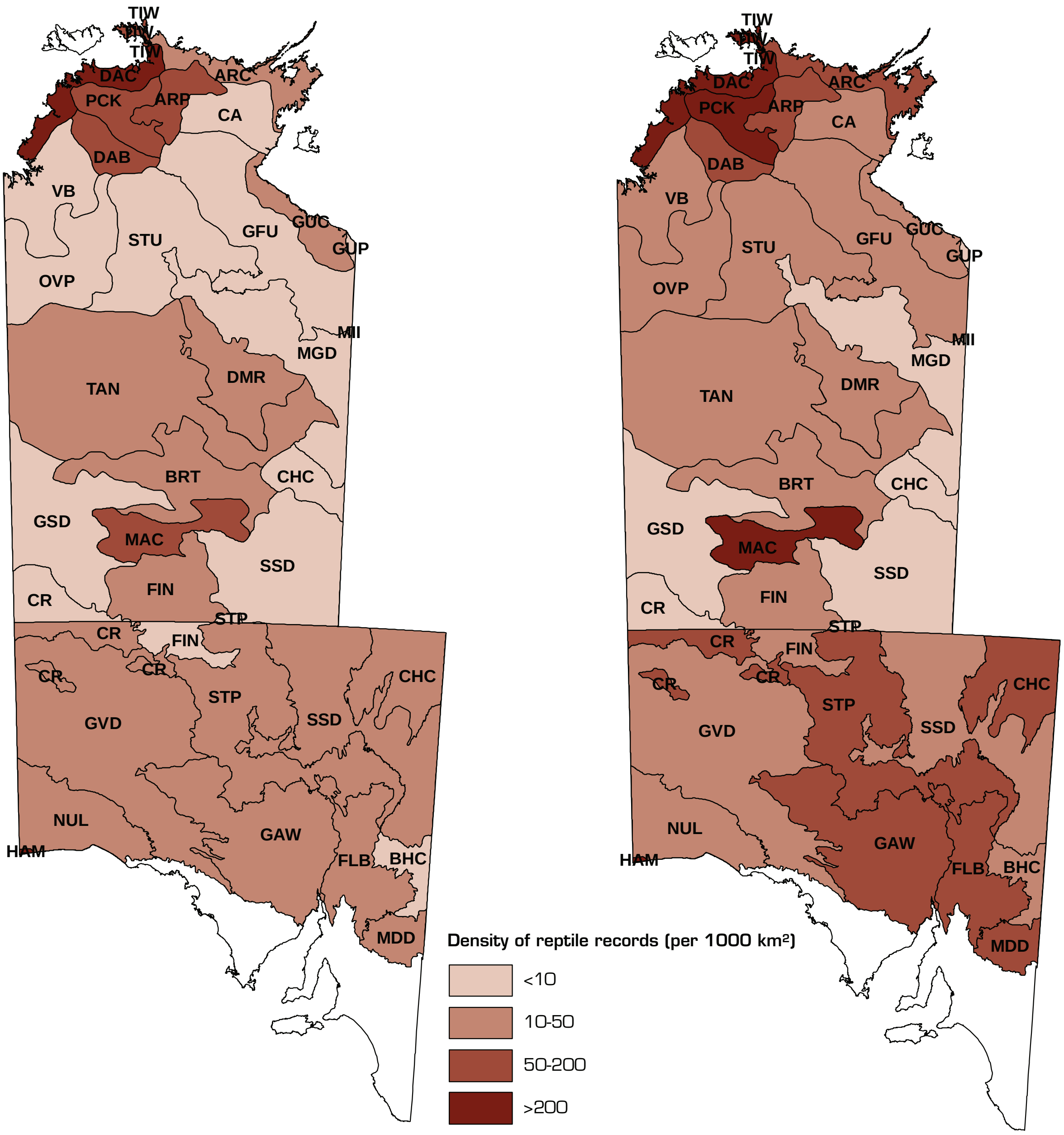


Before 1992

End of 2005

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

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



Before 1992

End of 2005

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

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

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

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

Case study: changes in fauna populations within bioregions

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

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

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

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

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

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

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

Reliability of fauna surveys

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

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

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

Key points

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

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

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

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

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

Flora surveys and records in rangelands

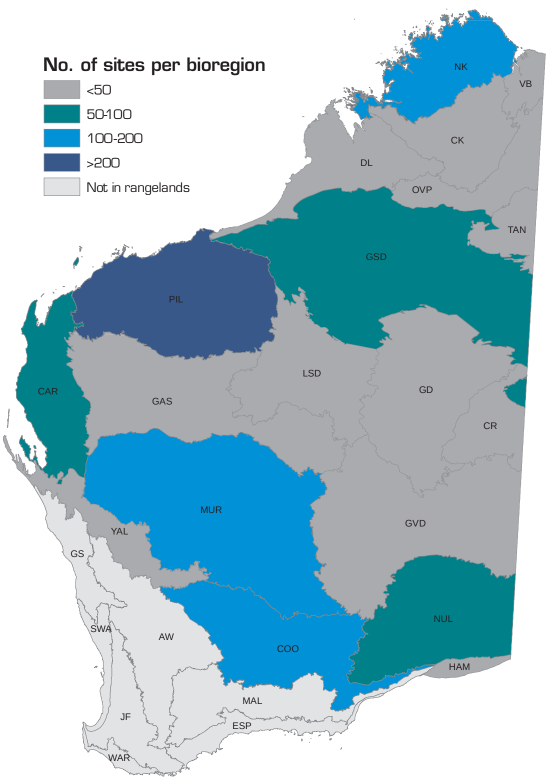
Changes in the number of sites surveyed for flora and in the number of plant species present on sites provide a useful indicator of how the diversity of the terrestrial flora elsewhere in the region is tracking. This information is particularly important at local scales if shifts are occurring in the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

Rangeland flora surveys and records

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

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

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



Source: WA Department of Environment and Conservation

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

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

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

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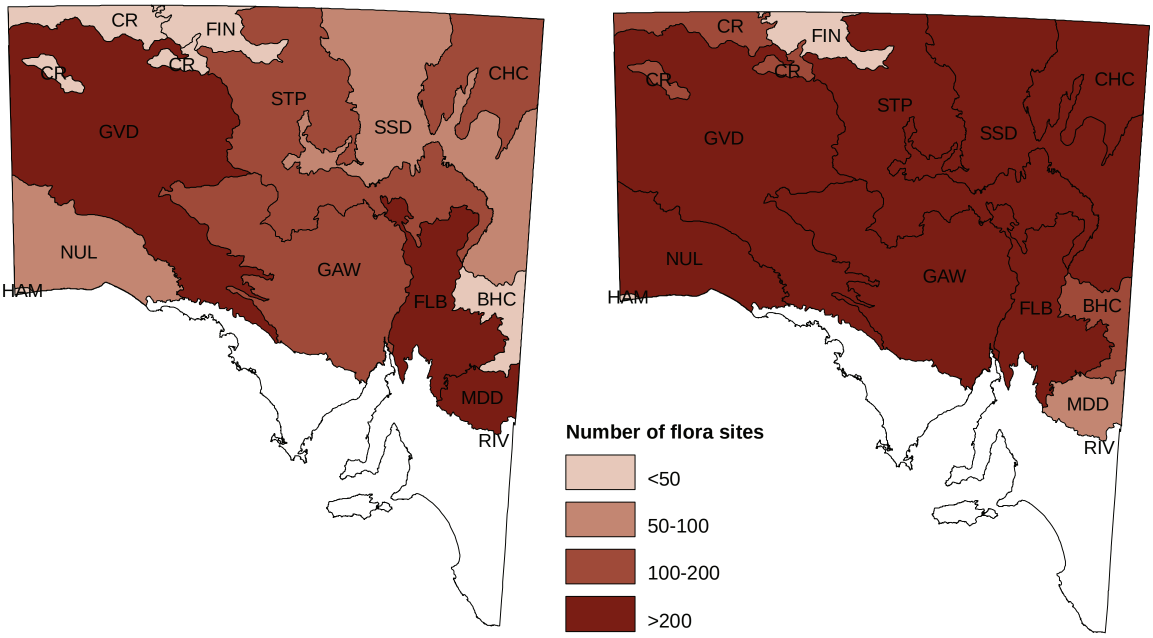
[28] http://www.dhimurru.com.au/plantanimal.html (accessed 27 March 2007)

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



Before 1992

Up to 2006

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

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

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

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

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

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

Figure 3.82 Measuring plant attributes as part of vegetation survey

Photo: CSIRO, Alice Springs

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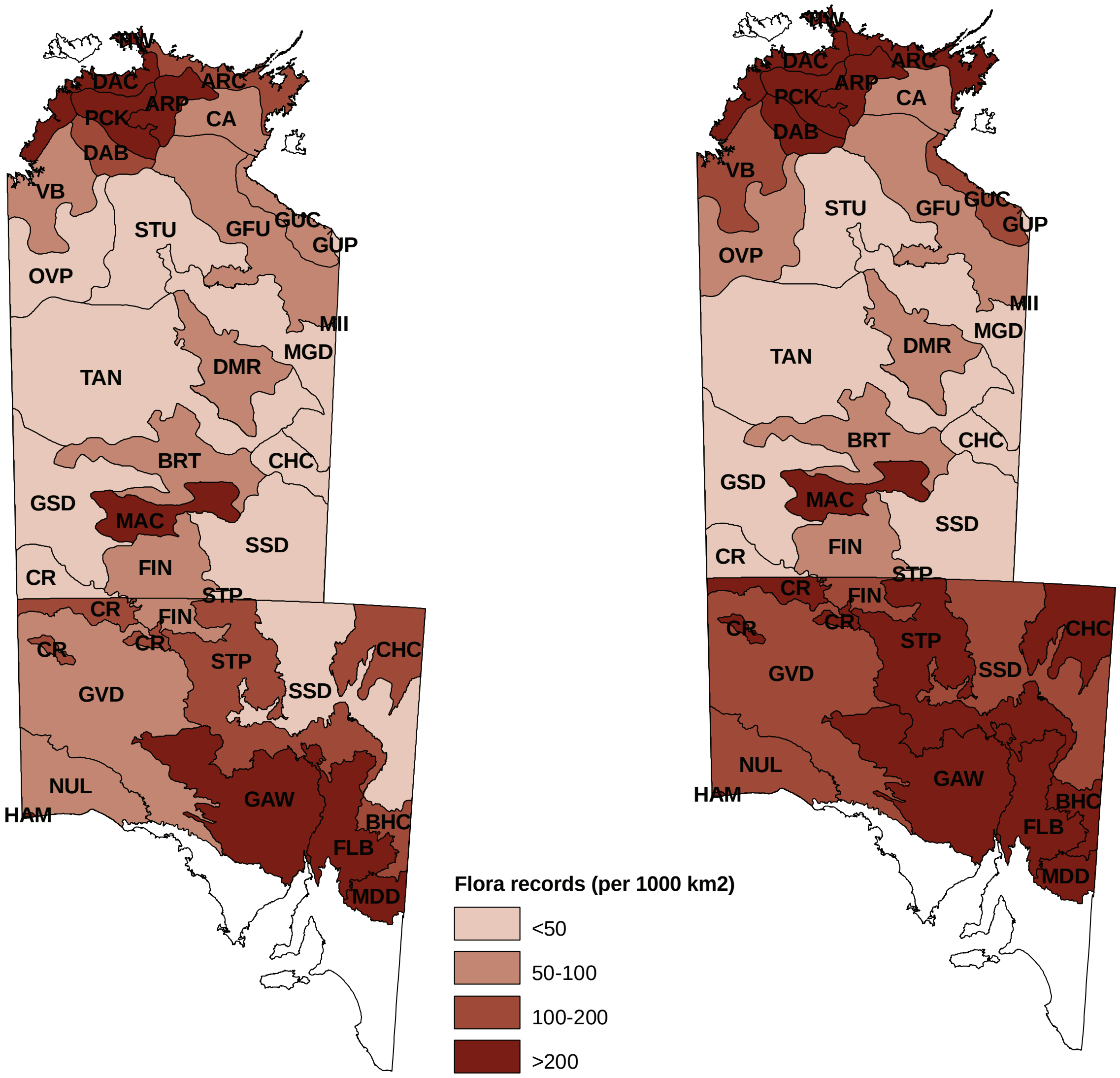
[29] http://www.nt.gov.au/nreta/wildlife/plants (accessed 26 March 2007)

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



Before 1992

End of 2005

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

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

Case study: changes in flora within a bioregion

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

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

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[30] http://www.environment.gov.au/biodiversity/abrs/online-resources/flora/main/index.html (accessed 26 March 2007)

These findings have been used to guide the fire management strategies applied in the park.

Key points

- As for fauna surveys and records, the number of flora surveys and records increased notably for those rangeland bioregions where data were available.
- Long-term monitoring is needed to provide useful information on how the native flora of rangeland vegetation is changing.

Transformer weeds

'Transformer' weeds are invasive plants that can greatly alter the basic attributes of habitats and the biota that depend on those habitats. Transformers can change the character, condition, form or nature of an ecosystem over a substantial area relative to its extent (Richardson et al 2000).

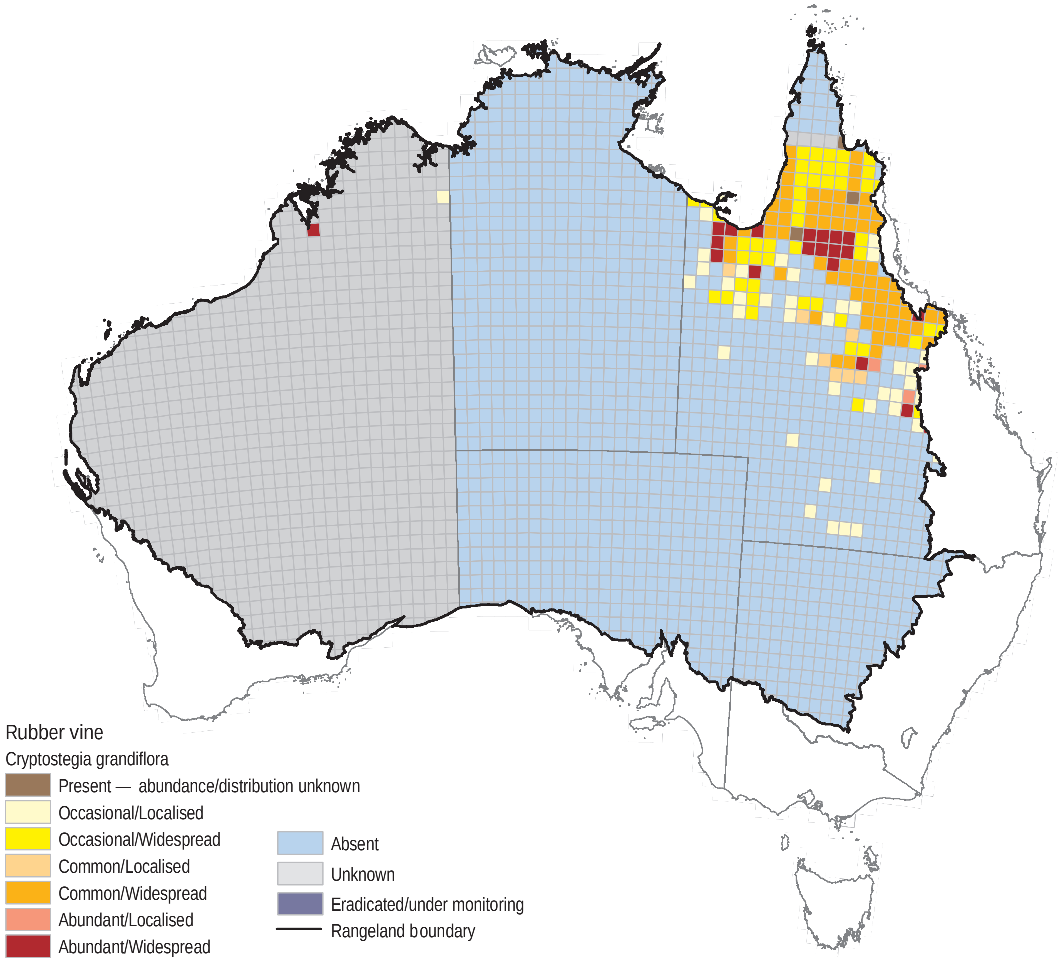
In Australia's rangelands, changes caused by transformer weeds are usually deemed undesirable. The weeds are typically introduced exotics that have the capacity to establish in relatively undisturbed landscapes. Because transformer weeds impact on biodiversity across Australia's rangelands, changes in their distribution and abundance are important indicators for assessing current and likely future impacts on biodiversity.

Although exotic weeds are briefly described in the Sustainable management section of this report as a factor reducing grazing values, the focus here is on transformer weeds that reduce biodiversity.

Indentification of transformer species

Because of their capacity to affect the economic potential of Australia's rangelands, as well as their impact on the environment, many of the transformer species identified here, such as rubber vine (*Cryptostegia grandiflora*), are also listed as WoNS. Although

Figure 3.84 Distribution of rubber vine (*Cryptostegia grandiflora*), Australia, 2006



Source: NLWRA, July 2007

rubber vine is currently mainly found in Queensland (Figure 3.84), it has the potential to invade extensive areas across Australia's rangelands, as shown by its high abundance in one area of WA.[31]

The National Weeds Strategy Executive Committee, in collaboration with the Bureau of Resource Sciences (now the Bureau of Rural Sciences [BRS]), evaluated 74 plant species nominated as WoNS and, using strict criteria, listed 20 WoNS (Thorp and Lynch 2000). That list has been reviewed by the ACRIS Biodiversity Working Group for those plants known to significantly 'transform' rangeland habitats and impact on biodiversity. The working group has selected seven transformer weeds from the WoNS list (Table 3.8) and has added four invasive exotic grasses known to be transformers because of their major impacts on biodiversity in the rangelands. The distribution and abundance of these transformer exotic grasses is an important indicator of change.

Habitat changes due to transformer weeds

Invasive exotic weeds can transform ecosystems by directly altering the composition of the vegetation (Grice 2006) and hence the life-forms required as habitat by the native animals in the original ecosystem. For example, mimosa (*Mimosa pigra*), has replaced native vegetation in many ecologically valuable wetlands of the Top End of northern Australia, greatly altering the distribution and abundance of native fauna.

Weeds can also affect ecosystems indirectly by altering attributes such as fire regimes. Invasive exotic grasses such as gamba grass (*Andropogon gayanus*) and buffel

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[31] http://www.weeds.org.au/natsig.htm (accessed 15 May 2007)

Table 3.8 Eleven transformer weeds considered by the Biodiversity Working Group to have major impacts on biodiversity in Australia's rangelands, with a comparison to weeds listed as Weeds of National Significance (WoNS), by Grice (2004) and by Humphries et al (1991)

Species	Common name	WoNS[a]	Grice[b]	Humphries[c]	Ecosystems
Acacia nilotica	prickly acacia	✔	✔	✔	Grasslands/woodlands
Andropogon gayanus	gamba grass		✔		Floodplains and riparian communities
Pennisetum ciliare (syn. *Cenchrus ciliarus*)	buffel grass		✔	✔	Arid zone key habitats
Cryptostegia grandiflora	rubber vine	✔	✔	✔	Dry rainforest, monsoonal riparian communities
Hymenachne amplexicaulis	olive hymenachne	✔		✔	Floodplains and riparian communities
Mimosa pigra	mimosa	✔	✔	✔	Tropical wetlands and floodplains
Parkinsonia aculeata	parkinsonia	✔	✔	✔	Tropical rangelands, semiarid zone wetlands
Pennisetum polystachion	mission grass		✔	✔	Tropical forests, woodlands
Prosopis spp.	mesquite	✔	✔	✔	Semiarid zone grasslands and woodlands
Tamarix aphylla	Athel pine	✔	✔	✔	Arid/semiarid water-courses and riparian zone
Urochloa mutica	para grass			✔	Floodplains and riparian communities

Data sources:

[a] http://www.weeds.org.au/natsig.htm

[b] Grice (2004), Tables 1 and 2

[c] Humphries et al (1991)

grass (*Pennisetum ciliare*) have greatly altered the frequency and intensity of fires in the rangelands of northern and central Australia. Such changes in fire regimes have impacts on many plant and animal populations.

Other effects of transformer weeds act in synergy with processes such as livestock grazing that transform habitats and change the competitive relationship of native plants and animals. A comprehensive study of how disturbances affect birds in savannas, which included areas with the exotic buffel grass, found that bird species richness declined significantly with increasing levels of disturbance (Hannah et al 2007). In particular, there was an increased abundance of miners (interspecifically aggressive colonial honeyeaters).

Case studies: biodiversity changes due to transformer weeds

Rubber vine

Rubber vine (*Cryptostegia grandiflora*), is a transformer weed that has invaded many riparian habitats in the savannas of northeastern Australia (Figure 3.84), where it can smother native vegetation and form dense thickets (Figure 3.85). It has major impacts on biodiversity. Of 132 lizards in riparian habitats, not one was observed in rubber vine vegetation, and only one was observed in rubber vine vegetation in the surrounding woodland habitat (Valentine 2006). Laboratory experiments found that lizards chose native vegetation litter over rubber vine litter 80%–85% of the time (Valentine et al 2007).

Buffel grass

One introduced plant not included on the WoNS list is buffel grass, *Pennisetum ciliare* (syn. *Cenchrus ciliaris*). The current distribution and rate of buffel grass spread in the rangelands is unknown but is being investigated. The capacity of buffel grass to spread across rangelands in Australia and elsewhere is well established (Humphries et al 1991). For example, it was first recorded in SA in 1981 and has spread along the major roads the length of the rangelands. It appears to be spreading away from the highways along minor roads and drainage systems into other pastoral and Aboriginal rangelands. Buffel grass is considered the weed with the greatest environmental impact in the Anangu Pitjantjatjara Lands (Lang et al 2003).

Buffel grass is known to transform Australia's rangelands in ways that can be viewed as both positive and negative. In the positive view, it has improved livestock production in many regions of inland Australia and provided economic benefits to pastoral communities, particularly in Queensland savannas where tree clearing to enhance pasture production has been widespread (Figure 3.86). However, it is now a significant environmental weed of the arid conservation estate, and modelling suggests that it has the capacity to expand across a large proportion of northern Australia (Friedel et al 2006).

Figure 3.85 Rubber vine smothering trees in a riparian area, northeastern Queensland

Photo: Tony Grice, CSIRO

Figure 3.86 Grazing lands cleared and sown to buffel grass (*Pennisetum ciliare*), central Queensland

Remnant woody vegetation remains in the background. The pasture is dominated by buffel grass.

Photo: CSIRO, Townsville

The establishment of buffel grass following tree clearing in central Queensland has reduced floral diversity in brigalow and eucalypt woodlands to a far greater extent than has land clearing on its own (McIvor 1998, Fairfax and Fensham 2000). Ludwig et al (2000) reported a decrease in the abundance of Carnaby's skink (*Cryptoblepharus carnabyi*) and the delicate mouse (*Pseudomys delicatulus*) with increasing cover of buffel grass in cleared eucalypt woodlands of central Queensland.

Studies on buffel grass in remnant woodlands suggest that increasing vegetative cover in the landscape may be effective in reducing buffel grass spread because the species is less likely to occur in remnants located in landscapes where more than 30% of the original vegetation is retained (Teresa Eyre, Queensland Environmental Protection Agency, pers comm, 2007). As a restorative measure, regrowth may be important for the maintenance of biodiversity values in those landscapes, given the demonstrated impact of buffel grass on floral diversity (Fairfax and Fensham 2000, Franks 2002, Jackson 2005) and of burning regimes that alter faunal habitat suitability (Butler and Fairfax 2003, Hannah et al 2007).

Key points

- Case studies have shown that invasive exotic weeds can 'transform' habitats, which in turn can change species composition.
- Although the approximate distributions and abundance of transformer weeds are known across Australia's rangelands, better maps of current distribution and better models to predict potential spread are needed. This is especially true for exotic grasses such as buffel grass, where research is needed to investigate the potential for buffel grass status to change as a consequence of climate change (Friedel et al 2006).
- Knowledge of how and where transformer weeds directly and indirectly affect different fauna and flora species is improving. This growing knowledge contributes to increased understanding of changes in the biodiversity of Australia's rangelands.

Wetlands

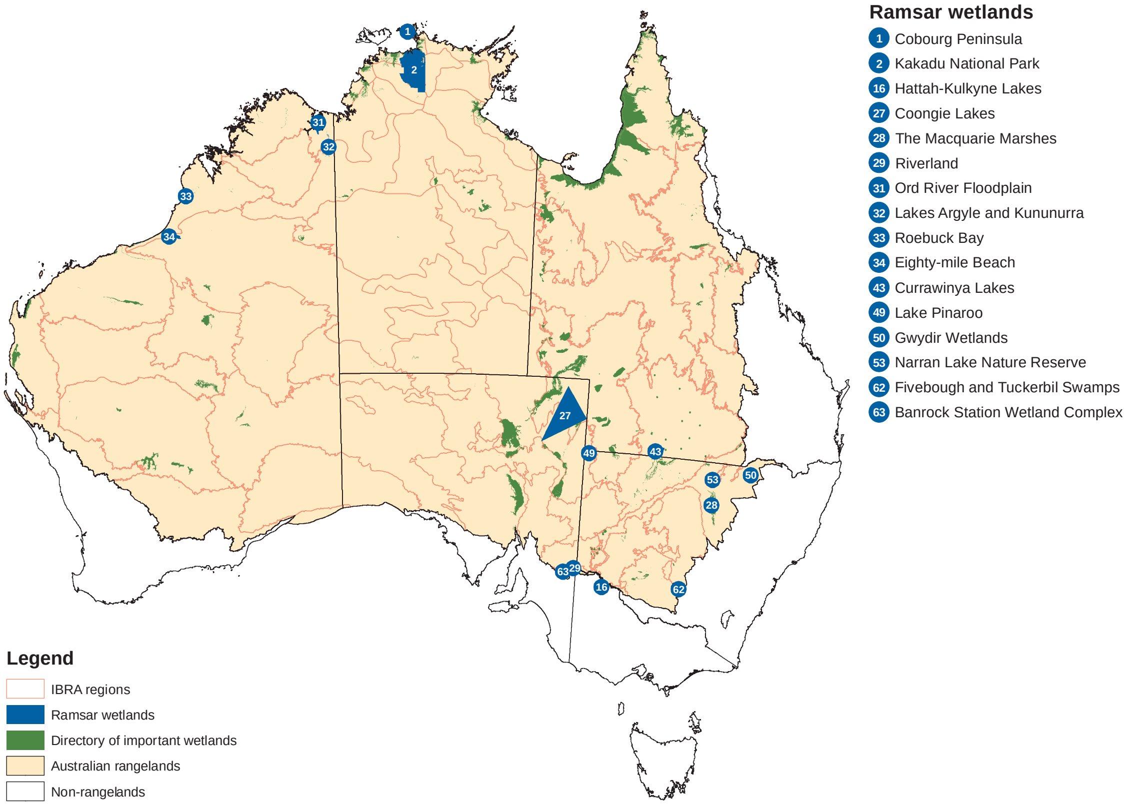
Wetlands across Australia's rangelands provide critical habitats for numerous components of biological diversity, such as waterbirds, freshwater fish and amphibians, and aquatic invertebrates (Figure 3.87). Because many wetlands are temporary across arid and semiarid rangelands, any change in their distribution or extent due to climate change and/or extraction of water has the potential to adversely affect dependent biota (Roshier et al 2001).

Temporary wetlands pose severe challenges to many species. In a drying phase, highly mobile species, such as waterbirds, can move to other available wetlands, but less mobile species, such as frogs, must have survival adaptation mechanisms.

Figure 3.87 Swamp area on the Barkly Tableland (Mitchell Grass Downs bioregion, NT) listed in *A Directory of Important Wetlands in Australia*

Photo: Roger Jaensch, Wetlands International

Figure 3.88 Internationally and nationally important wetlands within the rangelands, as listed under the Ramsar Convention on Wetlands and in *A Directory of Important Australian Wetlands*



Note: See http://www.environment.gov.au/water/publications/environmental/wetlands/directory.html for DIWA wetland names.

Source: Department of the Environment, Water, Heritage and the Arts, July 2007

Climate change may have significant effects on the condition and permanence of wetland habitats for biota across arid and semiarid rangelands, although there are currently limited data to demonstrate its potential to cause change. Emerging national wetland mapping and inventory work, if successful, may help to address this data deficit.

Listings of rangeland wetlands

'Ramsar wetlands' are designated as Wetlands of International Importance under the Ramsar Convention on Wetlands (Ramsar, Iran, 1971) because of their international significance in terms of ecology, botany, zoology, limnology or hydrology. Ramsar wetlands are also 'Matters of National Environmental Significance' and are protected under the EPBC Act.

In 2001, Australia had 57 sites designated as Ramsar wetlands. By 2006, that number had increased to 64, 16 of which are in the rangelands (Figure 3.88). A few of the 16 sites are coastal and might not be considered as 'rangeland' wetlands.

The Australian Government, in a cooperative project with state and territory governments, has developed the *Directory of Important Wetlands in Australia* (DIWA 2001). The directory aims to:

- identify sites and the wetland values in their local areas, particularly in relation to regional NRM planning and investment
- identify sites of importance for particular taxa, including threatened and migratory species
- provide the primary data source for identifying potential Ramsar sites.

The directory and its associated database provide information on the ecological and hydrological attributes of each nationally important wetland, and also contain information about wetlands' social and cultural values and some of the ecosystem services and benefits they provide. These data are accessible online at the website of the Department of the Environment, Water, Heritage and the Arts.[32]

Sixteen Ramsar wetlands were designated from 1974 to 2002, six of them after 1990. The DIWA database lists 291 wetlands within the rangelands as of 2006. Many of these are very small (eg 0.1-ha mound springs), but others, such as the tidal wetlands along the Gulf of Carpentaria on Cape York Peninsula, are very large (>1 million ha, Figure 3.88).

Monitoring and mapping Australia's wetlands

Satellite imagery of varying resolution (Landsat, SPOT[33], AVHRR) provides one data source for monitoring changes in the condition and distribution of temporary wetlands. Spectral matching using AVHRR data has been found to be a robust method for multitemporal studies of the presence/absence of water bodies in arid regions, provided salt-affected surfaces are excluded from the analysis. The accuracy of area estimates improves with size and regularity of shape of the wetlands being analysed. The low spatial resolution (1.1 km × 1.1 km pixels) precludes use of this methodology for area estimation in regions with complex, irregularly shaped drainage patterns (Roshier and Rumbachs 2004). The frequency of acquisition and the spatial resolution of satellite imagery are important considerations for monitoring wetlands because, as expected, temporary wetlands are strongly climate driven.

A study using analyses of satellite imagery to determine the distribution of different wetland types over 39 catchments within NSW found that approximately 5.6% of NSW is wetland (4.5 million ha), mostly (96%) in inland river catchments. Broad classification allowed identification of the extent of wetland types: floodplains (89%); freshwater lakes (6.6%); saline lakes (<1%); estuarine wetlands (2.5%); and coastal lagoons and lakes (1.5%). Conservation reserves protect only 3% of wetland areas (Kingsford et al 2004).

Figure 3.89 Wetland birds: little black cormorants (*Phalacrocorax sulcirostris*) and darters (*Anhinga novaehollandiae*) at nests

Many waterbird species are in decline in eastern Australia, Kingsford and Porter (in press).

Photo: Roger Jaensch, Wetlands International

Monitoring waterbirds

Repeat aerial surveys also demonstrate the importance of wetlands as critical habitats for waterbirds (Figure 3.89). A large area of eastern Australia, including extensive areas of rangeland, was monitored in 10 aerial surveys conducted in October between 1983 and 2004. Waterbird numbers were found to have declined across eastern Australia since 1983. The most significant decline occurred between 1984 and 1986, with further declines after 1991. The annual average number of birds during the first three years of the survey was about 1 100 000; from 1986 to 1995 about 405 000, and from 1996 to 2004 about 238 000 (Kingsford and Porter 2006).

Whether wetlands are regulated water bodies used as storages to manage river flows or unregulated natural lakes, it is important to define their condition and permanence as habitat for biota.

Key points

- The number of listed Ramsar and DIWA wetlands has increased notably since the early 1990s. This increase is an indicator of Australia's commitment to conserve habitats vital to the biota dependent on wetlands.

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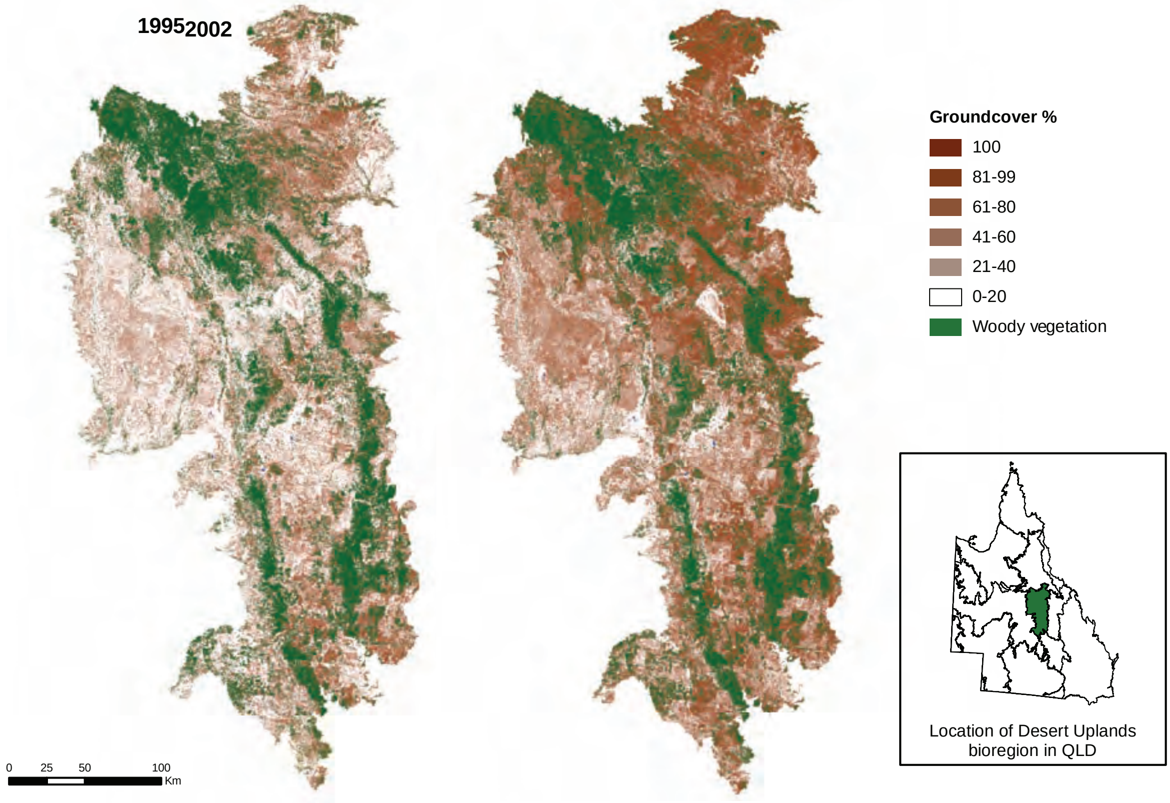
[32] http://www.environment.gov.au/water/publications/environmental/wetlands/database/ (accessed 4 April 2008)

[33] Le Système pour l'Observation de la Terre (French earth-observing satellites)

Figure 3.90 Groundcover over the Desert Uplands bioregion, 1995 and 2002 (%)



Source: Natural Resource Sciences, Queensland Department of Natural Resources and Water

- There is a continuing need for studies on the condition and persistence of wetlands as critical habitats for dependent taxa and for studies to improve our understanding of linkages between wetland habitat conditions (eg permanence, salinity, climate change effects) and specific components of biodiversity (eg waterbirds, frogs, invertebrates).

Habitat condition derived from remotely sensed groundcover

Remote sensing techniques have the potential to measure the amount and type of cover on the ground surface, such as the amount of perennial grass cover. The type and amount of ground surface cover (eg vegetation versus bare soil) indicates habitat condition for biota dependent on that cover. The amount of vegetation cover has also been used to indicate landscape function (see earlier in this chapter).

The capacity to use remote sensing to monitor land surface cover as habitat condition is improving. Landsat imagery has the spatial resolution and a historical archive that makes it valuable for understanding climate and management effects on native vegetation at a range of scales from small remnant to region. Regional and national vegetation monitoring programs based on time-series Landsat imagery are now operational in Australia (Wallace et al 2006).

However, remotely sensed groundcover only indirectly indicates biodiversity.

Monitoring groundcover as habitat condition

Remote sensing has mostly been applied to assess changes in the amount and type of groundcover for local landscapes within regions. Few groundcover assessments have been applied at regional scales, but the potential to do so can be shown by an example from Queensland's SLATS.

Imagery was acquired from the Landsat archive to cover the Desert Uplands IBRA bioregion in central Queensland, an area of about 69 000 km^2. The imagery was for every two years from 1989 to 2001 and then every year to 2004.

As an example of changes in a groundcover index[34], data for 1995 and 2002 were mapped (Figure 3.90). Changes are evident from the spatial differences in the intensity of white to light to dark brown colours. Much of the open rangeland in the northeast area of the Desert Uplands bioregion had a higher cover in 2002 (darker brown) than in 1995 (lighter brown). Note that areas covered by dense woody vegetation (green, areas of >20% foliage cover) and water (blue) are not considered in this comparison.

When interpreting maps of broad spatial changes in groundcover, it is important to keep in mind that the accuracy of detecting and monitoring changes in groundcover with satellite imagery depends on the openness of the vegetation. As woody cover increases, the accuracy of estimates of the groundcover index decreases. The index was not calculated where the projected foliar cover of woody vegetation exceeded 20%.

Case studies: habitat condition affects biodiversity

A number of significant relationships were found between plant, ant and vertebrate diversity measures (species abundance, composition, richness) and land condition based on regressions using 216 rangeland sites positioned across five land types in the Einasleigh Uplands of northern Queensland and the Ord Victoria Plains in the NT. These studies found that land condition appears to be the most strongly predictive for components of the biota whose ecology is closely linked to characteristics of the ground surface and density of ground layer vegetation, most notably ants.

However, there was only a weak relationship between land condition and many aspects of biodiversity, and the response of biota to land condition was complex and highly variable between taxa, land types and locations (Fisher and Kutt 2006).

The authors of the studies recommended that comprehensive biodiversity monitoring programs, at local or regional scales, include the direct assessment of selected biota.

Other studies in northern Australia's rangelands have found that decreases in habitat condition (low groundcover and poor soil surfaces) near cattle waterpoints contributed to declines in plant, small mammal, granivorous bird and invertebrate diversity (Woinarski 1999, Karfs and Fisher 2002, Churchill and Ludwig 2004).

Interpreting habitat condition for biodiversity

Although groundcover can provide a useful indicator of habitat condition, there are a number of constraints and limitations when using this information to interpret effects on biodiversity (Fisher and Kutt 2006):

- Components of biodiversity are likely to respond in a complex fashion to the spatial configuration of land condition across the landscape. Biodiversity status will be poorly predicted by limited point assessment of land condition.
- The history of land condition, other management influences such as fire frequency, and fine-scale climate variability are not necessarily reflected by the current condition.
- Rangeland condition assessment generally fails to capture the condition (ie health) of rare and restricted ecosystems, although these are generally areas of high biodiversity significance.
- Simplistic categorisations of land condition cannot adequately encompass the range of responses found in many biotic groups across different habitats.
- Perceptions of condition (and changes in condition) may diverge between ecological and production viewpoints (for example, in relation to introduced pasture and woody thickening).

According to Bastin and Ludwig (2006), challenges to using satellite-based data to map changes in vegetation condition are robustness, efficiency and generality. They conclude that mapping condition will always be difficult because of the large area, spatial complexity and temporal variability of arid-zone vegetation.

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[34] See Byrne et al (2004) and Scarth et al (2006) for details of this index.

Key points

- Changes in the amount of vegetation versus bare soil covering the ground surface can be a useful indicator of habitat condition, especially if considered relative to what might be expected for a given rangeland climate and soil type. Conceptually, the intactness of vegetation cover in a landscape indicates the structural and functional integrity of habitats, which is critical for maintaining plants and animal populations.
- More studies are critically needed to establish linkages between habitat condition indicators and the species dependent on critical amounts and types of groundcover.
- Studies linking groundcover with biological diversity have been largely based on local sites, but broader landscape and regional analyses are needed for the purposes of rangelands reporting.

Rangeland birds

Birds are a useful indicator of biodiversity (Mac Nally et al 2004) because changes in their population composition, abundance and distribution can signal that habitats have been significantly altered. Many such habitat changes affect not only birds but other biota.

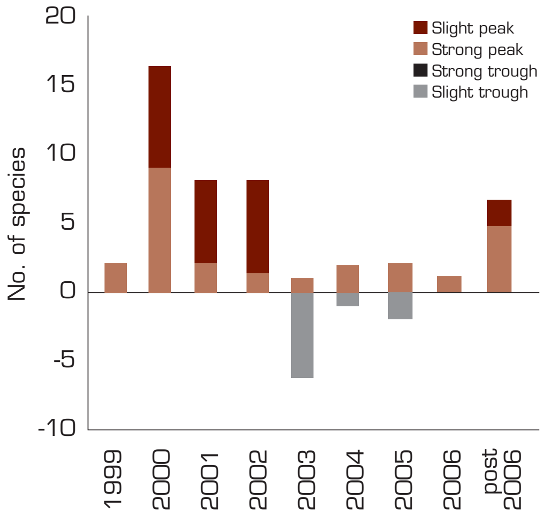
Birds are relatively easy to monitor: they are active during the day, are typically colourful, and have distinctive calls even if they cannot be seen. Many people enjoy observing, recording and contributing bird species information to formal databases, such as those maintained by Birds Australia.

Historical changes

Contrary to the expectation that there would be few bird conservation problems in Australia's rangelands, Reid and Fleming (1992) found that by the early 1990s a number of bird species had declined in abundance and extent since European settlement.

A recent analysis of changes in rangeland birds by Cunningham et al (2007) indicates that declines continue to occur for some species. Their analyses were based on 1999–2006 records in the Atlas of Australian Birds (Box 3.11). The reliability of trends in bird species composition depends on repeated surveys over long periods, so only those survey sites that had been repeatedly visited over a nine-year period (from 1998 to 2007) were included in their analyses.

Figure 3.91 Peaks and troughs in relative abundances of 60 rangeland bird species, 1999 to post-2006



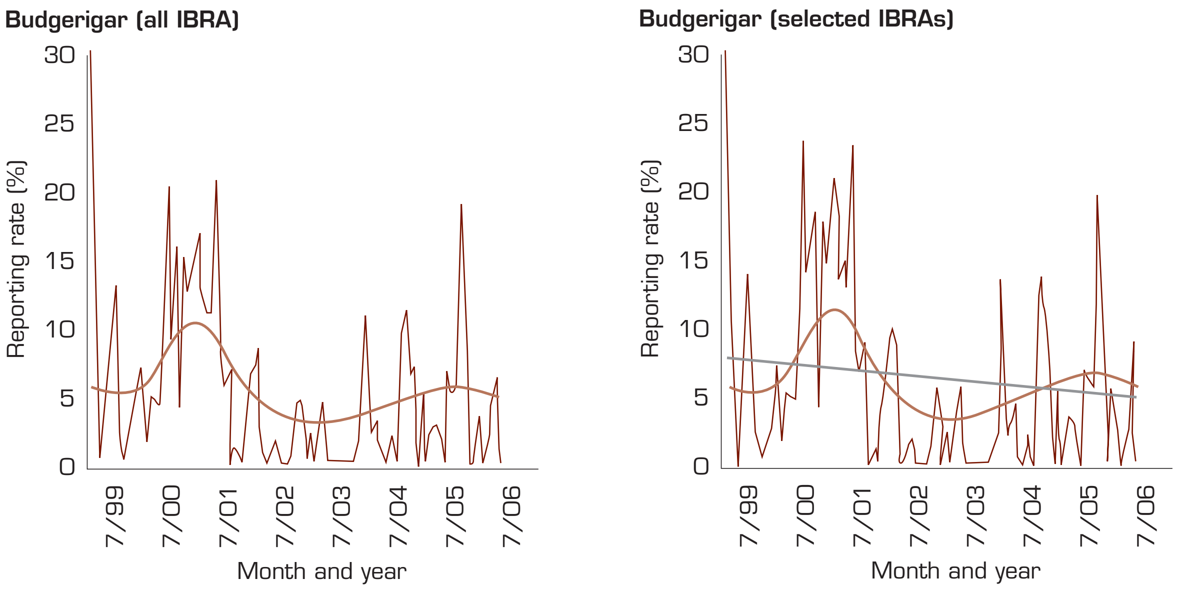
Source: Cunningham et al (2007)

Instead of using maps to represent the data, which would oversimplify complex patterns, this section uses graphs to illustrate four types of change: peaks and troughs in the overall relative abundance of 60 rangeland birds between 1999 and 2006, including an example of a species that peaked in the 2000–2001 wet period, and the trends for a 'decreaser' species, an 'increaser' species and a stable species.

Abundance of rangeland birds

Based on a high concordance among three experts evaluating peaks and troughs in the abundances of 60 rangeland birds over seven years (1999–2006), Cunningham et al (2007) found that many species showed peaks in occurrence in 2000 and 2001, followed by a less distinct period of troughs in 2003–2005 (Figure 3.91). They interpreted this pattern as corresponding to higher-than-average rainfalls before 2002 and the drought that occurred from then onwards. One species that clearly peaked in the number of times it was observed during the 2000–2001 wetter period was the budgerigar (*Melopsittacus undulatus*) (Figures 3.92 and 3.93).

Figure 3.92 Observed and smoothed reporting rates for the budgerigar (*Melopsittacus undulatus*)



Aggregated over year by month for all rangeland Interim Biogeographic Regionalisation for Australia (IBRAs)

Aggregated over year by month for only those rangeland IBRAs where the budgerigar was observed at least once. A linear trend is also shown.

Source: Cunningham et al (2007)

Changes in bird species

Of the 60 rangeland bird species evaluated, the three experts agreed that there were adequate data on 49 species to test for statistically significant trends (Cunningham et al 2007). They concluded that 11 species (22%) had decreased over the 1999–2006 period, 20 (41%) had increased, and 18 (37%) had remained stable. A species was also assigned a stable status when the three experts could not confidently assign a significant trend for the seven-year period. The grey crowned babbler (*Pomatostamos temporalis*; Figure 3.94) declined, while the crested pigeon (*Ocyphaps lophotes*) increased and the magpie-lark (*Grallina cyanoleuca*) remained stable (Figure 3.95).

Cunningham et al (2007) were constrained to using only the 1999–2006 period because of the available data. It was not possible to infer longer-term trends, given the highly variable climate of the rangelands and the fact that the ecologies of many species are responsive to irregular and unpredictable drought and rains, fire and many other factors. Detailed statistical analyses to Atlas of Australian Birds data for 10 rangeland IBRA bioregions could only be applied confidently because of the low numbers of bird surveys in most bioregions. Despite these

Figure 3.93 Budgerigars — observations peaked during the 2000–2001 wetter period

Photo: Robert Ashdown

Figure 3.94 Grey crowned babbler (*Pomatostamos temporalis*) — a species that has declined in the rangelands

Photo: Geoffrey Dabb

Box 3.11 Rangeland bird data

Based on bird surveys conducted in the rangelands soon after European settlement, Reid and Fleming (1992) analysed changes in bird species composition and found significant declines for some species. Their analyses built on information compiled by Garnett (1992). These data and analyses provide an assessment of the status of rangeland birds up to the early 1990s.

Changes in bird population composition and distribution across Australia and its territorial islands have been documented in The State of Australia's Birds reports (eg Olsen et al 2003). Changes noted in the reports are based on comparisons of findings from the first Bird Atlas, based on bird surveys conducted from 1977 to 1981, with those in the second Bird Atlas, based on surveys from 1998 to 2002. Those changes are not reported here, but readers interested in general changes in bird species across Australia are referred to Barrett et al (2003) and Olsen et al (2003).

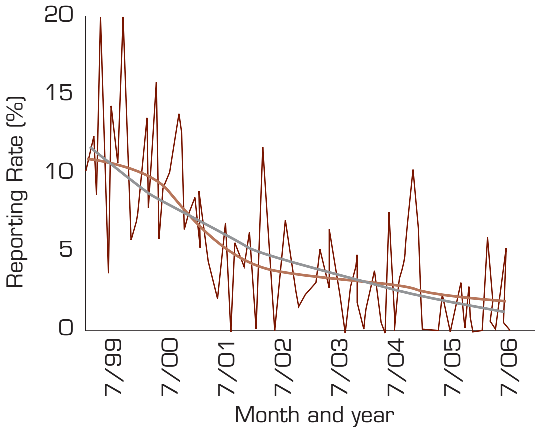
Bird Atlas data are collected by Birds Australia, the name used by the Royal Australasian Ornithologists Union, the goal of which is to conserve native birds and biodiversity. Its members have regularly observed birds and have provided their records to a database, known as the Atlas of Australian Birds, that now includes over 6 million records from across Australasia and Antarctica. Details of this volunteer system and the survey methods used by the Atlas can be found in Barrett et al (2003) and Weston et al (2006).

The most recent Bird Atlas records (up to 2007) have been analysed to detect significant changes or trends in Australia's rangelands (Cunningham et al 2007).

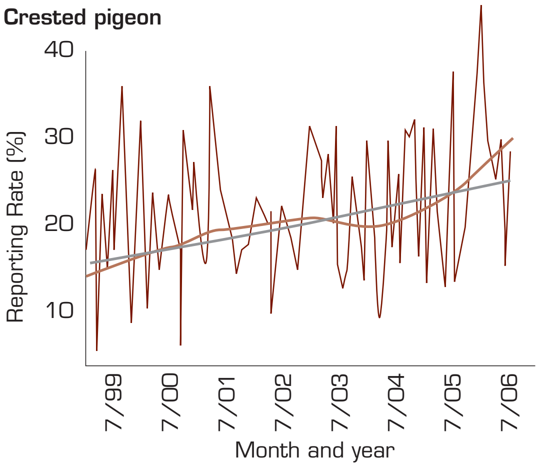
Bird species and numbers can fluctuate greatly between surveys: Maron et al (2005) found that 'site-level bird assemblage composition was markedly different between the two [yearly] survey periods'.

Figure 3.95 Observed and smoothed reporting rates for decreaser, increaser and stable species

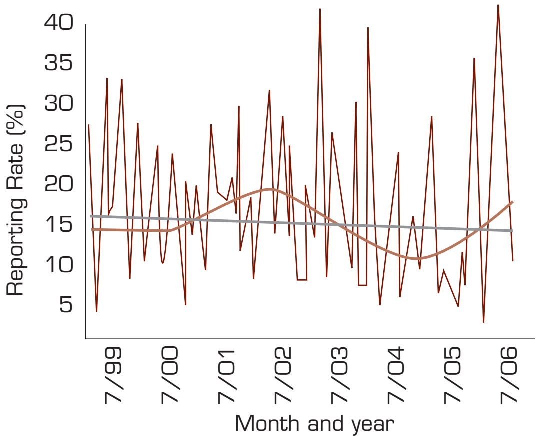
Grey crowned babbler



Crested pigeon



Magpie-lark



Top: A decreaser species
Centre: An increaser species
Bottom: A stable species

Note: Changes are based on data aggregated over year by month for only those rangeland IBRAs where the species was observed at least once. Linear trends are also shown.

Source: Cunningham et al (2007)

constraints, the authors stated that 'the results of this study flag changes in the relative occurrence of bird species that provide information on the current trends in bird populations in the rangelands. Placing these in the context of longer-term climatic or other variation will require more years of data collection.' Additional bird surveys would, they concluded, improve confidence in longer-term trends for those rangeland bioregions currently undersampled.

Key points

- The study by Cunningham et al (2007) demonstrated that records in the Atlas of Australian Birds could be used to explore significant trends over the seven-year period from 1999 to 2006.
- Substantial changes occurred among the 60 rangeland bird species analysed (some increased, some decreased and some remained stable).
- Causes of significant trends, and whether such trends would persist, were unknown, although records for many bird species peaked during the wetter 2000–2001 period and some showed troughs during the drought of 2002–2004.
- The adequacy of bird survey data has been summarised by Cunningham et al (2007) and is influenced, among other factors, by the variable climate in the rangelands and the low numbers of bird surveys in particular regions.

Conclusions

- Historically, there have been substantial declines in rangeland biodiversity. There is no reason to believe that the declines have ceased, given current land uses and time lags between impacts and their biological consequences.
- Realistically, there is only limited capability to report trends in biodiversity in rangelands at the national scale because of inconsistencies between jurisdictions in data collection, data gaps and limited specific biodiversity monitoring being undertaken to report at a bioregional or national scale.
- There are currently no coordinated broadscale biodiversity monitoring programs analogous to rangeland pasture condition monitoring (except for Birds Australia Atlas surveys).

- Although a set of useful indicators for reporting change in biodiversity has been developed, data for most of them are at best incomplete across the rangelands, and only some can currently report change over time.
- Improved 'habitat-condition' assessment tools at site scale relevant to rangeland users are needed (ie substantial research and development is required).
- There is a need to ensure consistency of indicator assessments at regional levels. The indicators used and their application should be meaningful for biodiversity conservation and management decision making.
- Substantial efforts and resources are needed to sample biota and measure ecosystem condition trends directly in order to track biodiversity. This may require the measuring and analysis of new biological indicators.

Box 3.12 Biodiversity monitoring activities

An ACRIS project was initiated in 2006 to find out:

- what biodiversity monitoring activities were occurring in the rangelands of each state and territory
- where monitoring was occurring
- whether respondents felt that this monitoring provided sufficient information to detect changes in biodiversity.

Project findings are reported in detail by Day (2007), with Table 4 in her report listing 15 'Current activities with potential for use in monitoring change in biodiversity', such as current pasture-monitoring programs. Information on current activities was obtained by interviews and a questionnaire, and the author notes that 'the low rate of [questionnaire] response means any conclusions are based only on the information available, and hence need to be interpreted with care'.

The following were among the key conclusions:

- There is a considerable amount of good baseline biodiversity information recorded in the relevant state/territory flora and fauna databases (eg Atlas of NSW Wildlife); however, there are gaps in coverage for the rangelands.
- Biodiversity programs that have a resampling component are usually short-term and local or regional in scale.
- Programs that are widespread usually provide only indirect information about biodiversity and/or sample the environment selectively.

Other findings suggest a considerable capacity for state/territory and Australian Government agencies to monitor biodiversity in the rangelands. For example, Day noted that 'Programs of relevance to the ACRIS report … included flora and fauna surveys by state and Commonwealth government departments and other organisations, large scale programs related to riparian systems (including waterbird surveys), individual species monitoring, specific research programs, local detailed fire mapping and the status of the national reserves system.'

Day's other, more general, conclusions about biodiversity monitoring in the rangelands included the following:

- The actual use of an indicator often depends more on the practicalities of application than on whether it is a good measure of biodiversity.
- For many indicators, much work still needs to be done to validate the proposed correlation between the indicator and biodiversity.
- To identify the best indicators for monitoring biodiversity in the rangelands, and make best use of the resources required to apply them, careful consideration needs to be given to their validation.

- Further investments (in an ACRIS-style model) and sustained efforts in coordinating and collating biodiversity data are required as part of a comprehensive biodiversity monitoring program involving state/territory agencies, and across regional NRM groups.

An analysis of the capacity to monitor biodiversity in Australia's rangelands by using a few key indicators has been provided by Day (2007), who assessed recent biodiversity monitoring activities (see Box 3.12).

Socioeconomic change

This section provides a socioeconomic update on the rangelands and reports on the value of non-pastoral products and on changes in land uses and land values. This information is critical because in Australia's rangelands non-pastoral activities and land uses are increasing and significantly contributing to overall economic value. Those activities have changed social structures (ie employment) and land market values.

Background

Natural resources are managed by people (Figure 3.96). Understanding the needs, capacities and motivations of Australia's land managers is critical to designing sound policy and program interventions and evaluating their impact at both the national and the regional scales. It is widely acknowledged that the condition of the natural resource base, a land manager's socio-demographic characteristics and management practices, enterprise financial status and the level of social capital in a community or industry are all interdependent.

Social and economic considerations in the rangelands are varied and complex. Since land management practices are crucial for positive 'triple bottom line' outcomes, a priority for those working with land managers has been to better understand their capacity to undertake a variety of land management practices. Measuring land manager capacity directly is problematic, so *Rangelands — Tracking Changes* (NLWRA 2001a) identified proxy indicators of capacity to undertake land management practices. These included median age of farmers, net emigration of young people and age-dependency ratio. However, preliminary work by the BRS indicates that proxy indicators are not a strong predictor of ability to adopt sustainable land management practices. Further studies are needed to understand land managers' behaviours in the rangelands.

The proxy indicators were tested in five pilot regions (ABS 2004). They showed that, in all regions except the Victoria River District in the NT, the median age of pastoralists was increasing, there was a net emigration of young people, and the age-dependency ratio was increasing.

Regional profiles

The sources of the data presented in this section are the ABS 2001 Census and the Australian Bureau of Agriculture and Resource Economics (ABARE) farm surveys from 1999 to 2006. In the absence of indicators of the ability of land managers to adopt sustainable land management practices, the information provided here gives context to the biophysical data provided in the other parts of this chapter, as well as outlining some socioeconomic trends.

Figure 3.96 People on the land — integral to managing the rangeland's natural resources

Coral Beebe on her family's property, Ucharonidge, NT.

Photo: Newspix / James Croucher

The pastoral zone used by ABARE to define the rangelands differs from the rangelands boundary adopted by ACRIS. Boundary differences are most marked in the east, where some of the most significant non-pastoral agricultural production occurs. Reporting is by statistical local areas (SLAs) rather than by IBRA bioregion, making it difficult to spatially compare commodity values by SLA with the IBRA regionalisation used by ACRIS.

Socioeconomic profiles based on ABS data

Characteristics of rangeland communities are listed below. The following 'headline' statements cover the whole of each rangeland SLA and therefore include people living in urban centres, as well as those actually managing the rangelands.

- *Age structure*: Overall, the changes in age structure in the rangelands reflect two trends: the aging of the national population (Figure 3.97) and the migration of young people away from rural areas.
- *People migration*: No region had in-migration of young people (Figure 3.98). Out-migration was still occurring even in the places where it had previously been low.
- *Education*: The level of educational attainment suggests that the traditional farming education of learning on the job is more common than in the non-rangelands areas.
- *Employment*: There was a dramatic drop in unemployment in the rangelands over the 10-year period to 2001. This rangelands trend mirrors the decrease in unemployment across Australia as a whole through that decade.
- *Dependency*: There was an overall slight decrease in the dependency ratio across the rangelands; that is, there were fewer people aged either under 15 or over 65 per 100 people in the rangelands.
- The SEIFA[35] *Index for Relative Socioeconomic Disadvantage* shows that the most disadvantaged areas in the rangelands are well below the Australian average score. Much of the NT and WA and the western half of SA comprised the two most disadvantaged categories.
- *Employment diversity*: Regional employment diversity tracks the number of people employed by the three main employment sectors in the region. Low-diversity areas have more than 60% of their employment in the three main sectors, and high-diversity areas have less than 50%. Diversity is desirable because it adds resilience to a community during poor times in one employment sector. Roughly equal numbers of IBRA regions are categorised as having low or moderate employment diversity. The Nullarbor, Cape York and the west coast are the sites of low diversity. The moderate-diversity regions are in a nearly continuous belt across the country. Most of the high-diversity IBRA regions are on the north coast of the NT (Hanslip and Kelson 2007).

Profiles based on ABARE statistics

An ABARE farm survey is a sample rather than a census. In the rangelands, the number of farms included in a single rangeland region ranged from a low of five to a high of around 100. As a result, any conclusions based on these data must be considered indicative; however, they provide information in addition to that available from the ABS statistics.

- *Extent of training*: Training was a priority among most farmers in the majority of regions sampled in 1999. In almost all the regions for which there are data, a majority of farmers had recent training.
- *Off-farm income*: Based on the few regions for which there are data, off-property incomes in the rangelands are low (mostly less than $20 000), with the highest income category being just over $20 000. This compares unfavourably with the off-property incomes reported by non-rangelands farmers in BRS landholder surveys.
- *Level of income*: No area of the rangelands is clearly associated with particular income levels. The southwest and northeast seem to have higher levels of income than the southeast. If there were a financial barrier to adoption of any particular practice, it would more likely occur in the regions included in the lowest income category.

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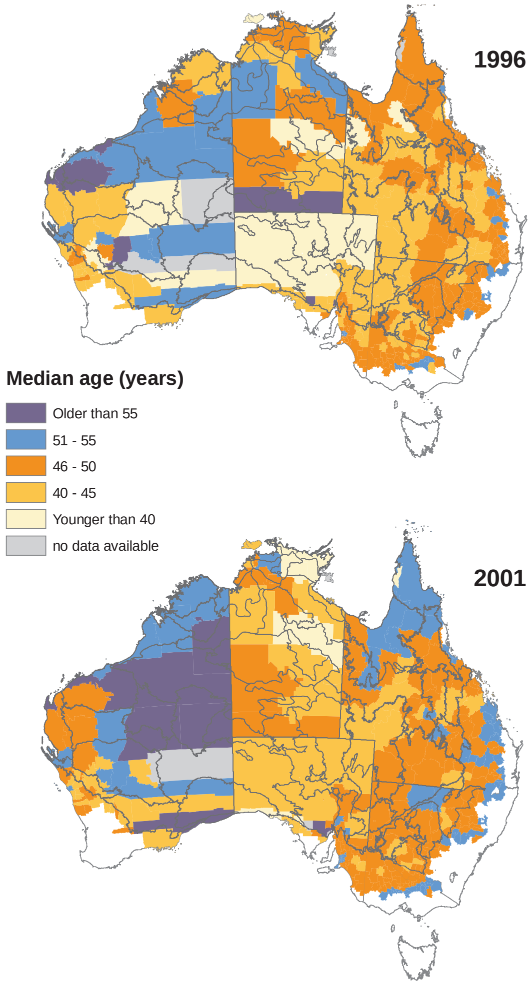
[35] Socio-Economic Indexes for Areas: http://www.abs.gov.au/websitedbs/D3310114.nsf/home/Seifa_entry_page (accessed 9 April 2008)

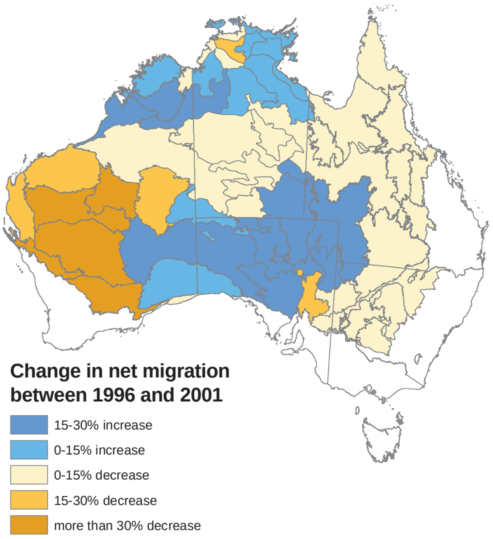
Figure 3.97 Change in median age in rangeland SLAs, 1996 to 2001



Data: ABS Population and Housing Census, 1996 and 2001. Map: BRS, 2007

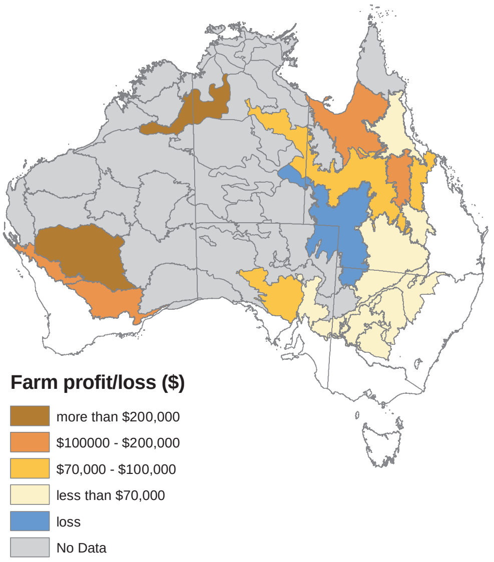
- *Profit at full equity*: Four regions in the western part of the rangelands are in the same category for farm cash income as they are for profit at full equity (Figure 3.99). This indicates low debt levels. In the east, many of the regions move down in category, indicating that they carry debt. One region is in an average loss position after debt is taken into account. Virtually all the regions for which there are data are in a healthy equity-ratio situation.

Figure 3.98 Change in net youth migration, 1996 to 2001



Data: ABS Population and Housing Census, 1996 and 2001. Map: BRS, 2007

Figure 3.99 Profit at full equity (2004–06 average)



Data: ABARE Farm Surveys. Map: BRS, 2007.

Figure 3.100 Cotton — a significant contributor to non-pastoral agricultural production in the rangelands

In 2001, cotton production was worth $56.6 million, or 23% of the total value of all rangeland crops.

Photo: CSIRO

Key points

- The rangelands share two main traits with the rest of Australia: low unemployment and an aging population.
- Factors that separate the rangelands from non-rangeland areas include the rangelands' inaccessibility, relatively low educational levels and socioeconomic disadvantage.

Contributing elements to socioeconomic change

Many elements contribute to the complete socioeconomic picture for the rangelands. In the following sections, three elements that are particularly relevant to agriculture in the rangelands are presented:

- non-pastoral agricultural activity
- land use
- pastoral land values.

Agriculture in the rangelands is changing in response to pressures and opportunities.

Non-pastoral agricultural activity

This section describes the importance of non-pastoral agricultural activity, primarily cropping and horticulture, across Australia's vast rangelands. Data are based on SLAs within a pastoral zone defined by ABARE (Figure 3.102). The ABARE pastoral boundary differs in places from the rangelands boundary used in other themes in this report, which are based on IBRA bioregions.

National overview

In 2001, non-pastoral enterprises in rangeland regions (Figures 3.100 and 3.101) contributed $627 million or 26% of the total value of Australia's agricultural products from the rangelands ($2427 million) (Table 3.9). Traditional pastoral production (grazing of sheep and cattle) contributed the other $1800 million (74%) to the total.

Of the 23 716 people employed within the rural sector of the rangelands in 2001, 27% held jobs in the non-pastoral sector. These data were collected by SLA (Figure 3.102), primarily in the 2001 Census conducted by the ABS and in farm surveys conducted by ABARE. Enterprises and industries were defined using Australian and New Zealand Standard Industrial Classifications.

Products from horticulture and field crops contributed the greatest values from non-pastoral rangeland agriculture in 2001 (Table 3.10.1). The principal horticultural products included grapes, mangoes,

Figure 3.101 Grapes — an important component of horticulture in the rangelands

In 2001, there were 464 grape-growing enterprises that collectively generated $104.9 million, 30.3% of the total value of rangelands horticulture ($345.7 million).

Photo: NT Department of Primary Industries, Fisheries and Mines

Table 3.9 Estimated value of agricultural products, number of holdings and people employed, pastoral and non-pastoral enterprises within Australia's rangelands, 2001

2001	Pastoral	Non pastoral	Total
Value of products[a] ($m)	1 800	627	2 427
Number of holdings[b]	3 997	1 888	5 885
People employed in agriculture	17 197	6 519	23 716

Note: 'Agriculture' is defined broadly and includes pastoral, field cropping and horticultural activities. Pastoral enterprises include sale of cattle for meat and sheep for meat and wool. Any other agricultural activity was considered 'non-pastoral', including production from livestock other than sheep and cattle.

[a] ABS estimates the gross value of a product for an SLA by taking production data and multiplying by an average price for that product for the state where the SLA is located. The production data provided by the ABS refer to those SLAs in the Australian rangelands where some agricultural production was reported in the 2001 Census.

[b] With an estimated value of agricultural production greater than $22 500 per year.

Source: ABS

citrus and vegetables (Table 3.10.2). The total value of field crops was dominated by wheat and cotton. Livestock, other than sheep and cattle, produced in the rangelands include goats, pigs and poultry. In 2001, more than 6500 people were employed in these non-pastoral enterprises (Table 3.10.3).

Figure 3.102 Statistical local areas within the rangelands, as defined by ABARE

Note: SLAs within the pastoral zone defined by ABARE as those areas experiencing very low rainfall. Non-rangeland areas are those with medium to high rainfall. These rangeland SLAs are used in reporting survey statistics.

Map: Chudleigh and Simpson (2004).

Table 3.10.1 Principal land uses contributing to non-pastoral agriculture in the rangelands, 2001

Land use	Gross value ($)	% total non-pastoral production value
Horticulture	345 724 536	55
Field crops	238 638 536	38
Other livestock	38 080 561	6
Not defined [a]	4 646 699	1
Total	627 090 332	100

[a] Data are not suitable for publication by ABS because of small sample size.

Table 3.10.2 Number of enterprises, by non-pastoral product, 2001

Crop	Number of enterprises
Mangoes	566
Grapes	464
Cereals for grain	413
Citrus	369
Vegetables	312

Note: More than one product may be produced on the same holding, so the number of enterprises cannot be added with any confidence.

Table 3.10.3 Employment, by industry sector, 2001

Industry sector	People employed	% total non-pastoral employment
Horticulture	3003	46
Field crops	2682	41
Other livestock	477	7
Undefined	357	6
Total	6519	100

Source: Data based on Chudleigh and Simpson (2004).

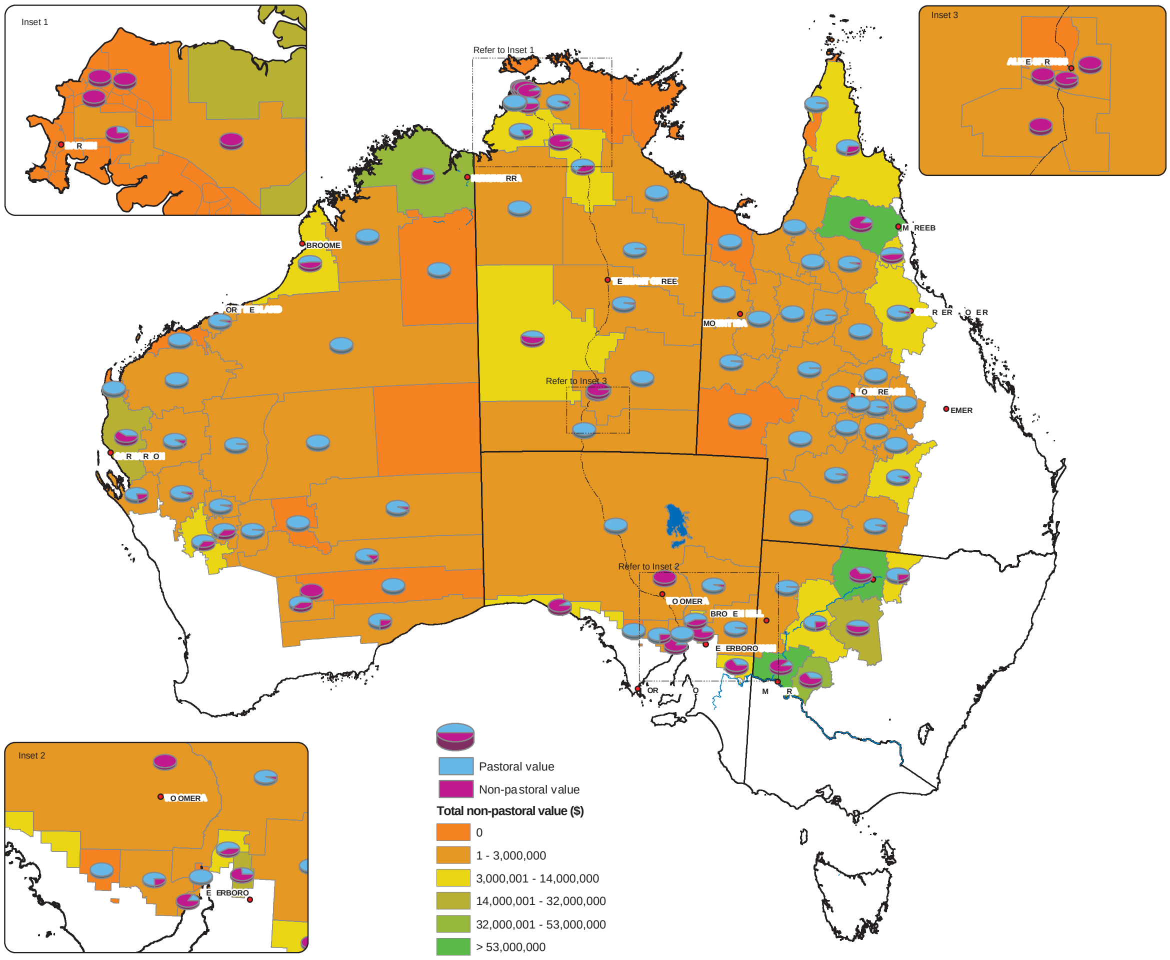
Land areas contributing to non-pastoral activities remain small, with only 0.2% (11 909 km^2), being used for dryland agriculture in 2001 (Table 3.11) and an even smaller area (510 km^2) for irrigated agriculture.

Table 3.11 Land areas used for conservation, pastoral and agricultural production, and urban settlements in Australia's rangelands, 2001

Land use	Area (sq km)	Area (%)
Conservation and natural environments	2 292 270	38.65
Production from relatively natural environments	3 513 376	59.24
Production from dryland agriculture and plantations	11 909	0.20
Production from irrigated agriculture and plantations	510	0.01
Intensive uses (eg urban)	2 422	0.04
Water	110 417	1.86
Total	**5 930 904**	**100.00**

Source: Stewart et al (2001), reproduced in Donohue (2003).

Figure 3.103 Gross value of non-pastoral agricultural production in the rangelands, 2001



Data based on Chudleigh and Simpson (2004). Map: NLWRA.

State and territory non-pastoral products and values

In 2001, the value of non-pastoral products from rangelands varied considerably among states and territories (Figure 3.103; Table 3.12). Value was highest for NSW, where non-pastoral production (largely of cereals, grapes and cotton) contributed 60% of total agricultural production. The second highest value was for Queensland, which produced fruit (excluding grapes), sugar and peanuts, mostly on the Atherton Tableland. WA was the leader in vegetable production. As expected, the lowest contributions were typically from SLAs in the more arid rangelands.

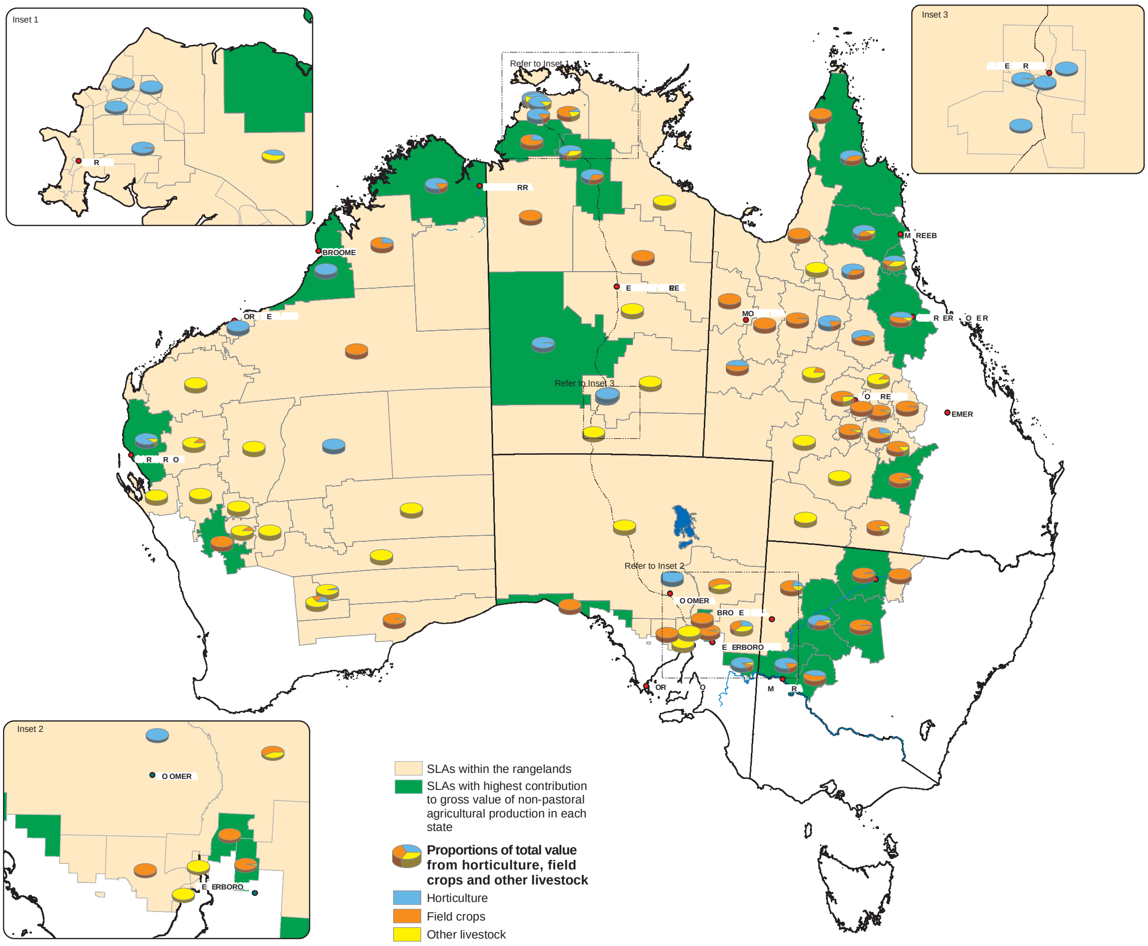
The proportional value of rangeland non-pastoral products varies considerably between jurisdictions (Figure 3.104), but overall is only a very small proportion of their total non-pastoral production. An exception is the NT, which is entirely defined as rangeland SLAs.

Table 3.12 Value of non-pastoral products from each state or territory in the rangelands, 2001

State	Value of pastoral industries ($m)	Value of non-pastoral industries ($m)	Total value of agriculture ($m)	Non-pastoral agriculture as a percentage of total agriculture
New South Wales	196.6	270.7	467.2	58%
Queensland	1167.9	157.0	1324.9	12%
Northern Territory	198.4	71.2	269.6	26%
Western Australia	189.1	90.6	279.7	32%
South Australia	83.2	37.7	120.9	31%
All Australian rangelands	1835.2	627.2	2462.3	26%

Source: Data based on research by Chudleigh and Simpson (2004).

Figure 3.104 Proportional gross value of horticulture, field crops and livestock for each SLA across the rangelands



Data based on research by Chudleigh and Simpson (2004). Map: NLWRA.

As might be expected, the value of production of non-pastoral agriculture is concentrated in specific areas of the rangelands (Figure 3.104) — those with higher rainfall, irrigation schemes, aquifers with suitable groundwater for irrigation and better soils. A small number of rangeland regions contribute a high proportion of non-pastoral value.

Rangeland horticulture

In 2001, horticulture contributed $345.7 million (56%) of the total value of non-pastoral agricultural production across Australia's rangelands (Table 3.13). Relative to the gross value of Australia's total horticultural production of $6604.6 million, the contribution from rangelands was 5.2%. The rangelands contributed 7.6% of Australia's fruit production (excluding grapes) and 3.4% of Australia's vegetable production.

Table 3.13 Contribution of rangeland horticulture to Australian horticulture, 2001

Product group	Rangelands ($m)	Australia ($m)[a]
Fruit (excluding grapes)	155.7 (7.6%)	2041.5
Grapes	104.9 (6.9%)	1517.5
Vegetables	74.7 (3.4%)	2182.6
Nurseries, flowers and turf	10.4 (1.3%)	794.7
Total value of horticultural production	345.7 (5.2%)	6604.6

[a] Includes rangelands states as well as Victoria, Tasmania and ACT

Source: Chudleigh and Simpson (2004).

Based on ABS Census data for 1997 and 2001, the value of horticultural products in the rangelands increased by 54% (Table 3.14), although caution is advised when interpreting these results, as climate and prices may have contributed to the increase.

Table 3.14 Changes in value of rangeland horticultural production, 1997 to 2001

Product group	1997 ($m)	2001 ($m)
Fruit (excluding grapes)	107.1	155.7
Grapes	56.9	104.9
Vegetables	50.9	74.7
Nurseries, flowers and turf	10.2	10.4
Total value of horticultural production	225.1	345.7

Source: Data based on research by Chudleigh and Simpson (2004).

In 2001, 3003 people were employed in horticultural industries in the rangelands, compared to 69 481 people employed in horticultural activities nationally.

Notable differences between states and territories exist in horticultural production across the rangelands (Table 3.15).

- Queensland produces 44% of the value of fruit (excluding grapes), or $68 million of the total value of $155.7 million.
- NSW and the NT each make up about 22% of the total value of fruit production (excluding grapes).
- Fruit production (excluding grapes) was mostly citrus in NSW and mangoes and bananas in WA and the NT.
- Queensland also produced mangoes and bananas but to a lesser extent, and produced a greater variety of fruits.
- The value of grape production in the rangelands was dominated by NSW, followed by the NT.
- WA dominated vegetable production.

Table 3.15 Values of different horticultural products from the rangelands, by state or territory, 2001 ($ million)

State	Fruit excluding grapes	Grapes	Vegetables	Nurseries, flowers and turf	Total
New South Wales	35.1 (22%)	89.7 (86%)	5.3 (7%)	2.0 (19%)	132.1 (38%)
Queensland	68.0 (44%)	0.2 (0.2%)	14.0 (19%)	4.1 (39%)	86.3 (25%)
Northern Territory	34.3 (22%)	14.3 (14%)	3.9 (5%)	3.6 (35%)	56.1 (16%)
Western Australia	14.7 (9%)	0.3 (0.3%)	51.5 (69%)	0.7 (7%)	67.2 (19%)
South Australia	3.6 (2%)	0.4 (0.4%)	0.03 (0.4%)	0.0 (0%)	4.0 (1%)
Australian rangelands	155.7	104.9	74.7	10.4	345.7

Source: Data based on research by Chudleigh and Simpson (2004).

Horticultural production was concentrated in those rangeland regions where irrigation is usually feasible and where soils are suitable for irrigated agriculture (Figure 3.105). Although there were general similarities in regions with different horticultural products, there were specific differences for grapes (Figure 3.106), vegetables (Figure 3.107) and mangoes (not shown).

Rangeland cropping

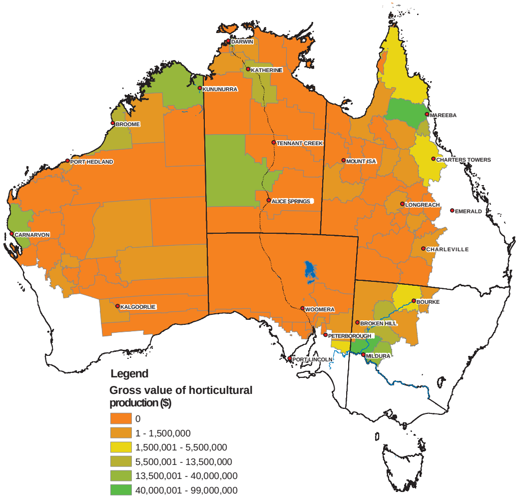
Crop production is a significant industry in Australia's rangelands. In 2001, cropping contributed $239.2 million or 38% to the total value of non-pastoral agricultural production (Table 3.16). This crop production was mostly wheat and cotton, but other cereal crops, sugarcane and hay contributed significantly to the total.

Table 3.16 Values of different crops produced across the rangelands, 2001

Crop	$m	%
Wheat	100.1	42
Cotton	56.6	23
Other cereals, oilseeds, legumes and peanuts	23.4	10
Pastures and grasses and crops for hay	16.2	7
Other crops	42.9	18
Total	239.2	100

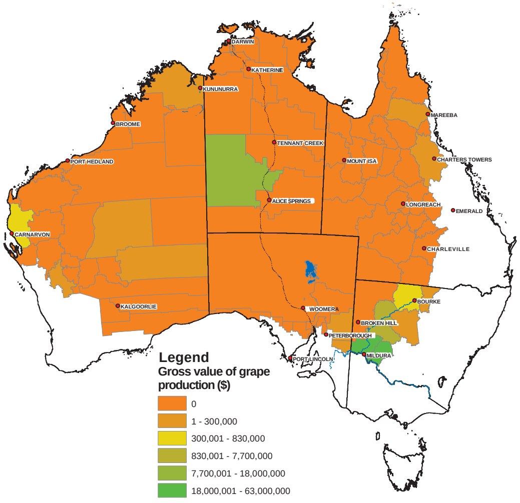
Source: Data based on research by Chudleigh and Simpson (2004).

Figure 3.105 Gross value of all horticultural products, by rangeland statistical local area, 2001



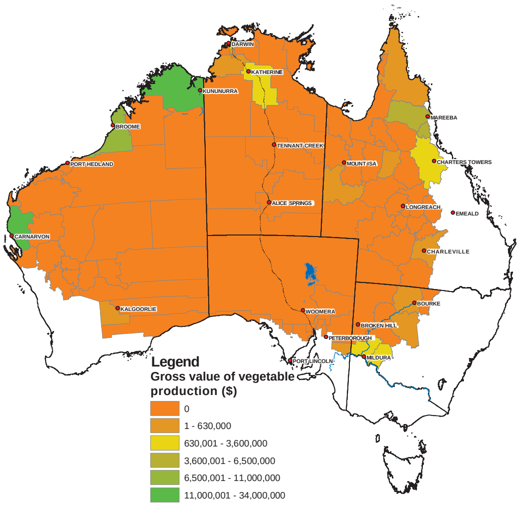
Source: Chudleigh and Simpson (2004). Map: NLWRA.

Figure 3.106 Gross value of grapes produced, by rangeland statistical local area, 2001



Source: Chudleigh and Simpson (2004). Map: NLWRA.

Figure 3.107 Gross value of vegetables produced, by rangeland statistical local area, 2001



Source: Chudleigh and Simpson (2004). Map: NLWRA.

The contribution from rangelands cropping was 2% of the total value of Australia's field crop production in 2001. Cotton growers in the rangelands produced 4.3% of Australia's total value of cotton production.

Based on ABS Census data in 1997 and 2001, the value of cotton and some grain crops decreased, but the overall value of all field crops increased, largely due to wheat (Table 3.17). Caution is advised when looking for trends because climate and prices may have contributed to the changes reported.

Table 3.17 Rangeland crop production, 1997 and 2001 ($ million)

Crop	1997	2001
Wheat	63.3	100.1
Cotton	80.8	56.6
Other cereals, oilseeds, legumes and peanuts	29.5	23.4
Pastures and grasses and crops for hay	5.1	16.2
Other crops	42.1	42.9
Value of all field crop production	220.8	239.2

Source: Data based on research by Chudleigh and Simpson (2004).

ABARE data from broadacre holdings in the rangelands show that, in the 14 years to 2001, there was a significant increase in non-pastoral product receipts in SA and NSW while the NT showed a significant decrease. Queensland and WA showed no significant trend over those years.

At a regional level, several of the ABARE regions showed significant trends in the value of non-pastoral products. Cape York (Queensland) and the Pilbara (WA) regions had positive trends, while Alice Springs (NT) and Victoria River (NT) both showed negative trends. Increasing diversification in the rangelands of the NT has arisen mainly from horticultural production, but the impact of this would not have been captured in the ABARE broadacre survey.

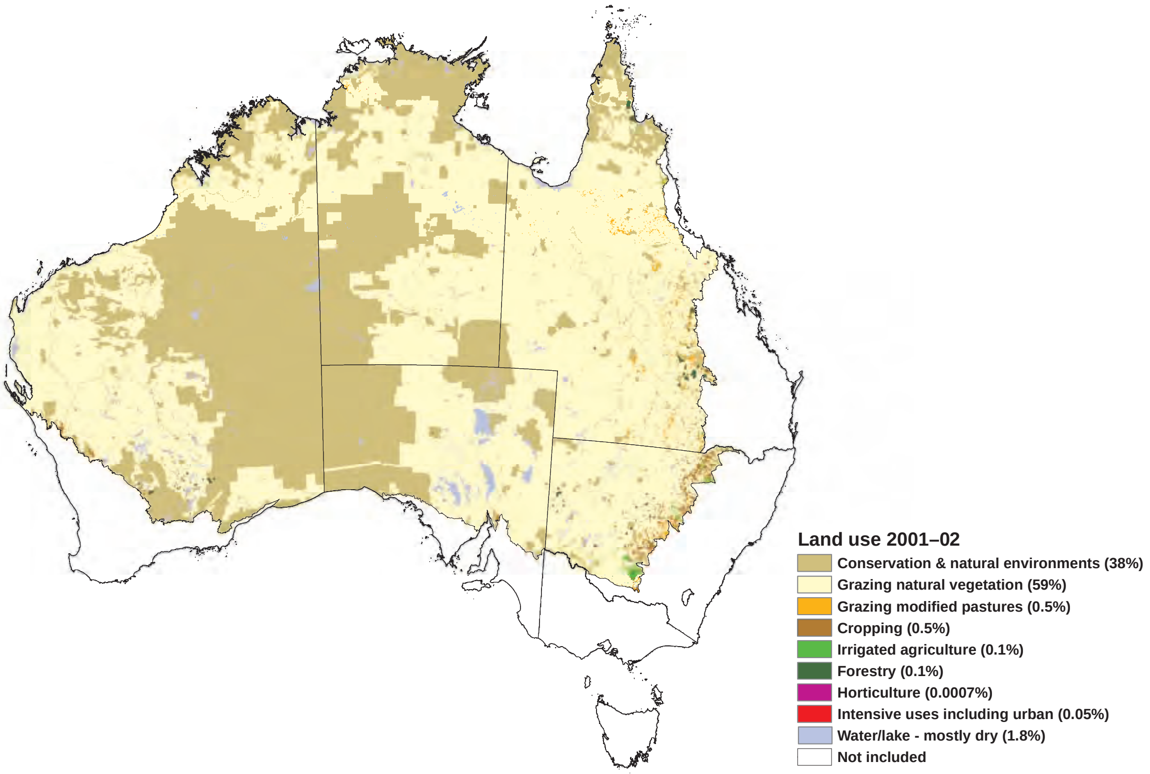
Cropping in the rangelands employed 2682 people, or 7.5% of the 35 745 employed in the whole of Australia's cropping industry. Each state and territory within the rangelands contributed differently to this

Table 3.18 Values of different crops produced in each state and territory across the rangelands, 2001 ($ million)

State	Wheat	Cotton	Other cereals, oilseeds, legumes and peanuts	Pasture and grasses and crops for hay	Other crops	Total
New South Wales	69.6	51.5	11.6	3.9	0.1	136.7
Queensland	0.9	4.5	3.9	3.5	35.2	48.0
Northern Territory	0.0	0.0	0.7	7.2	0.3	8.2
Western Australia	3.5	0.6	2.2	0.8	7.2	14.3
South Australia	26.1	0.0	5.1	0.8	0.1	32.0
Australian rangelands	100.1	56.6	23.5	16.2	42.9	239.2

Source: Data based on research by Chudleigh and Simpson (2004).

Figure 3.108 Land uses across Australia's rangelands, July 2001 to June 2002



Note: The 'Conservation and natural environments' class is characterised by a relatively low level of human intervention. It includes nature conservation, areas managed primarily for the sustainable use of natural ecosystems (including traditional Indigenous uses), unallocated Crown land, and other minimal uses (such as defence and stock routes).

Data: BRS. Map: NLWRA.

total value (Table 3.18). Of the $100 million worth of wheat produced in all the rangelands in 2001, NSW contributed $70 million (70%) and SA $26 million (26%). The NSW rangelands also dominated production of other cereals and cotton. Queensland rangelands dominated sugar and tobacco, largely from the Atherton Tableland.

Key points

- Non-pastoral products (particularly cropping and horticulture) contribute significantly to regional economies in different parts of the rangelands. Cropping is concentrated on the rangelands' eastern, southern and southwestern margins, which have better soils and relatively more reliable rainfall. Horticulture is more widespread, as it is supported by groundwater that allows irrigation.
- The value of the main horticultural products (grapes, other fruit and vegetables) increased substantially between 1997 and 2001. The overall value of all field crops (and mainly wheat) increased during the same period, although the value of cotton and some grain crops decreased. These changes should be interpreted cautiously, as climate and prices may have contributed to reported changes. A longer period of reporting is required to quantify the rate of change in the value of non-pastoral products.
- The pastoral zone used by ABARE to define the rangelands differs from the rangelands boundary adopted by ACRIS. Boundary differences are most marked in the east, where some of the most significant non-pastoral agricultural production occurs. Reporting is by SLA rather than IBRA bioregion, making it difficult to spatially compare commodity values by SLA with the IBRA regionalisation used by ACRIS.

Box 3.13 Land use mapping

Data and maps on land uses across Australia's rangelands have been generated using the SPREADII (Spatial Reallocation of Aggregated Data) model (Knapp et al 2006). The model was developed by the Bureau of Rural Sciences (BRS 2006). SPREADII links agricultural statistics for various crops and pastures with time-series satellite data and with available spatial data on non-agricultural land uses. Linking those different data requires caution because:

- the land use maps are a snapshot of land use at a particular time
- the resolution (pixel size) of the AVHRR satellite data used is 1.1 km, which is too coarse to map land uses covering small areas
- some agricultural land uses and crop types are impossible to distinguish with satellite data alone, and other spatial data must be used.

Model outputs are mapped to the nationally agreed Australian Land Use Mapping (ALUM) system. That mapping method is statistically robust and cost effective, making it useful for detecting gross land use changes over large areas such as the rangelands. ALUM maps have been generated by BRS for ACRIS to cover the 1992 to 2002 period.

Catchment-scale land use data have also been collected by states and territories. Those data are available for most of the rangelands, but have been collected only for about 10 years and are still incomplete for many areas. Therefore, catchment-scale land use data were not used in this report.

Land use

Australia's rangelands encompass a rich variety of different land uses, as illustrated by a map for 2001–02 (Figure 3.108). In addition to the typical grazing of natural vegetation by livestock, other land uses include conservation in large areas and cropping and horticulture in smaller areas.

Land use changes: 1992 to 2002

Changes in land use across the rangelands are associated with expansion of the conservation estate, Indigenous land ownership, mining activity and the development of non-pastoral enterprises. Land use maps covering rangeland regions from 1992 to 2002 have been generated (Box 3.13), and the information assessed.

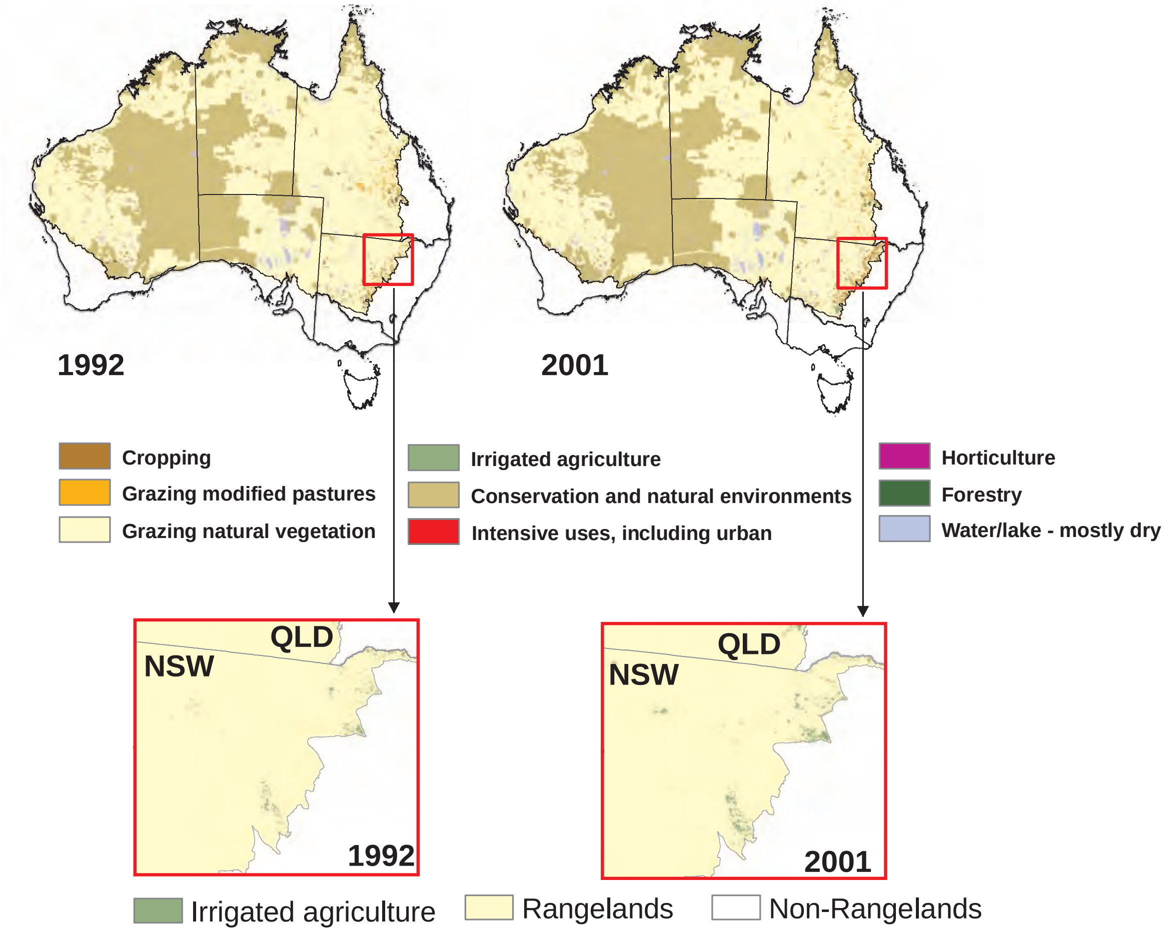
Comparing land uses in 1992 and 2001 across all rangeland regions (Figure 3.109) indicates that very little has changed — pastoral and conservation land use remained extensive while other land uses varied somewhat but remained relatively small in area (Table 3.19). However, by 'zooming in' on an area

Table 3.19 Land uses, selected financial years between 1992–93 and 2001–02 (km^2)

Land use	1992–93	1993–94	1996–97	1998–99	2000–01	2001–02
Conservation and natural environments	2 318 507	2 320 796	2 325 253	2 339 217	2 365 104	2 368 415
Grazing natural vegetation	3 731 800	3 725 300	3 729 100	3 697 900	3 663 100	3 666 400
Forestry	12 008	12 008	12 024	12 007	11 730	11 697
Grazing modified pastures	31 161	30 627	17 114	27 301	33 403	30 478
Cropping	47 624	20 024	25 345	31 282	33 301	28 903
Horticulture	66	53	84	5 427	71	45
Irrigated agriculture	4 752	6 076	5 898	6 961	7 801	8 617

Source: see Box 3.13.

Figure 3.109 Land uses, 1992 and 2001



Top: All rangelands

Bottom: Smaller area in northeastern NSW and southeastern Queensland

Source: see Box 3.13. Map: NLWRA.

along the eastern margin of the rangelands (northeastern NSW and southeastern Queensland), it is evident (Figure 3.109, lower panels) that irrigated agriculture has increased in that area. Survey data confirm that irrigated agriculture more than doubled in area over the 10 years across all the rangelands (Table 3.19).

Key points

Between 1992–93 and 2001–02:

- land use type was relatively static across the rangelands
- the predominant land use in the rangelands remained domestic livestock grazing of natural vegetation, which decreased by 65 400 km^2
- conservation and natural environment land uses increased by ~50 000 km^2
- irrigated agriculture, including sugar, cotton and other irrigated enterprises, increased steadily.

Land values

Changes in land values over various periods from 1991 to 2006 are reported for each state or territory either by IBRA bioregion or by pastoral district, although only the average for 2002–06 for each rangeland bioregion is reported for Queensland.

Pastoral land values are a useful socioeconomic indicator for rangeland enterprises:

Box 3.14 Pastoral land value data

Queensland land values were compiled regionally, with valuations made progressively during the period from June 2002 to June 2006 (but only reported in 2006). The valuations were averaged for rural land parcels after applying a number of filters for minimal size and primary land use. Queensland was not able to report changes in land values. Valuations were based on 'unimproved' property values sourced from the Queensland Valuations and Sales System.

SA reported changes in land values for the area of pastoral lease tenure within IBRA bioregions for 1998 and 2004. The SA Valuer-General provided an 'unimproved' value for each pastoral lease, based on recent sales. The SA Pastoral Board uses these unimproved values as a component in setting annual rental charges for pastoral leases. Rangeland bioregions with less than 50% pastoral tenure and/or fewer than five leases were excluded from this report.

The NT reported land values for pastorally significant IBRA bioregions for 1991 and 2003. Bioregions were excluded if they had limited pastoral tenure and/or a small number of pastoral leases.

WA reported changes in 'lease and improvement value', also known as 'bare' lease value (ie lease and all fixed improvements), by pastoral area on an annual basis between 1992 and 2006. Valuations were estimated as average levels of value on either a dry sheep equivalent (DSE) or large stock unit basis (1 large stock unit = 7 DSEs). Land values by pastoral area have been approximately aligned with rangeland IBRA bioregions. 'Lease and improvement' values for WA are not directly comparable to the 'unimproved' values for Queensland, SA and the NT.

NSW pastoral lease values were selected from data available online*. This provided the area, carrying capacity (DSE basis) and property market values (1996, then 2002 to 2006 on an annual basis) for a typical property from eight localities in the Western Division. A 'typical' property is one that is considered representative of the locality and will indicate the market trend. Values were converted to $\$/km^2$ and are reported for the corresponding IBRA bioregion of each locality. These are typical values, not the average (or some other statistical) value for the whole of each bioregion. NSW values reflect changed market values, which are different from the 'unimproved' lease values for Queensland, SA and the NT.

All values were adjusted to 2005 dollars using the Consumer Price Index.

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* 'Western grazing', Table 16, http://www.lands.nsw.gov.au/valuation/nsw_land_values (accessed 3 April 2007)

- Land values underpin inherent resource potentials and indicate relative profitability for different rangeland regions. They help identify declining regions, where various forms of economic and social adjustment may be required.
- Land values help identify areas where pastoralists may be cash poor (based on gross margins) but asset rich. If the ratio of profitability to asset value declines below a critical threshold, it can be very difficult for those buying into (or expanding in) a region to repay loans, which may result in land resources being stocked beyond sustainable limits to service loan debts (particularly during periods of lower *seasonal quality*).
- Rangeland values indicate the extent to which land values are being forced up by recent large increases in property prices elsewhere (eg prices for residential real estate).

Changes in pastoral land values are reported separately for each state and territory, as the data were provided in different forms (Box 3.14). The separate state and territory analyses are also assessed for general changes in land values across the rangelands.

Table 3.20 Unimproved rangeland values for Queensland IBRA bioregions and sub-IBRA regions

Bioregion	Average unimproved value ($/km^2)	Total valued area (km^2)	Average unimproved value ($m)[a]	Sub-IBRA value range ($/km^2)	Number of valued entities
Brigalow Belt North	34 873	58 636	1.058	3 772 – 64 328	587
Brigalow Belt South	17 780	50 149	0.559	3 293 – 21 182	567
Channel Country	598	196 820	0.535	104 – 1 234	105
Cape York Peninsula	11 731	49 737	0.457	420 – 34 234	73
Desert Uplands	4 953	62 690	0.441	1 183 – 14 031	372
Darling Riverine Plains	10 950	7 283	0.373	5 272 – 13 571	125
Einasleigh Uplands	26 712	105 915	0.637	6 282 – 52 058	601
Gulf Fall and Uplands	n.d.	2 415	n.d.	n.d.	1
Gulf Plains	2 876	203 029	0.736	38 – 12 610	259
Mitchell Grass Downs	4 792	242 952	0.504	333 – 6 668	1 166
Mount Isa Inlier	16 246	53 852	0.203	302 – 19 074	73
Mulga Lands	2 262	168 576	0.187	220 – 4 582	909
Simpson–Strzelecki Dunefields	43	12 858	0.113	39–49	5

n.d. = not disclosed

[a] 2005 dollars

Source: Queensland Valuations and Sales System; see Box 3.14.

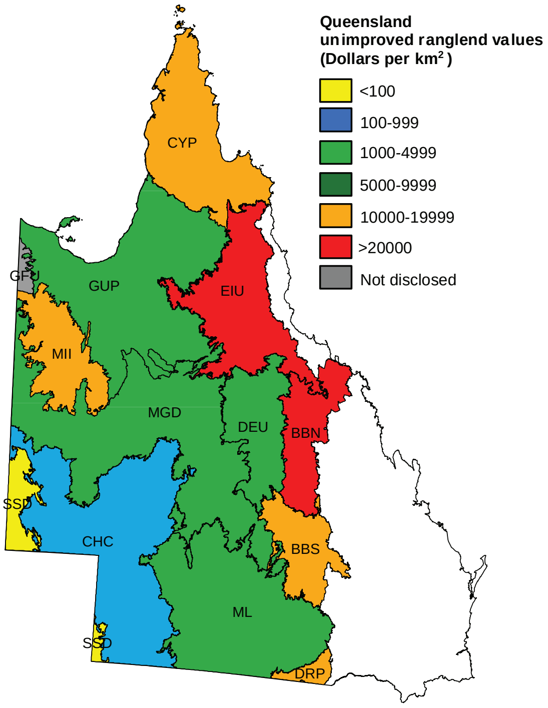
Queensland

There was a very large range in average land value between rangeland bioregions (Table 3.20), with the most valuable land being in north and northeast bioregions, such as the Brigalow Belt North and Einasleigh Uplands (Figure 3.110). As expected, the least valuable lands were in the dry southwest (the Channel Country and Simpson–Strzelecki Dunefields). The Mount Isa Inlier is an exception: the high mean value and large range in land values may be associated with mining interest in the region. However, reporting averaged values masks high variability within IBRA bioregions.

Within some bioregions, there were large differences in land values between component sub-IBRAs (Table 3.20). The differences reflect differing soils and the resulting vegetation growth under similar climatic conditions. The Mulga Lands, for example, had sub-IBRA mean values ranging from \$220/km^2 to \$4582/km^2; an even larger range was found in the Gulf Plains (\$38/km^2 to \$12 610/km^2).

The average areas of entities (akin to properties) in the Mulga Lands, Desert Uplands, Mitchell Grass

Figure 3.110 Classes of averaged unimproved values for Queensland bioregions



Source: Queensland Valuations and Sales System, see Box 3.14.

Table 3.21 Changes in unimproved values for SA pastoral leases, 1998 to 2005, averaged by IBRA bioregion

Bioregion	Unimproved lease value ($/km^2, 2005 $) 1998	2005	Ratio of change (1998 to 2005)
Finke	15	28	1.9
Channel Country	25	42	1.7
Stony Plains	27	46	1.7
Gawler	63	105	1.7
Broken Hill Complex	126	206	1.6
Flinders Lofty Block	115	184	1.6
Murray-Darling Depression	127	204	1.6
Simpson–Strzelecki Dunefields	23	37	1.6

Source: SA Valuer-General; see Box 3.14.

Table 3.22 Changes in unimproved average pastoral lease values, NT bioregions, 1991 to 2003

Bioregion	Unimproved lease value ($/km^2)[a] 1991	2003	Ratio of change (1991 to 2003)
Daly Basin	410	623	1.5
Sturt Plateau	220	319	1.5
Gulf Fall and Uplands	155	203	1.3
Ord Victoria Plain	537	569	1.2
Burt Plain	142	162	1.1
Finke	82	89	1.1
Mitchell Grass Downs	522	544	1.0
Channel Country	107	112	1.0

[a] 2005 dollars

Source: see Box 3.14.

Downs and Einasleigh Uplands bioregions were similar (Table 3.20), but their average value was much less in the Mulga Lands and comparatively high in the Einasleigh Uplands. Unimproved values were not well correlated with mean property size.

Changes in land values could not be assessed from the available data for Queensland. Future data acquisition and analysis will provide the basis for reporting changes in land values for Queensland bioregions.

South Australia

Unimproved values of pastoral leases increased between 1998 and 2004 in all SA rangeland IBRA bioregions (Table 3.21), with the largest relative increase (factor of 1.9) in the Finke bioregion. Relative increases were similar (1.6–1.9) across bioregions, which may indicate continued confidence in pastoralism (both sheep and cattle) by the majority of rangeland business enterprises in SA. There was a general south to north decline in averaged values of pastoral leases in line with increasing aridity.

Northern Territory

Unimproved land values increased in all pastorally significant NT IBRA bioregions between 1991 and 2003 (Table 3.22), although data were not available to report changes for individual years. The more northern Daly Basin and Sturt Plateau bioregions had the greatest increase in values over the 12-year period. This is consistent with recent infrastructure

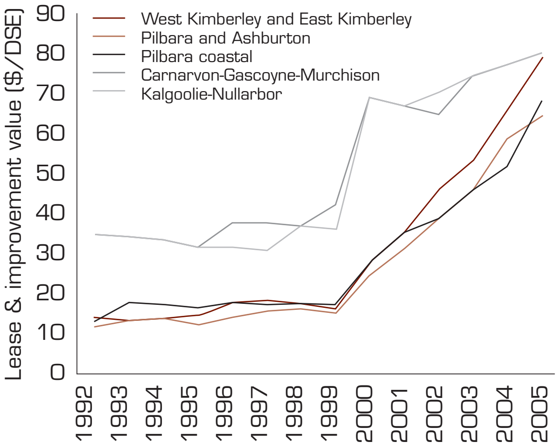
Table 3.23 Changes in average 'lease and improvement' values, WA pastoral areas, 1992 to 2005

Pastoral area	Component bioregions	$ per dry sheep equivalent[a]		Ratio of change (1992 to 2002)
		1992	2005	
West Kimberley and East Kimberley	Central Kimberley, Dampierland, North Kimberley, Ord Victoria Plain, Victoria Bonaparte	13.96	78.57	5.6
Pilbara and Ashburton	part Pilbara, part Gascoyne	11.96	64.29	5.4
Pilbara Coastal	part Pilbara	13.96	67.86	4.9
Carnarvon–Gascoyne–Murchison	Carnarvon, part Gascoyne, part Murchison, part Yalgoo	34.89	80.00	2.3
Kalgoorlie–Nullarbor	Coolgardie, part Murchison, Nullarbor	34.89	80.00	2.3

[a] 2005 dollars

Source: see Box 3.14.

Figure 3.111 Changes in average 'lease and improvement value' for pastoral areas, WA, 1992 to 2005



Note: Pastoral areas have been aligned to IBRA bioregions.

Source: see Box 3.14.

development and land use intensification in the Sturt Plateau region and the further subdivision of pastoral leases in the Daly Basin bioregion. These regions also have more reliable seasonal conditions and relatively stable livestock carrying capacities.

Unimproved land values remained relatively unchanged in southern bioregions of the NT (Table 3.22), such as the Channel Country and Mitchell Grass Downs. The arid Finke bioregion had the lowest valuation, which was consistent with its highly variable climate and low stock carrying capacity.

Western Australia

There were few or no changes in the estimated average 'lease and improvement' value of pastoral leases between 1992 and 1999 in WA bioregions (Figure 3.111). There was a large increase in the average value of southern (predominantly sheep-grazed) pastoral leases between 1999 and 2000 and a less steep, but continuous, increase between 2002 and 2006. Between 1992 and 2005, values of northern cattle-grazed pastoral leases increased more than fivefold, while values of southern leases roughly doubled (Table 3.23).

Factors that probably contributed to increased rangeland values in WA include:

- an increase in the live-cattle trade and prices, particularly in northern pastoral areas
- an increase in herd productivity, particularly through the sale of younger cattle
- a sustained run of good seasons in the northwest and the Kimberley, resulting in higher cattle birth and growth rates and allowing for increased build-up and turn-off of herds
- shorter runs of good seasons in the south, allowing for higher turn-off.

Table 3.24 Changes in property market values for pastoral leases in NSW rangeland bioregions

Locality	Associated IBRA bioregion	Property market value ($/km^2)[a]			Ratio of change (1996 to 2005)
		1996	2002	2005	
Hay	Riverina	8 519	10 653	20 605	2.4
Brewarrina	Darling Riverine Plains	4 328	5 164	7 753	1.8
Bourke	Cobar Peneplain	468	375	774	1.7
Wilcannia	Mulga Lands	368	310	642	1.7
Lightning Ridge	Brigalow Belt South	3 241	3 685	4 935	1.5
Balranald	Riverina	3 374	2 322	3 966	1.2
Wentworth	Murray-Darling Depression	2 080	1 428	2 537	1.2
Cobar	Cobar Peneplain	868	424	865	1.0
Average — Riverina		7 444	7 004	12 285	1.7
Average — Cobar Peneplain		836	431	820	1.0

[a] 2005 dollars

Note: Values are for a typical property in each bioregion, not the average of all properties within the region.

Source: see Box 3.14.

New South Wales

Between 1996 and 2002, values of NSW pastoral properties typical of various rangeland localities either declined or remained fairly constant (Table 3.24). Properties in the Cobar Peneplain bioregion (Cobar and Bourke) showed the biggest decreases. Property values also fell in the southern part of the NSW rangelands, including the Wentworth (Murray-Darling Depression IBRA) and Balranald (western Riverina IBRA) regions. Properties in the Hay area were an exception: their value typically increased.

Between 2002 and 2005, property values increased in all NSW localities (Table 3.24), with particularly strong growth in the Hay region and less in the Brewarrina, Bourke, Wilcannia and Lightning Ridge regions. These increased land values have mostly been contrary to the general level of profitability of NSW rangeland enterprises. One reason for this is that increasing prices for prime agricultural land further east have had a 'ripple' effect, as primary producers have progressively moved their operations towards more marginal areas where land values are perceived to be better aligned with returns.

Property values in the Cobar Peneplain bioregion recovered after a 1996 to 2002 decline, to a value in 2005 similar to that in 1996 (Table 3.24). In this and other eastern rangeland bioregions in NSW, relatively small properties have been rendered non-viable by woody thickening and have been purchased for recreational pursuits, mainly hunting. Purchasers generally seek lower-valued properties and are influenced by the perception of 'bargain' prices for relatively large areas. Rather than being 'lifestyle' blocks, these properties generally have absentee owners.

Probable reasons for regional differences in NSW rangeland values include:

- large gains in the eastern rangelands driven by opportunities for alternative enterprises, such as dryland and irrigated cropping in the Riverina and beef cattle and dryland cropping in the Darling Riverine Plains
- declines in some localities due to poorer *seasonal quality* through the 1990s and low wool prices, leading to marginal profitability for wool growers

- higher meat prices for sheep in recent years, providing opportunities to cross merinos with meat-sheep breeds
- higher demand for goat meat, providing an alternative income stream for woolgrowers who can harvest feral goats or run domesticated goats
- strong beef cattle prices, providing a higher income from raising cattle on pastoral leases that traditionally ran sheep.

Key points

- Land values have increased appreciably across most of the grazed rangelands. Despite the problems in comparing jurisdictional land value data, the increases can be estimated to be in the order of 150% to 300%. This is a very substantial barrier for those seeking to buy into rangeland pastoral enterprises and implies that landholders are under considerable pressure to maintain returns on equity.
- Information on change in pastoral land values provides underlying information about relative profitability, asset-to-income ratios and ability to service debt. These all contribute to an understanding of longer-term viability and may also provide insight into regional change in stocking density (ie sustainable management).
- Typical increases in rangeland values were far higher than could possibly be accounted for by increases in real productivity (ie turn-off of meat and/or fibre). Increasing cattle prices during parts of the 1992–2005 period may have contributed to increased financial productivity over and above any gains in biophysical productivity, but this was not the case for wool. Hence, there must be some concern about the long-term viability of some pastoral enterprises.
- The considerable differences among jurisdictions in the way in which pastoral land values are provided makes cross-jurisdictional comparisons difficult. The NSW system of reporting the indicative market value of properties by district could be an effective model for improving cross-jurisdictional consistency.