Australian Government

National Land & Water Resources Audit

Extract from Rangelands 2008 — Taking the Pulse
2. Assessing change

ISBN 978 0 642 37146 1
ISBN 978 0 642 37147 8 (CD-ROM of the report)
ISBN 978 0 642 37148 5 (PDF)
Product number: PN21387

Suggested citation

Bastin G and the ACRIS Management Committee, Rangelands 2008 — Taking the Pulse, published on behalf of the ACRIS Management Committee by the National Land & Water Resources Audit, Canberra.

Acknowledgments

Rangelands 2008 — Taking the Pulse is the work of many people who have provided data and information that has been incorporated into this report. It has been possible due to significant in-kind contributions from the State and Territory governments and funding from the Australian Government through the Natural Heritage Trust. Particular thanks are due to staff of the Desert Knowledge Cooperative Research Centre, including Melissa Schliebs, Ange Vincent and Craig James.

Cover photograph

West MacDonnell Ranges (photo Department of the Environment, Water, Heritage and the Arts)

Principal author: Gary Bastin, CSIRO and Desert Knowledge CRC
Technical editor: Dr John Ludwig
Editors: Biotext Pty Ltd
Design: Design ONE
Printed in Australia by Lamb Print

Printed with vegetable-based inks on stock that comprises 80% recycled fibre from postconsumer waste and 20% totally chlorine-free pulp, sourced from sustainable forests.

August 2008

2 Assessing change

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

Detecting change

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

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

Figure 2.1 Change in the Ord Victoria Plain bioregion, NT

April 1973

June 1978

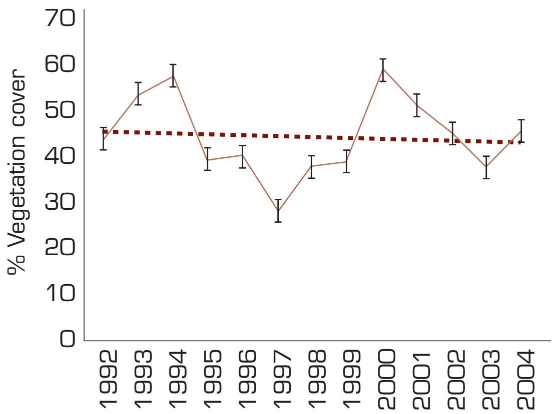
June 1989

June 2000

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

Photos: CSIRO, Alice Springs

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



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

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

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

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

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

Drivers of change

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

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

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

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

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

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

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

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

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

Interpreting change

There are three important components to interpreting change:

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

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

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

2. Is the change good or bad?

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

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

Box 2.2 Reference areas

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

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

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

Reference area 1973

Assessment area 1973

Reference area 1989

Assessment area 1989

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

Photos: CSIRO, Alice Springs

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

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

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

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

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

Sources of data on change

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

The ACRIS datasets

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

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

Social and economic census data

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

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

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

Other datasets

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

Scale and resolution

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

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

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

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

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

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

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

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

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

Regionalisations

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

Interim Biogeographic Regionalisation for Australia

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

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

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

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

Natural resource management regions

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

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

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

Statistical local areas

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

Comparing regional assessments

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

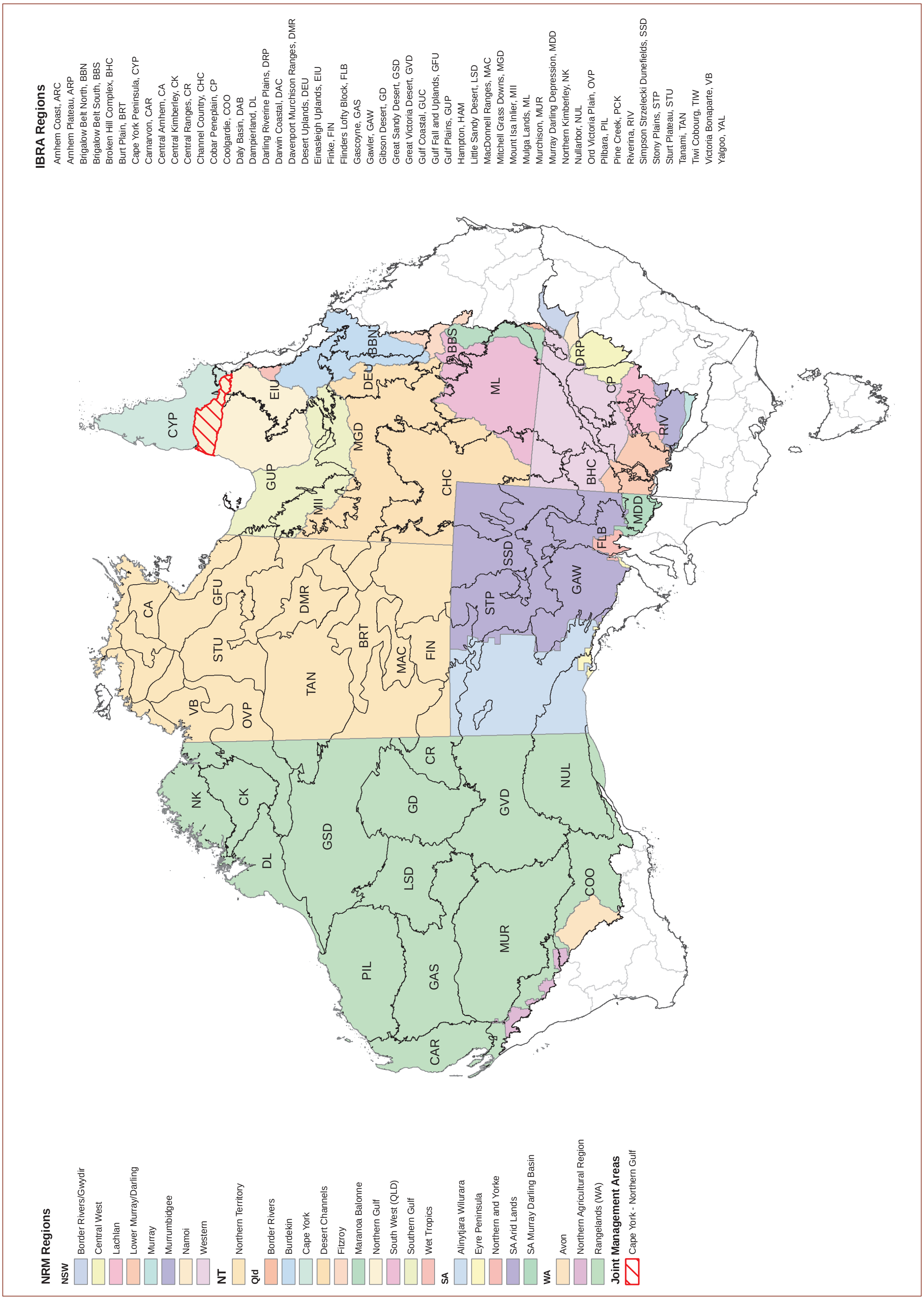
There are important constraints to note when assessing and comparing change using different regionalisations. For example, a group of ground-based monitoring sites may broadly represent an IBRA but not an SLA. Depending on the density and distribution of monitoring sites, it may be possible to report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

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

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

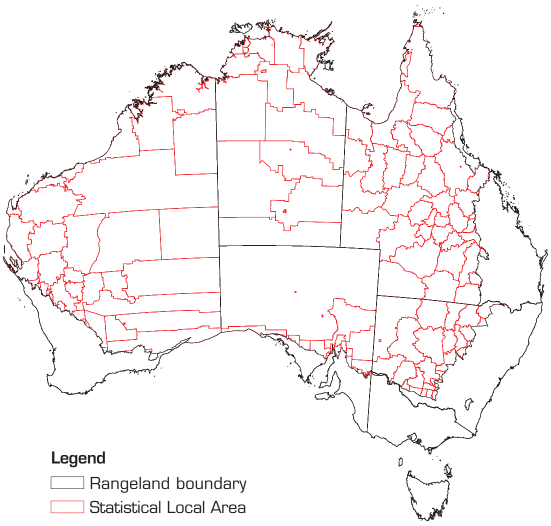
Using concordance procedures, it is usually technically possible to compare assessments by adapting datasets from one regionalisation to another, but this can be a laborious process. Where data are based on few and dispersed samples, concordance from one regionalisation to another may not be possible.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

Figure 2.3 IBRA and NRM regions within Australia's rangelands



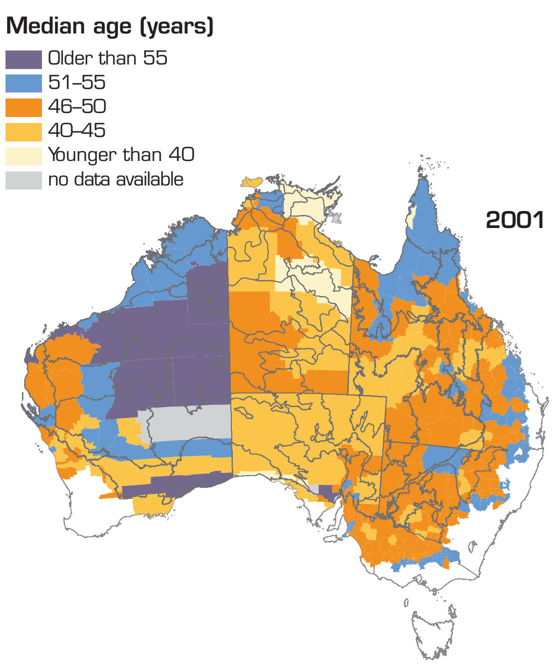
Source: Department of the Environment, Water, Heritage and the Arts

Figure 2.4 Statistical local areas for Australia's rangelands



Source: Australian Bureau of Statistics

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



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

Assessing change using ACRIS

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

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

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

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

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

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

Box 2.3 Reporting change

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

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

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

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

Figure 2.6 Erosion front, Murchison region, WA

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

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

Reliability in reporting change

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

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

Site-based monitoring

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

1. Site density in each bioregion

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

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

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

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

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

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

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

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

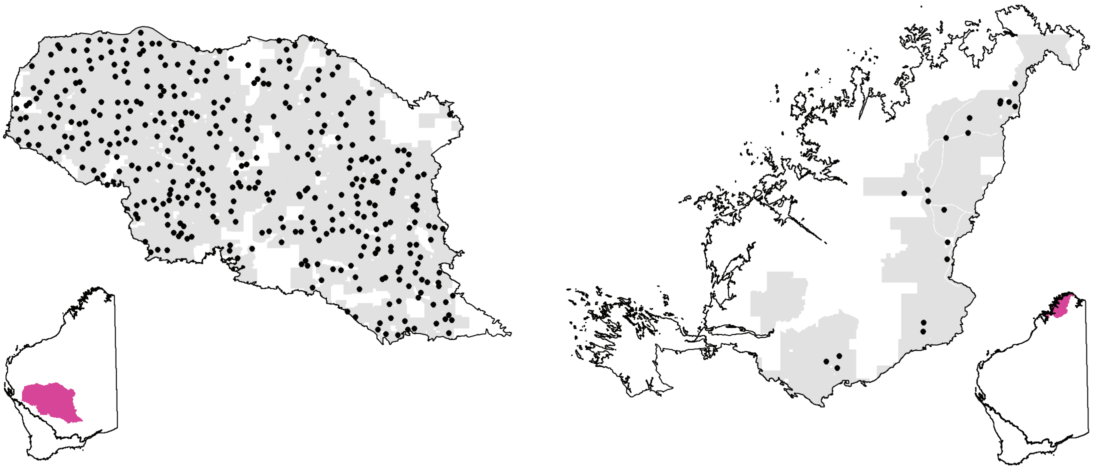
5. Relevance of data type for reporting change in the information type (very high = 10, very low = 1).

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

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

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

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



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

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

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

Source: WA Department of Agriculture and Food

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

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

Remote sensing-based monitoring

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

Reliability of other data sources

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

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

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

Photo: Simon Eyres, WA Department of Agriculture and Food

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

State/territory pastoral monitoring programs

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

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

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

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

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

Key points

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