ACRIS

Reporting Change

IN THE RANGELANDS

Australian Collaborative Rangeland Information System: Reporting Change in the Rangelands

National synthesis of reports from pilot regions

June 2005

Gary Bastin (ACRIS Coordinator) and members of the ACRIS Management Committee (particularly Ian Watson, WA, Ben DellaTorre, SA, Russell Grant, NSW and Bob Karfs, NT, lead authors of reports from pilot regions contributing to this synthesis)

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ACKNOWLEDGEMENTS

I particularly thank the lead authors of reports on the pilot regions for providing the material to compile this national analysis: Ian Watson (Gascoyne–Murchison), Ben DellaTorre (Gawler), Russell Grant (Darling Riverine Plains), Bob Karfs and Mandy Trueman (Victoria River District). These people willingly assisted me to extract the most relevant information from their respective reports and build it into a hopefully accurate, meaningful and useful synthesis. Richard Silcock and Ken Dixon, among others, contributed to the content and meaningful representation of Desert Uplands material in this report and for that I am grateful.

With regard to national datasets, Maria Cofinas coordinated ERIN's analysis of, and reporting on, change in forest cover based on AGO image products. Thank you, Maria, and your group, for providing this analysis in a timely and useful manner. Maria also assisted the delivery of other ERIN products (national rangelands boundary, seasonal quality images) to the ACRIS Management Unit and coordinated the necessary data licence agreements accompanying these products. John Carter willingly provided the regional Aussie-GRASS products and gave additional explanation and interpretation as requested. Thanks, John, for your ready assistance here. Blair Wood and Rob Thorman of the National Land and Water Resources Audit organised and coordinated the contract with ABS to compile the regional socio-economic profiles that provided consistency in answering Question 4.

I am particularly grateful to the small group of ACRIS Management Committee members who gave me helpful advice, encouragement and editorial assistance to complete this synthesis. You know who you are, but to give you due public recognition: Mark Stafford Smith, Annemarie Watt, Ian Watson and Margaret Friedel. Finally, I thank all of the ACRIS Management Committee for your support and advice through this reporting activity.

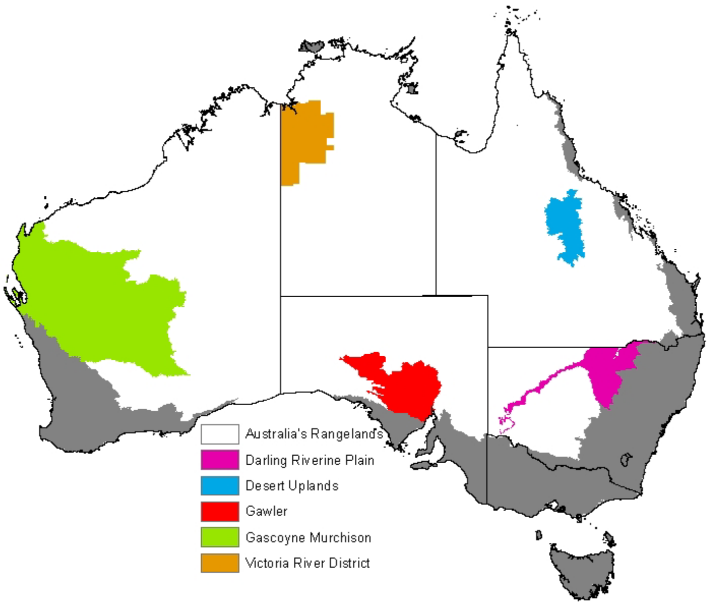
SUMMARY

ACRIS – reporting change in the pilot regions

Reporting on change in the rangelands is a substantial task. The rangelands cover some 75% of the Australian continent, include some of the most remote places, and support some of the least disturbed landscapes in Australia. It is important that we monitor and understand change in the rangelands, so that we can step in quickly and effectively to maintain or improve ecological, economic and social values.

The Australian Collaborative Rangeland Information System (ACRIS) is a coordinating mechanism that brings together rangeland information from State, Northern Territory and Commonwealth agencies and other sources. ACRIS has a Management Committee comprising representatives of Australian and State/NT governments and a small Management Unit co-located with the Desert Knowledge Cooperative Research Centre (CRC) in Alice Springs. We report to the Audit Advisory Council on technical issues, and Natural Resource Programs and Policy Committee on issues of policy.

The critical first stage for the ACRIS has been testing the quality of our information and our capacity to bring it together into a national picture. We have tested the reporting system against five questions in five pilot regions (Gascoyne–Murchison, WA; Gawler bioregion, SA; Darling Riverine Plains bioregion, NSW; Desert Uplands bioregion, Queensland; and the Victoria River District [VRD], NT). These regions have a combined area of 1,030,960 km^2, approximately 16.2% of the rangelands and 13.4% of Australia.



The reporting period covers the years 1992 to 2002.

The system test has shown that we have a decreasing information base for monitoring change, many information gaps, and differences in the quality and coverage of data across the country. But the good news is that we have been successful in reporting on change and can now look to addressing the above challenges in developing the information system so that we can report across the entire rangelands. The main source of data is driven by pastoral land management needs and predates current concepts that focus on monitoring broad biodiversity outcomes.

Test questions

We identified five questions upon which to report in testing the system. The questions, and the rationale for each, were:

Question	Rationale
Q1: Change in *Critical stock forage productivity*	• Focussed on long-term pastoral productivity • Pastoral monitoring programs can provide relevant information • Data based on species known to indicate grazing pressure (decreaser species) rather than species necessarily contributing the largest amounts of forage
Q2: Change in *Native plant species*	• We recognise that this question reports on only a narrow component of biodiversity • Question also recognises that, as yet, there is little monitoring of biodiversity and that pastoral monitoring programs have a limited capacity to provide such holistic information
Q3: Change in *Landscape function*	• Describes the capacity of landscapes to capture and use scarce resources (rainwater and nutrients) for plant growth • Currently there is limited use of formal procedures for assessing landscape function in some jurisdictional monitoring systems and there are few accepted protocols to use, anyway • Tests the reporting ability of proposed alternative indices
Q4: *Capacity for people to change*	• Pastoralists manage large areas of the rangelands – how adaptable are they to change? (E.g. implementing improved land management practices) • Better understanding of capacity for change should lead to improved policy initiatives and appropriate funding support by governments – leading to better outcomes for the rangelands
Q5: Change in *Cover*	• Cover is obviously important for protecting the soil surface against erosion • Equally, different forms of cover and the balance of cover components are important as habitat for fauna and in maintaining ecosystem function • Remote sensing using satellite imagery has the potential to provide regular and total coverage of large regions but a limited capacity to differentiate types of cover

Considerations in reporting in the rangelands

Separating rainfall effects from management

The amount and timing of rainfall has a profound effect on short-term vegetation change, particularly the biomass and composition of the pasture layer. Separating rainfall effects on vegetation from those due to management remains a fundamental problem in interpreting change in biophysical monitoring data. The ACRIS is using a 'quality of preceding seasons' by 'direction of change' matrix (illustrated following page) to partially filter shorter-term seasonal influences and better identify possible change due to grazing management. (Wildfire, particularly where frequent in northern Australia, can also affect vegetation and may need to be accounted for as a cause of change.)

Matrix for filtering seasonal effects on change.

Seasonal conditions	Condition / Attribute		
	Decline	No change	Improve-ment
Above average	XX	X	~
Average	X	~	√
Below average	~	√	√√

The quality of seasonal conditions is based on the amount of rainfall in the growth season(s) prior to the monitoring period compared with the long-term record.

Column figures report the percentage of monitoring sites where reported attributes of vegetation (or landscape) are unchanged, have improved or declined.

In this schematic, XX denotes adverse decline when seasonal conditions would suggest that improvement should have occurred. Conversely, √√ shows improvement when past seasons would indicate clear potential for decline.

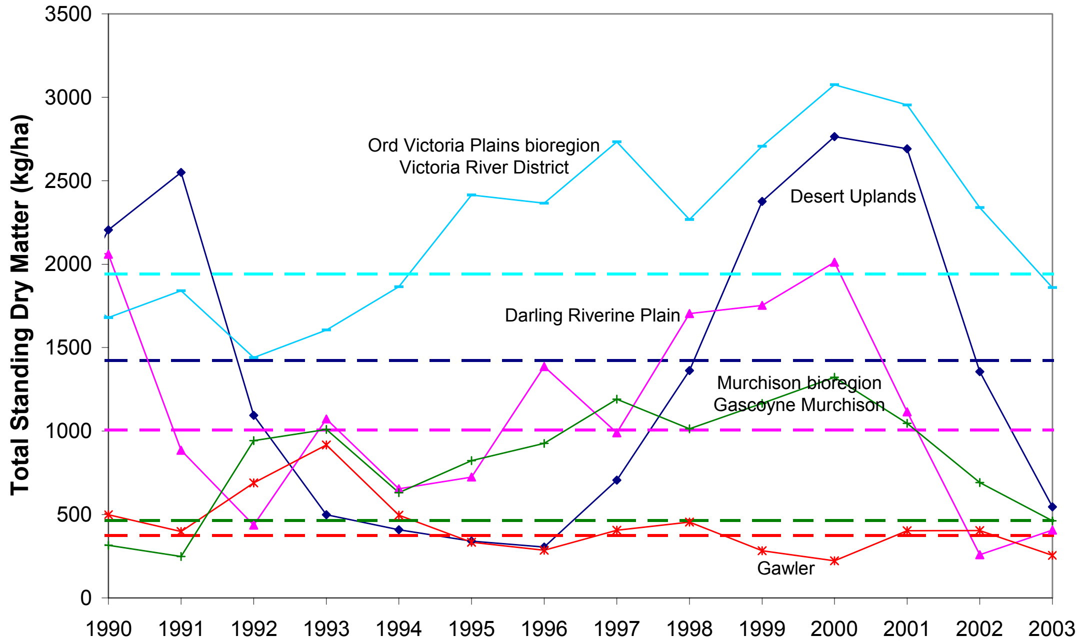
The utility of this matrix is enhanced where possible by selectively reporting data that enhance management effects, both positive and negative. For example, seasonal effects are dampened by focussing on longer-lived perennial species (Questions 1 and 2), and grazing effects are sharpened by reporting change for those species known to decline with heavy and prolonged grazing (Question 1). This assumes that seasonal conditions alone have the same impact on decreaser, increaser and intermediate species.

Seasonal conditions as context

Seasonal conditions between 1990 and 2002 are illustrated on the next page using simulated pasture availability (total standing dry matter under current land use) produced by the Australian Grassland and Rangeland Assessment by Spatial Stimulation (Aussie-GRASS) pasture model. These values are the average for each bioregion in each year and are shown against the corresponding long-term mean (1890-2003) – represented by a dashed line of the same colour. The Gascoyne–Murchison and Victoria River District pilot regions include several bioregions and an example bioregion is used for each.

These simulated results indicate that:

- In the Victoria River District (NT), accumulated pasture growth from 1995 to 2002 has been above the long-term mean. This response coincides with above-average wet seasons occurring throughout the reporting period, apart from 1992 and, to a lesser extent, 1998.



- There was a period of poor pasture growth associated with very dry years in the Desert Uplands (Qld) in the mid 1990s. A wetter period with much higher simulated biomass then occurred around 2000, followed by further dry years (with reduced biomass).

- The Darling Riverine Plains (NSW) had drier years and lower pasture biomass between 1992 and 1995 then better seasons to 2000. Drought conditions prevailed in 2001–03.

- Using the Murchison bioregion as an example of seasonal conditions in the Gascoyne–Murchison (WA), above-average years were experienced through the mid and late 1990s, followed by drier years to 2003.

- In the Gawler bioregion (SA), seasonal conditions were better than the long-term average at the start of our reporting period (1992–93) and were then similar to the average conditions for most of the period. Poorer seasons were experienced in 1999 and 2000.

Change in the pilot regions

Key results compiled from pastoral monitoring data, and other sources where relevant, are summarised on the following pages. (Monitoring programs are briefly described in the shaded box on page 30). The italicised confidence ranks indicate our degree of confidence in the summarised results. These ranks are based largely on the relevance of the monitoring data to the question (where much of the data come from fixed sites) and are moderated (downwards) where sampling density is perceived to be low. (Further explanation and justification for these rankings is provided in Section 9 under ‘Quality of answers to questions’. Note that the ranks assigned in Table 43, page 129 are for two components: relevance to the question [as indicated here] and spatial adequacy [i.e. sampling intensity] across each reporting region.)

Question 1: Critical stock forage productivity

Region	Change	Evidence
Gascoyne–Murchison	Shrublands – general improvement *High confidence*	• 40% of sites with stable or increasing density of decreaser species in below-average seasons (suggesting positive grazing management) • 15% of sites with declining density of decreaser species in above-average seasons (suggesting adverse grazing management)
	Grasslands – more variable *High confidence*	• 18% of sites had an increasing frequency of decreaser perennial grasses • 15% of sites had a declining frequency of decreaser perennial grasses
Gawler	General improvement *High confidence*	• 51% of sites had a higher density of perennial decreaser species following below-average seasons (64% had a higher density following average seasons)
Darling Riverine Plains	Mainly in response to season *High confidence*	• Frequency of palatable perennial (2P) grasses on the Northern Floodplains generally aligned with the amount of rainfall preceding the assessment – 7% of sites with increased 2P frequency in below-average seasons – 17% of sites with decreased 2P frequency in above-average seasons
Desert Uplands	Mainly seasonal responses *Moderate confidence*	• Frequency of palatable, perennial and productive (3P) grasses declined at 11% of sites following above-average rainfall • Remaining sites had trends in 3P frequency consistent with that expected for preceding amounts of rainfall • Reported change based on data from limited number of sites
Victoria River District	Improvement during wetter period *Moderate confidence*	• Overall, sites were stable or improved in assessed range condition • This is the expected result given above-average wet-season rainfall through the majority of the reporting period • Rank of 'moderate' for confidence because assessed condition not directly aligned with question (critical stock forage productivity)

Question 2: Native plant species

- For the Gascoyne–Murchison and Gawler regions this question was answered by reporting change in the density of all perennial species (i.e. similar to Question 1 but including species that increase or are not affected by grazing as well as decreaser species).

    - In the Gascoyne–Murchison shrublands, there was an overall increase in the density of shrubs and recruitment for most species (*moderate confidence*). Population densities were maintained or increased at 43% of sites following below-average seasons.

- The frequency of all perennial species, including perennial grasses, tended to decrease in the Gascoyne–Murchison grasslands (*moderate confidence*). From two periods of site reassessment, 15% of sites had a decreased frequency of perennial grasses at both assessments and 68% had decreased frequency between the second and third assessments.

- Species richness of perennial shrubs remained the same or increased on 80% of WARMS (Western Australian Rangeland Monitoring System) shrubland sites (*moderate confidence*). When only decreaser species were considered, the corresponding figure was 83%, suggesting that the changes in richness of decreasers were similar to other species.

- Species richness on grassland sites remained the same or increased on 63% of sites over the first assessment interval and 55% of sites over the second reassessment interval (*moderate confidence*). Only 7.5% of sites showed a decline in species richness over both reassessment intervals.

- The majority of sites (68%) in the Gawler region had a similar or improved density of perennial species following below-average rainfall (88% of sites following average seasonal conditions) (*moderate confidence*).

- In the Darling Riverine Plains:

  - There was overall stability in the diversity of pasture species at monitoring sites on the Northern Floodplains. Diversity increased in wetter years but, throughout the reporting period, there were generally greater than 20 species per site, with less than five of these being exotics (*moderate confidence*).

  - There was a 115% increase in the area under cultivation (mainly for cereal cropping) between 1992 (84,845 ha cropped) and 2003 (183,461 ha cropped). This is indirect evidence of a change in native species and does not indicate actual clearing (some woodland communities have been extensively cleared; in more open country, machinery is able to work around clumps of timber). However, a change in native species is inferred because cultivation disturbs native species, and annual grasses and weeds predominate in out-of-crop years (*high confidence* in area affected, *moderate confidence* in actual change in native species).

- Data from a limited number of sites in the Desert Uplands:

  - Indicate that a high frequency of native pasture species have been maintained through the reporting period. Exotic species (mostly buffel grass) were present, generally at a low frequency, and there was a small increase in their frequency. (*Low to moderate confidence* in result because of restricted sampling.)

  - The results of a repeat biological survey at the southern edge of the bioregion provide encouragement that broader elements of biodiversity can be monitored. Between the mid 1970s and 2002–03, there was a major reduction in the number of waterbirds (attributable to drier seasons), significant increases in typically grassland birds and decreases in typically woodland birds (related to extensive tree clearing) and a major increase in the cane toad.

- Site monitoring data in the Victoria River District:
  - Did not readily allow reporting of change in native plant species.
  - Using other data sources:
    Interpretation of air photos from the 1950s to the 1990s shows extensive thickening of woody species in parts of the region (*moderate confidence*). Evidence of this thickening is supported by a comparison of historical photos with recent ones of the same scene, and research results such as exclosures.

Question 3: Landscape function

This question posed particular difficulties because formal landscape function assessment is only routinely conducted in the Gascoyne–Murchison and Victoria River District (the latter at a restricted number of sites). Inferences about landscape function over larger areas of the VRD are drawn from relationships between ground data and cover change monitored by remote sensing. Various indices of landscape function have been calculated from monitoring of the soil and vegetation in other regions.

- In the Gascoyne–Murchison, the Resource Capture Index (RCI) derived from formal landscape function assessment:
  - Remained stable or increased at 31% of shrubland sites. (Higher RCI values mean improved landscape function.)
  - RCI was stable or increased at 36% of grassland sites.
  - The converse of this is that landscape function appears to have declined at two-thirds of the WARMS monitoring sites in the Gascoyne–Murchison.

  (*High confidence* for change on both shrubland and grassland communities.)

- In the Victoria River District:
  - From ground data, RCI was stable or increased at 66% of Tier 2 monitoring sites (*moderate confidence* in result, largely because of restricted sampling). (There are 33 sites at which detailed monitoring data have been collected.)
  - There was an increase of 8% in the number of Tier 1 sites at which perennial pasture species were identified (total of 254 Tier 1 sites, rapid visual assessments made). This result suggests current stability in landscape function for pastoral land (*moderate confidence*).
  - Based on Landsat data, the mean cover of areas surrounding sites was consistently higher and more stable throughout the reporting period compared with the preceding 10 years (1983–92). Historically high cover levels and stability is used as a surrogate for satisfactory landscape function.
  - The relationship was extrapolated beyond Tier 1 and Tier 2 ground sites to infer that much of the extensive and pastorally important basalt plains land type had

improved function between 1992 and 2002 compared with the previous 10 years (*moderate confidence*).

- Based on condition ratings at pastoral monitoring sites used as input to a functionality index, landscape function appears to have improved in the Gawler bioregion (*moderate confidence*). Just more than one-half of sites assessed following average seasonal conditions had a higher rating for landscape function compared with their initial assessment. Slightly more than one-quarter of sites assessed following poor seasonal conditions had an improved rating for landscape function.

- Two scales of information are available to indicate change in landscape function on the Northern Floodplains of the Darling Riverine Plains:

  - Based on the frequency of perennial grasses, extent of soil surface cover and presence of bare ground or erosion at monitoring sites, landscape function is inferred to have improved through the mid to late 1990s and then decreased with very dry years from 2001 onwards (*moderate confidence*). These changes are thought to be mainly due to seasonal influences.

  - Of more concern, evidence is accumulating that upstream water diversions are reducing the extent of flooding in the Northern Floodplains. This altered flooding regime may have significant implications for the future stability of landscape function at the site to enterprise scale.

- Based on the frequency of perennial herbage species and ground cover, there was an apparent improvement in landscape function in the Desert Uplands between 1992 and 2001 (*low confidence* in result, mainly because of restricted sampling).

Question 4: Capacity for people to change

Analysis of national census data and surveys of agricultural production and value by the Australian Bureau of Statistics (ABS) show that:

Result	Probable explanation	Possible implications for change
Median age of 'farmers' (pastoralists) is increasing in all regions except the VRD.	The VRD has a much higher proportion of pastoral leases that are company owned. Company managers tend to be younger and more mobile.	Younger people may be more adaptable to, and accepting of, change. Counter to this, the finances of younger pastoralists who own leases (specifically debt burdens) may mean they are less able to implement change.
Net migration of young people is negative in all regions apart from the VRD.	Young people are leaving most regions to further their education and seek satisfying employment and career paths. The VRD has a higher proportion of Indigenous people, with these younger people perhaps more likely to stay in the region.	Allied with the above assumption that younger people may be better able to accommodate change, is the importance of retaining at least some of these people in the community. Change also comes partly from innovation and such innovation may be more appropriate if it is locally based (i.e. relevant). Younger, well-educated people can contribute to regional innovation and adaptation of technologies and practices that lead to improved resource management.
Age dependency ratio is increasing in all regions except the VRD. (Ratio of younger and older people to working age population.)	The VRD has a higher proportion of Indigenous people. From above, working-age (particularly younger) people appear more likely to stay in the VRD.	Regional economies may be more dynamic when there is a good balance between the proportion of working-age people and those that need support in society (partly the very young and the old). (This assumes that the majority who are of working age are in employment.) Presumably, healthier regional economies are better able to adapt to, and cope with, change.
Regional populations have declined in the Desert Uplands and Darling Riverine Plains. Populations have increased elsewhere (by 17.6% between 1991 and 2001 in the VRD).	The number of people in the VRD may have increased because of its high proportion of Indigenous people (and, possibly, higher birth rate). The Desert Uplands and Darling Riverine Plains economies are largely dependent on agricultural commodities, whereas other regions have a broader base to their economy.	Growing regional populations and broadly based industries should generate economic growth and more vibrant and diverse communities. Such growth is likely to generate change in many areas and make communities more accepting of change.

Result	Probable explanation	Possible implications for change
Grazing (pastoralism) is an important source of income in all regions. Additionally, mining is important in the Gascoyne–Murchison and Gawler regions with Defence facilities important in the VRD.	Grazing was the first land use as the rangelands were taken up and developed by Europeans. Mining is conducted where resources exist, operations are profitable and government regulations allow. Defence operations occur in some regions because of low land values, sparse populations and other logistical reasons.	Resident mining companies (as distinct from 'fly in – fly out' operations), in particular, may introduce new sources of income and employment to regions. This broadens the economic base and, as explained above, may generate change – as well as making communities more accepting of change.

Question 5: Change in cover

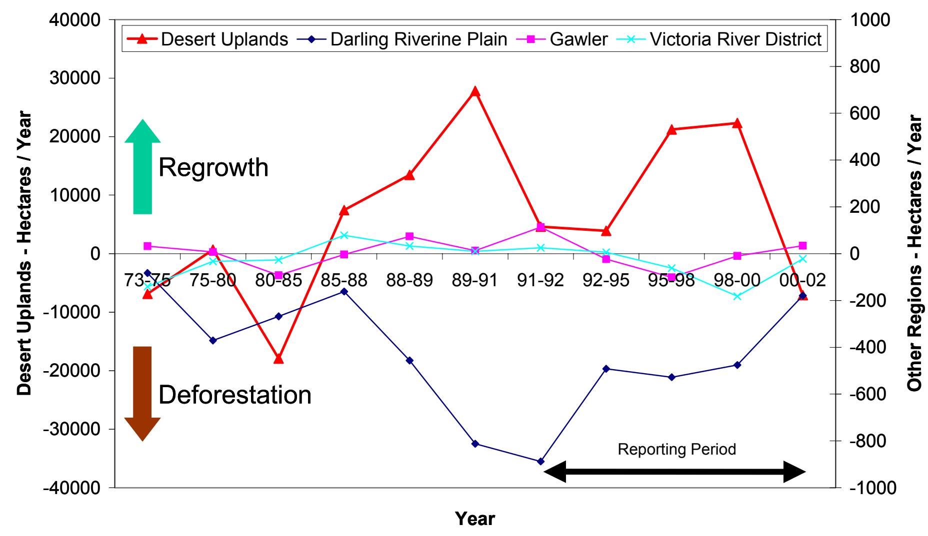
Cover, either vegetation cover or its converse – bare ground, can be monitored and reported on in a number of ways. For the pilot regions, we used nationally available data (Aussie-GRASS simulation and Australian Greenhouse Office [AGO] forest cover) and the results of jurisdictional monitoring programs. The Aussie-GRASS results are not summarised here but are reported in Section 8 (page 113).

Forest cover

Forest is defined by the AGO as the 'potential to reach a minimum 20% canopy cover, 2 metres in height and minimum area of 0.2 hectares'. AGO data and methods show that there have been substantial changes in forest cover in the Desert Uplands through the reporting period (see graph next page), both deforestation (clearing) and reforestation (mainly regrowth), with a net increase over the reporting period. Forest cover increased in the Darling Riverine Plains between 1991 and 2002; however, there was a net overall reduction in forest cover for this bioregion from the start of the Landsat record (used for monitoring) in 1972. There were very small changes in forest cover in the Gawler and VRD regions, both regrowth and deforestation, with no apparent net change. (Forest extent area, i.e. areas having at least 20% canopy cover, was not available for the VRD at the time of reporting nor were validated results available for the Gascoyne–Murchison.) *High confidence* in available results.

Note that change for the Desert Uplands should be interpreted with respect to the left-hand scale (graph next page), with other regions using the right-hand scale. Figures above the zero horizontal axis represent net regrowth for the reporting interval; values below the axis show net deforestation.

Monitoring of woody cover (more than 7% woody foliage projected cover) by the Queensland Government (its Statewide Landcover and Trees Study [SLATS] program) shows there has been a substantial decline in wooded area in the Desert Uplands between 1991 and 2001 (54,210 km^2 in 1991, 50,272 km^2 in 2001). *High confidence* in results.



Region	Forest area in 2000 as % of region
Gascoyne–Murchison	n/a [1]
Gawler	11.0
Darling Riverine Plains	2.2
Desert Uplands	25.0
VRD	n/a [1]

[1] n/a – results not available at time of reporting

Jurisdictional monitoring

- There was a general increase in canopy cover of perennial shrubs in the Gascoyne–Murchison shrublands – 82% of sites and 95% of species had increased cover. Cover was maintained or improved at 41% of sites following a period of below-average rainfall (i.e. when a decrease could have been expected). *Moderate confidence*.

- The crown cover of woody species generally increased in the Gascoyne–Murchison grasslands (increase at 64% and decrease at 21% of sites). *Moderate confidence*.

- Cover of perennial species increased slightly in the Gawler region, averaged across all available monitoring sites. There was a significant reduction in perennial cover for the 'mulga over perennial and annual grasses' vegetation type. The cover of annual plants and litter generally decreased, producing a concomitant increase in the amount of bare ground. These latter changes are considered to be due to seasonal variation in rainfall (generally a reduction). *High confidence*.

- Ground cover increased with better seasons in the Northern Floodplains of the Darling Riverine Plains between 1994 and 2000 and then decreased with drought conditions (*high confidence*). Despite this decrease, all but one province of the bioregion (Bogan–Macquarie) had higher ground cover at the end of the reporting period compared with the start.

- Ground cover was relatively low (<40%) in the period 1994–96 at sites in the Desert Uplands. Ground cover was considerably higher between 1999 and 2002 but decreased according to measurements made in 2003. These changes are considered to be mainly due to season. (*Low to moderate confidence* in result because of restricted sampling.)

- Cover at Tier 2 monitoring sites in the Victoria River District increased from 33% in 1996 to 53% in 1999 then decreased to 44% in 2003 (*high confidence*). This was through a period of generally above-average rainfall. The decline at the end of the ground-sampling period was attributed to the increased extent and frequency of wildfire.

- Cover indices derived from Landsat images over the 1983–2003 period show different responses for the two main bioregions in the VRD Pastoral District. The more southerly Ord–Victoria Plains bioregion and its major basaltic land types showed remarkable stability and historically high cover index values in the period 1993–2003 compared with the earlier decade 1983–92. The average cover index value for the 1993–2003 period was 15% higher than for 1983–92 (*high confidence*). Time-traces of the more northerly Victoria–Bonaparte bioregion and its major land types of rugged sandstone hills and alluvial plains indicate a strong increase in cover from 1987 to 2000, followed by a sharp fall in 2001 and a slight recovery by 2003. The sharp drop in cover for 2001, represented by a historically low cover index value, is diagnostic of the widespread fires that occurred in the Victoria–Bonaparte bioregion in 2000 and 2001 (*high confidence* for Victoria-Bonaparte result).

Key issues for further reporting

The most critical issues for expanded (even continued) reporting by ACRIS relate to the availability of suitable data and institutional capacity among agencies in the different rangeland States and the NT.

- There are considerable differences in spatial extent (coverage) of pastoral monitoring programs and the frequency of reassessment.

  - There has been no systematic public-domain ground-based monitoring in Queensland (i.e. activity in QGraze, a vegetation and soil monitoring system operated by QDPIF) in recent years. This may improve in the near future where monitoring is used in some areas to determine sustainable use of the resource base.

  - The second complete round of pastoral monitoring associated with mandatory lease reassessments is about to commence in South Australia. Thus, for many sites, there is as yet only one monitoring record.

  - Both New South Wales and Western Australian members of the ACRIS Management Committee report that their respective monitoring programs are likely to experience difficulty in maintaining past levels of pastoral monitoring activity in the future.

  - Thus, for some jurisdictions the current capacity to report over larger areas is likely to be limited. Future reporting capacity is likely to decrease for most jurisdictions because of likely diminishing resources for existing monitoring programs.

- Apart from a reducing capacity to sustain future monitoring activity, most jurisdictions report that there is a shortage of identified people within agencies with the skills, experience and time to undertake expanded reporting to ACRIS. Outsourcing to suitable consultants may be one option, but this detracts from building human-resource skills and expertise within agencies for continued input to ACRIS and government decision-making.

- ACRIS doesn't yet have access to suitable monitoring data to report change in biodiversity adequately. Our challenge in the absence of such data is to synthesise relevant available information from various sources into a coherent and accurate assessment of change in biodiversity components (as best we can) while also recognising their limitations.

- We need to expand our ability and confidence in the socio-economic domain. Perhaps the best way of increasing our capacity in this area is through the continued use of targeted questions (as in Question 4 for the current activity) and commissioned analysis and reporting (e.g. further contracts with the Australian Bureau of Statistics or Bureau of Rural Sciences).

A number of other logistical and technical issues impacting on the current and likely future ability of ACRIS to report change are listed in the concluding section of this report.

Further reporting

Given the above limitations, ACRIS will now work towards compiling a national report on change for as large an area of the rangelands as possible. This report (Activity 2 of the ACRIS Workplan) is due in mid 2007. Jurisdictional capacity to report against products identified in *Rangelands – Tracking Changes* was clarified at the March 2005 meeting of the ACRIS Management Committee. Probable products will include (table, following page):

Theme	*Tracking Changes* product	Measure
Landscape/Ecosystem (including soil)	*Expanded landscape assessment* (change in landscape function)	• Landscape function assessment • Cover (site-based and remote sensing) • Plant density and frequency
	Dust reporting (additional national product)	• Dust Watch (Griffith University) • Dust Storm Index (Bureau of Meteorology)
	Regional resource condition assessments	• Periodic lease assessments (where available)
Biodiversity	*Interpretation and report of clearing extent*	• Change in forest cover (AGO, National Vegetation Information System [NVIS]) • Other available remote sensing and ground data
	Biodiversity monitoring and analysis	• Pasture and shrub species diversity (focussing on perennials)
Sustainable Management	*Collate, interpret and report on currently collected pastoral estate information*	• Various data from pastoral monitoring programs (focussing on potential for production from grazing)
	Updating of national photographic record	• Photos
	Predicting and managing pasture availability (Aussie-GRASS as contextual information)	• Simulated biomass and cover (additional products if required)
	Fire	• Extent, frequency and timing

The above products will be supported by relevant nationally available information on seasonal conditions as context to help interpret change. These could include images and statistics of seasonal quality and rainfall data. Additional information on the above probable products, national-level support products and possible additional products is included towards the end of Section 9.

As this pilot reporting activity concludes, the ACRIS Management Unit will start working with jurisdictions to confirm their capacity to participate in a timely and meaningful way, and to develop tailored workplans to facilitate reporting of change across a broader area of the rangelands by mid 2007.

SECTION 1 – INTRODUCTION

Australian Collaborative Rangeland Information System (ACRIS)

The Australian Collaborative Rangeland Information System is a coordinating mechanism that brings together rangeland information from State, Northern Territory and Commonwealth agencies and other sources. ACRIS grew out of the Rangeland Monitoring theme of the first phase of the National Land and Water Resources Audit (NLWRA) and its detailed report *Rangelands – Tracking Change* (NLWRA 2001 and the audit web site http://audit.ea.gov.au/ANRA/atlas_home.cfm).

ACRIS has a Management Committee comprising representatives of Australian and State/NT governments, and a small Management Unit co-located with the Desert Knowledge CRC in Alice Springs.

The ACRIS Management Committee has an agreed workplan that comprises several activities:

- Development of a reporting framework
- Testing ACRIS's ability to report change in nominated pilot regions for specific criteria (the purpose of this report)
- National reporting of rangeland change using existing data
- Facilitating further development and implementation of products that will allow more comprehensive reporting of change (e.g. biodiversity and socio-economics)

Reporting on the pilot regions

A critical first stage for ACRIS is developing our reporting ability using existing data (ACRIS Workplan Activity 4). The Management Committee has endorsed a preliminary assessment to develop and test reporting procedures across jurisdictions to obtain a national picture of elements of change in the rangelands, and showcase potential outputs. This activity is designed to test the reporting process, particularly our ability to integrate the results from a variety of data types. It is not intended to provide a comprehensive account of change in the rangelands based on all available and relevant data.

To focus reporting activity, the Management Committee has specified five questions against which to report change. Questions 1–3 and 5 have a biophysical focus, mainly related to the effects of climate and grazing (and for some regions, fire) on vegetation and soils. This is the area where most of the State and NT agency rangeland monitoring activity has concentrated in the last two decades.

Focus questions

1. What is the change in critical stock forage productivity?

This question has a specific focus on long-term pastoral productivity and, to the extent possible, is answered by the data about species known to indicate grazing pressure, i.e. 'decreasers', or species that decrease with grazing pressure.

2. What is the change in native plant species? (Including information on change in native animal species where available.)

   Rangeland monitoring has traditionally focussed on documenting and understanding change in the biophysical environment from the perspective of pastoral productivity. We recognise the need to broaden this reporting base. Although techniques and systems are being developed and progressively implemented for monitoring aspects of biodiversity, data to report change are as yet limited. This question tests the ability of established pastoral monitoring programs and other relevant data sources to report on one narrow component of biodiversity. We have expanded the question to include 'change in native animal species' in those regions where relevant data are available.

3. What is the change in landscape function?

   Landscape function describes the capacity of landscapes to capture and retain, not leak, rainwater and nutrients, the resources for plant growth (Ludwig et al. 1997). Functional landscapes have a good cover and arrangement of persistent vegetation patches (typically perennial vegetation) such that much of the rainfall is retained and is able to infiltrate the soil. Because there is little runoff, there is limited movement of sediment and loss of entrained nutrients, organic matter (litter) and seeds. Similarly, the good cover and arrangement of vegetation patches minimises wind erosion and loss of nutrients in dust. As patch cover decreases and patches become more distant, runoff increases resulting in lower infiltration and increased nutrient loss in transported sediments (i.e. erosion). Landscapes with lower cover are also exposed to a greater risk of wind erosion and nutrient loss in dust. These eroding landscapes become progressively more dysfunctional, i.e. have reduced landscape function.

4. What is the capacity for change in the region?

   Question 4 recognises that people are an integral part of the rangelands, and particularly pastoralists, because their land management actions can have a profound effect on biophysical change. This question is designed to extend the reporting capacity of ACRIS into the socio-economic domain. Our reporting ability for Question 4 has been facilitated by the National Land and Water Resources Audit (with funding from Department of Agriculture, Fisheries and Forestry) contracting the ABS to analyse and report on national census and other socio-economic data.

5. What is the change in cover?

   In theory, this is a straightforward question that can be answered through the use of a number of data sources, including remote sensing (air photography and satellite data). Vegetation cover is important for protecting the soil surface against erosion, assisting infiltration and as part of nutrient cycling. Cover can be partitioned into various components (tree, shrub, herbage, litter, cryptogam etc) and thus can be monitored and reported on in a number of ways. The different forms, and balance, of cover components are important in providing habitat for fauna.

Approach in answering questions

There are very few consistent datasets available for the entire rangelands that allow a nationally uniform approach to data analysis and reporting. The ABS census data and Australian Greenhouse Office (AGO) data on change in forest cover gained through its National Carbon Accounting System (NCAS) are examples of two such datasets (although the AGO NCAS dataset is not yet available for the entire rangelands). Note that a more complete, albeit brief, description of datasets is provided in Section 3 (including Table 6).

Rather, agencies within each jurisdiction have data collection, and often monitoring, programs to suit their required reporting and administration purposes. Some characteristics of these programs are summarised in the following dot points with more detail in the box on the following page.

- Monitoring programs are generally focussed on reporting change in the biophysical environment on pastoral leases. Descriptions of agency pastoral monitoring programs can be found at <http://audit.ea.gov.au/ANRA/rangelands/rangelands_frame.cfm?region_type=AUS&region_code=AUS&info=monitoring>.

- Most pastoral monitoring programs are ground based, but remote sensing is an important component of Tier 2 monitoring in the NT. The States and the NT use remote sensing to varying degrees for reporting some forms of change separate to pastoral lease monitoring – e.g. the SLATS program in Queensland is based on Landsat TM imagery for reporting change in tree cover due to clearing.

- WA, SA, NSW and the NT have ongoing pastoral monitoring programs, albeit with varying frequencies of reassessment (annual in NSW, every five years in the WA southern shrublands, at least once every 14 years in SA). Regular monitoring in Queensland through the QGraze program has halted but monitoring of vegetation change is occurring on a somewhat opportunistic basis through other work programs (e.g. monitoring at some QGraze and GrassCheck [pasture monitoring system for Queensland graziers] sites as a component of the Desert Uplands Build-Up and Development Strategy, Ken Dixon [QNRM] pers. comm.; remeasuring some Tree Recording and Processing System [TRAPS] sites through Meat and Livestock Australia funded projects, Madonna Hoffman [QDPIF] pers. comm.).

- Within jurisdictions, there is considerable regional variability in the spatial density of monitoring data and the temporal frequency of data collection. The nominated pilot regions represent the best datasets within jurisdictions but, within these, there is still considerable variation in the quantity and quality of available data.

- Although past monitoring activity has been focussed on pastoral land, in some regions data may be available for areas with other land uses (conservation, defence, Aboriginal land etc) but the data are generally so sparse or infrequent that it is not possible to report change with any confidence.

Features of State and NT monitoring programs

Monitoring Program	Features
WA – WARMS	• Used to monitor pastoral rangelands at regional scale • Ground-based: ~1,600 sites located on representative areas of pastoral leases • On average, about 3 sites per lease – data bulked for reporting at regional scale, not property scale • In northern grasslands, sites assessed every 3 years; southern shrublands assessed on 5 year cycle • Quantitative data collected (shrublands – demography of shrubs, grasslands – perennial grass frequency), also formal landscape function analysis, and cover or canopy size of trees and shrubs
SA – Pastoral lease monitoring	• Combination of photopoint monitoring sites (~5,500 across 328 pastoral leases in SA), Land Condition Index sample points (~20,000 – mainly in southern sheep-grazed rangelands) and paddock assessments (~4,500) where particular land management actions may be deemed appropriate • No firm schedule for reassessment, monitoring conducted under Pastoral Land Management and Conservation Act that specifies that leases and photopoints be revisited after 14 years, second comprehensive round about to commence • At photopoint monitoring sites (southern sheep grazed leases), shrub density is measured in a fixed belt (Jessup) transect and cover (by type) is estimated by step pointing
NSW – Range Assessment Program	• Ground-based – 340 sites within 7 broad range types distributed across the western NSW rangelands, recorded annually since the early 1990s • Intent is regional scale reporting and encouragement of landholder monitoring • Measurements include biomass, frequency and composition of pasture species; soil surface characteristics; density of perennial chenopods; and canopy cover of trees and shrubs, photopoint images and grazing management information also collected
Qld – various	• Ground-based – QGraze, GrassCheck and TRAPS (mainly woodland areas); Remote sensing – SLATS; Modelling (spatial simulation) – Aussie-GRASS • 350 QGraze sites established since 1991 – records frequency of pasture species, frequency and size of woody species and ground cover in quadrats; pasture yield, soil surface condition and tree basal area recorded across site area • GrassCheck used to encourage pastoralists to do their own monitoring as part of adaptive management (data confidential at site and property level) • SLATS uses Landsat TM to report regularly on extent, condition and trend of woody cover and land use across Qld
NT – Tier 1 and Tier 2	• Tier 1 – ground-based, all NT pastoral leases; permanent photo sites in major paddocks on leases; estimated pasture composition, woody density and cover • Tier 2 – based on remote sensing supported by quantitative data at ~100 fixed ground sites • Northern tropical savannas – Land Cover Change Analysis (Landsat TM and MSS) • Southern arid and semi-arid interior – Grazing Gradient Analysis (Landsat)

- Because of the focus of monitoring on pastoral lands, data collected have generally included vegetation attributes of (livestock) production (i.e. Question 1 above). In some monitoring programs, measured or observed attributes have had a broader basis including landscape function (WA, NT; Question 3) and soil surface characteristics (stability, erosion etc). Rarely are comprehensive data available for the broader suite of biodiversity attributes, and where they are, they are generally only available (as yet) as once-off surveys. (Hence the emphasis of Question 2 on native plant species.)

- The reports compiled for each pilot region illustrate the resourcefulness of ACRIS participants in accessing other data sources that have some relevance to answering each question (particularly Question 4). (See Watson et al. 2005 [WA], DellaTorre 2005 [SA], Grant 2005 [NSW], Karfs and Trueman 2005 [NT] and Bastin 2005 [Qld].) However, these examples also illustrate the disparate nature of some of these data and serve to highlight the difficulties in performing a consistent analysis across datasets and regions to compile a national synthesis.

Given the considerable variation in the nature of most available data, a consistent or systematic approach to data analysis for answering each question at the national level was not always possible. Rather, the information provided in answer to each of the five questions has two forms:

1. Where possible, it is drawn from nationally consistent data with a uniform approach to data analysis. Examples include (i) Aussie-GRASS simulations of biomass and cover (relevant to Question 1 and Question 5), (ii) ABS's reporting on census and other socio-economic data for Question 4 and (iii) Environmental Resources Information Network (ERIN)'s analysis of the AGO-produced change in forest cover data (part of Question 5).

2. A 'meta-analysis' of the results drawn from agency monitoring programs (and other data) presented in the report from each pilot region. This meta-analysis largely amounts to summarising commonalities among regional results for similar data types and drawing attention to seemingly notable differences. The meta-analysis can be criticised for being little more than expert judgement (even opinion) by the author but comes from a broad background in rangeland monitoring, familiarity with most biophysical data types, some understanding and appreciation of the regional environments and the support of peer review of content by similarly knowledgeable 'experts' from the ACRIS Management Committee.

Each of the five questions is answered in Sections 4 (Question 1) through 8 (Question 5). The format for reporting is to present a summary of the results (expert judgement) for each question followed by a listing of data sources and the more detailed meta-analysis of results presented in regional reports.

The regions

There are five reporting regions (Figure 1), each nominated by their respective State or NT Management Committee member(s) because of the greater quantity and/or volume of monitoring data that can be used as a basis upon which to answer the various questions. Some statistics that can be used to compare these regions are listed in Table 1.

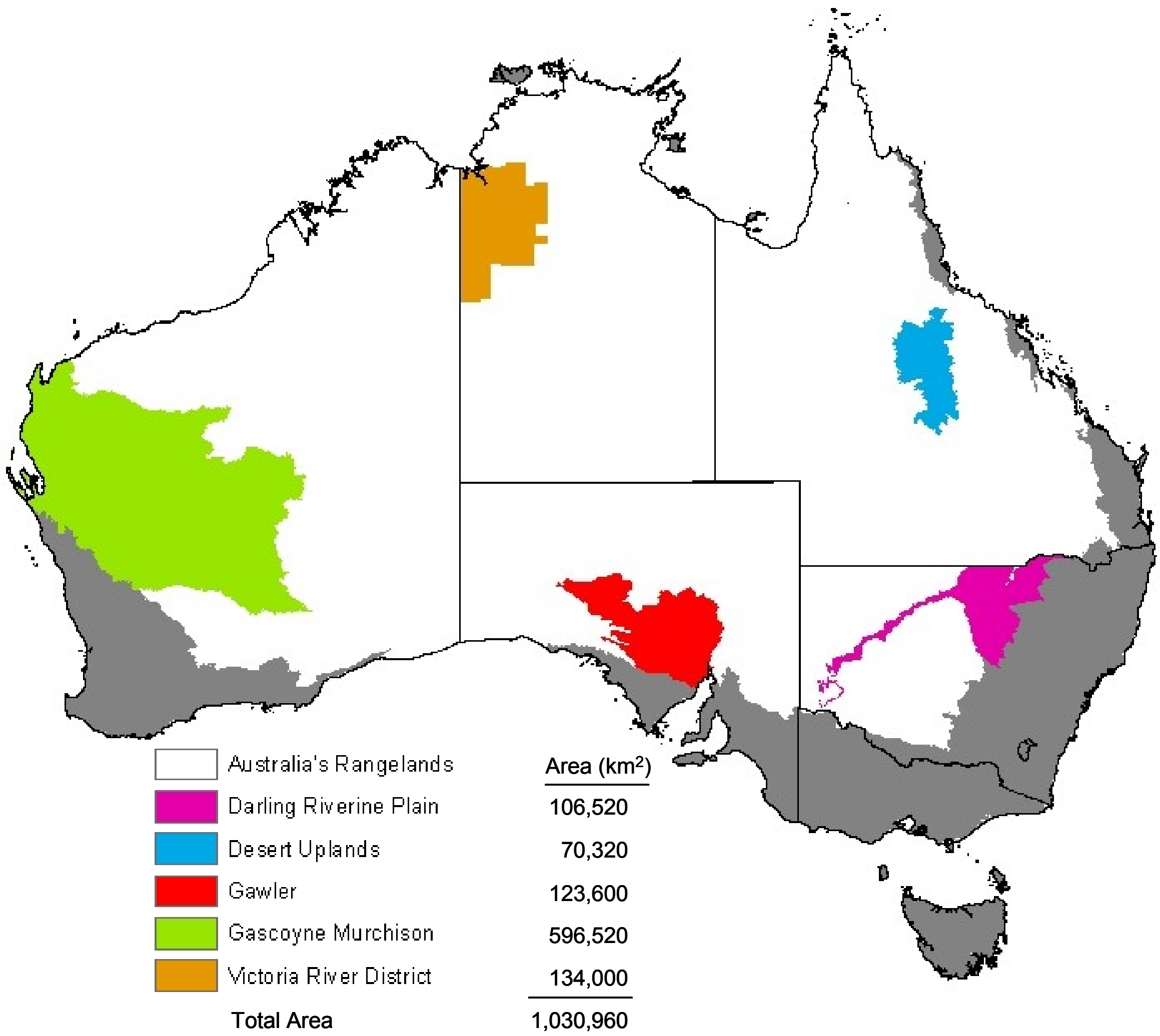


Figure 1 ACRIS pilot reporting regions

Table 1 Some statistics of pilot reporting regions

Region	Area (km^2)	Percentage of rangelands	Percentage of Australia	Number of leases/ properties	Number of bioregions
Gascoyne–Murchison (WA)	596,520	9.35	7.76	292 [1]	5
Gawler (SA)	123,600	1.94	1.61	75 [2]	1
Darling Riverine Plains (NSW)	106,520	1.67	1.39	~ 120 [3]	1
Desert Uplands (Qld)	70,320	1.10	0.92	~ 320 [4]	1
Victoria River District (NT)	134,005	2.10	1.74	29	4
Total	1,030,965	16.16	13.42		12

1 Includes 18 leases recently added to the conservation estate.

2 75 pastoral properties within the bioregion. These properties extend across 97 pastoral leases.

3 Western Lands leases greater than 5000 ha upstream of Bourke (generally corresponding with Interim Biogeographic Regionalisation of Australia [IBRA] provinces of the Northern Floodplains range type that monitoring data are reported on).

4 From the Desert Upland Build-Up and Development Committee Position Paper (psitionpaper.pdf) available at <http://www.desertuplands.org.au/pubs/pgtwo.html>.

As listed in Table 1, SA, NSW and Queensland are reporting on a single bioregion in each State. (In effect, the NSW reporting region is confined to the northern rivers [Northern Floodplains range type], generally within the Western Division, and excludes the 'panhandle' of the Darling Riverine Plains bioregion extending south-west along the Darling River.) WA and the NT are reporting on several bioregions, either in their entirety or part thereof (both WA and NT).

Key features of each region are summarised in Table 2 (extracted from *Rangelands – Tracking Changes* (<http://audit.ea.gov.au/ANRA/rangelands/rangelands_frame.cfm?region_type=AUS&region_code=AUS&info=description> – click on the appropriate bioregion on the map).

Further brief descriptions follow. These have been extracted from the reports compiled for each pilot region (and, in some cases, supplemented with further information obtained from web-based material accessible from *Rangelands – Tracking Changes*).

Table 2 Key features of ACRIS pilot reporting regions

Region	Features
Gascoyne–Murchison (WA)	Carnarvon bioregion • Follows the WA coastline. Major population centres are Carnarvon and Exmouth • Arid climate with coastal areas receiving more winter rainfall. Low, gently undulating landscape and open drainage • Main land use is extensive pastoralism. Horticulture based on the Gascoyne River aquifer surrounds Carnarvon. There are several conservation reserves, including part of the Shark Bay World Heritage Area Murchison bioregion • Inland from, and to the south-east of, the Carnarvon bioregion • The mulga region of WA • Arid climate with winter rainfall. Low hills and mesas separated by flat colluvium and alluvial plains • One of the main pastoral (sheep and cattle) and mining (gold, iron and nickel) areas in WA Gascoyne bioregion • East of the Carnarvon bioregion. Includes the catchment areas for the Gascoyne River and much of the Ashburton River • Arid climate with erratic and unreliable rainfall. Low, rugged ranges and broad, flat valleys • Extensive cattle and sheep grazing • Region is rich in gold, nickel, mineral sands, zinc, petroleum products and natural gas
Gawler (SA)	• Characterised by rounded, rocky hills, plains and salt-encrusted lake beds • The Gawler Ranges form the southernmost extent of the bioregion • Lake Torrens and Lake Gairdner are large saline playas • Major population centres are Whyalla, Port Augusta, Roxby Downs and Woomera • Mild to hot summers and cool to mild winters • Mostly leasehold land with some conservation reserves • Predominant land uses are grazing of sheep and mining
Darling Riverine Plains (NSW)	• Extensive floodplains and network of rivers and creeks that flow into the Darling River • Noted for the many wetlands associated with the river system • Includes both rangelands (grazing) and more intensive agriculture, particularly cereal cropping (to the east) • Most of the land is freehold, with some leasehold (Western Division),

Region	Features
	which is used for sheep and cattle grazing • Main towns in the rangelands component include Wilcannia, Bourke, Brewarrina, Nyngan and Lightening Ridge • Experiences hot, dry summers with cooler winters
Desert Uplands (Qld)	• Straddles the Great Dividing Range in northern Queensland between Blackall and Pentland • Dominated by sandstone ranges and sand plains • Lies within the eastern margin of the Great Artesian Basin • Thickly vegetated by eucalypt woodlands, with open spinifex and acacia woodlands • 80% of land is leasehold and used for cattle grazing • Semi-arid climate with variable rainfall
Victoria River District (NT)	Victoria–Bonaparte bioregion • Towns include Dagaragu-Kalkaringi and Timber Creek • Semi-arid monsoonal climate • Landforms include dissected plateaux and alluvial plains, and a number of river basins • Eucalypt woodlands are the dominant vegetation community • Pastoralism is the dominant land use. The amount of Aboriginal-held land is significant. Tourism is a growing industry with increasing use of four-wheel drive vehicles in rugged country Ord–Victoria Plains bioregion • Covers much of the upper catchments of the Victoria River system adjoining the Tanami bioregion • Semi-arid monsoonal climate • Pastoralism (grazing of cattle) is the dominant land use • The bioregion forms an interzone for some bird and mammal species of the arid and tropical regions

Gascoyne–Murchison

The region contains four bioregions and one province (sub-IBRA) of a fifth bioregion:

- Carnarvon – covering 83,800 km^2 on the west coast from Denham to Onslow, including the Northwest Islands and islands within Shark Bay.

- Gascoyne – covering 180,700 km^2, includes the catchment areas for the Gascoyne River and much of the Ashburton River. Broad valleys divide Kenneth, Waldburg and Robinson Ranges. Major lakes in the bioregion are Lake Carnegie and the Nabberu Lake system.

- Murchison – 281,200 km^2. This is the mulga region of WA and one of the main pastoral (sheep and cattle) and mining (gold, iron and nickel) areas in WA.

- Yalgoo – 35,000 km^2 of sand and alluvial plains, low ranges and lakes at the south-western edge of the Murchison bioregion. Regarded as the interzone between the mulga/spinifex country to the east and the south-western eucalypt environments.

- The Edel province of the Geraldton Sandplains bioregion (9,300 km^2) south of the Carnarvon bioregion in the Shark Bay area.

The following description of the natural environment and resource management issues is based on the most extensive bioregions (Gascoyne and Murchison), with some additional information provided from the Carnarvon bioregion.

Climate

Carnarvon bioregion: coastal areas are semi-desert with winter rainfall. Further inland, it has an arid climate with winter rainfall. Daytime temperatures for Carnarvon are approximately 21.9°C in July and 32°C in January. Inland at Gascoyne Junction the daytime temperatures are about 22°C in July and 40.5°C in January.

The Murchison bioregion has an arid climate with winter rainfall. Mean average annual rainfall is about 210 mm, ranging from 190 mm in the north-east to 240 mm in the south-west. Summers are hot and dry, with an average daytime temperature that reaches 38°C in January and can exceed 40°C. Winters are mild with cool nights.

Landforms

The Gascoyne bioregion is characterised by low, rugged sedimentary and granite ranges and broad, flat valleys. The catchment areas of the Ashburton and Gascoyne Rivers dominate the western half of the bioregion. Of note, Mt Augustus in the west of the bioregion is the largest exposed monolith in the world.

The Murchison bioregion is dominated by granite-greenstone terrain seen as low hills, mesas of duricrust separated by flat colluvium, and alluvial plains. The Murchison Catchment encompasses the western half of the bioregion. Drainage is westwards towards the Murchison River and to the south into Lake Austin. There are three major ephemeral wetlands within the bioregion, Lake Barlee, Annean Lake and Wooleen Lake.

Soils

Soils of the Gascoyne region are typically shallow red-brown earthy to stony loams with some clay soils. Old lateritic soils form mesas and benches. Fine textured soils have developed on active alluvial floodplains. The Murchison bioregion has alluvial soils and sand mantles associated with the granitic and greenstone terrain. These soils are shallow, sandy and infertile. Underlying the soils in low areas is a red-brown siliceous hard-pan. The soils in the eastern half of the bioregion are typically red sands, lithosols, calcareous red earths, duplex soils and clay. The Carnarvon bioregion is characterised by alluvial and sandy plains, red sand dunes and tidal flats. The alluvial plains are associated with the main river systems (Ashburton, Gascoyne and Wooramel). The limestone rocks of the Peron Peninsula have developed calcareous sands.

Vegetation

The Murchison region is essentially the mulga region of Western Australia. Vegetation in the bioregion is closely associated with the geology, soils and climate. Areas of outcropping rock with skeletal soils support low mulga woodlands. Calcareous soils support predominately saltbush shrubland and samphire (*Halosarcia* sp.). Low shrubland occurs on the saline alluvium areas. In the east of the bioregion, the red sand plains support mallee-mulga parkland over hummock grassland.

For the Gascoyne bioregion, hard-pan plains support open mulga woodlands. Mulga scrub and *Eremophila* shrublands dominate the ranges. Salt lakes are characterised by succulent steppes. The Ashburton floodplain consists of tall shrublands of *Acacia xiphophylla* with an understorey of silver saltbush (*Atriplex bunburyana*) or *Senna artemisioides* subsp. *oligophylla*) and tall saltbush (*Rhagodia eremaea*). The ranges and ridges support a mulga shrubland of *Acacia aneura* with sparse, low scrub, forbs and annual grasses. The exotic perennial grass, buffel (*Cenchrus ciliaris*), has colonised large areas of river frontage and floodplain in both the Ashburton and Gascoyne catchments. Sandy plains are dominated by soft spinifex (*Triodia pungens*) grassland and sparse shrubs of *Acacia ancistrocarpa* and *A. inaequilatera*. The low plains consist of *Acacia aneura* and other *Acacia* species, tall open shrublands or low woodlands with hard spinifex (*Triodia wiseana*) grassland.

Land use and resource condition

Pastoralism – grazing of sheep and cattle – is the predominant land use in the Gascoyne bioregion. The area under conservation has expanded in recent times as a result of the Gascoyne-Murchison Strategy (GMS, see Watson et al. 2005). Severe local erosion and vegetation degradation has occurred under high stocking rates in the past (Wilcox and McKinnon 1972, McKeon et al. 2004). Erosion is reported to be the major cause of land degradation in the Gascoyne bioregion. Goats, wild dogs, cats and foxes are the main pest species of the bioregion.

The major land use in the Murchison bioregion is sheep and cattle grazing, with the area in conservation reserves having expanded under the GMS. Mining is economically very significant. As in the Gascoyne bioregion, past overgrazing has been the main cause of land degradation. Soil erosion has resulted from loss of perennial vegetation. Mining activities between the 1890s and 1970s have resulted in localised environmental impacts from abandoned pits, waste material and vegetation loss. The main pest species are goats, foxes, wild dogs, camels and cats. Weed infestations are common along roads. The common species include buffel grass (*Cenchrus ciliaris*), saffron thistle (*Carthamus lanatus*), thorn apple (*Datura stramonium*) and mexican poppy (*Argemone ochroleuca*).

A similar situation occurs in the Carnarvon bioregion. Extensive pastoralism, principally sheep grazing, is the dominant land use. Overgrazing is the main cause of land degradation. Feral herbivores, such as rabbits and goats, have contributed to the overgrazing damage. The main pest species include goats, rabbits, foxes, donkeys, camels and cats.

Gawler

The following description has been summarised from DellaTorre (2005). Further resource information, including numerous web links, is available in the web material associated with *Rangelands – Tracking Changes* (including web links at the end of the Gawler description).

Climate

The Gawler bioregion has a semi-arid to arid climate with long, hot, dry summers and cool, mild winters. Average rainfall varies across the bioregion: southern parts have higher and distinctly winter-dominant rainfall (up to 300 mm) while in the north and east, totals of less than 150 mm are received, falling irregularly throughout the year. The mean summer temperature ranges from 17°C to 35°C. The mean temperature range in winter is between 6.8°C – 17°C.

Landscapes

There are a wide diversity of sub-regional landscapes within this bioregion. In the central and southern parts abutting the agricultural areas, distinctive granitic rocky hills forming the Gawler Ranges contrast with a number of large salt lakes that surround it. The sand plains and dunes with *Acacia aneura* (mulga) woodlands to the north-west – an extension from the Great Victoria Desert bioregion – contrast with the undulating stone-covered Arcoona tableland along the western edge of Lake Torrens. This tableland supports mainly *Atriplex vesicaria* (bladder saltbush) and *Sclerostegia* species. Calcareous plains with a *Maireana sedifolia, M. astrotricha* (bluebush species) and *Atriplex vesicaria* chenopod shrubland occur across the central and northern parts of the region, while similar country in the south-eastern portion supports open *Acacia papyrocarpa* (western myall) woodlands with chenopod shrublands of *Maireana sedifolia* and *Atriplex vesicaria*.

The water resources in the region are limited, with only a few reliable wells and springs. The pastoral industry relies on surface-water catchment storages and bore water.

Land use

The dominant land use is grazing of sheep on native pastures for the production of wool and meat. In addition, several pastoral stations to the north stock cattle. The other main land uses are conservation and mining; conservation reserves make up 12.9% of the bioregion. Mining is carried out at Olympic Dam (Roxby Downs), Andamooka, Iron Knob, Iron Baron and Mt Gunson. Tourism interest is focussed on the Gawler Ranges National Park, as well as at Olympic Dam and the Andamooka and Coober Pedy Opal Fields. Active Defence Force and aerospace facilities are located at Woomera.

Resource condition

From the information collected in the Gawler bioregion, and in common with other arid and semi-arid rangeland regions, there has been a substantial loss of biodiversity since European colonisation. The expansion of water points for grazing by domestic stock throughout the bioregion has led to extensive land degradation, and an overall decline in biodiversity. Notably there has been a significant loss of original mammal fauna, and in areas a breakdown in the landscape's ability to function in a natural state. Seven plant and 14 fauna species within the bioregion have been identified as nationally threatened.

Darling Riverine Plains

The following information has been extracted from the description of the Darling Riverine Plains bioregion in *Rangelands – Tracking Changes* (<http://audit.ea.gov.au/ANRA/rangelands/rangelands_frame.cfm?region_type=NSW&region_code=DRP>) and <http://www.nationalparks.nsw.gov.au/npws.nsf/Content/Darling+Riverine+Plains+Bioregion>.

The Darling Riverine Plains bioregion is spatially complex in terms of climate, landscape and land use. It includes a 'panhandle' consisting of the Darling River Floodplain, which bisects the NSW rangelands from north-east to south-west, traversing both summer- and winter-dominant growing seasons along a gradient of decreasing rainfall. Only the western half of the principal extent of the bioregion to the north-east is considered to be rangeland. The boundary of the rangelands approximates the Western Division boundary, although the rangelands extend to the east of this line in the Macquarie–Bogan Province of the bioregion.

Climate

Annual mean rainfall across the Darling Riverine Plains ranges between 225 and 625 mm. Bourke has a mean annual rainfall of 355 mm, decreasing in the south to 243 mm at Menindee. Summer rainfall is more predominant in the bioregion, although there is a trend for more uniform rainfall throughout the year in the southern parts. The bioregion experiences hot dry summers with cooler winters. At Bourke the mean temperatures range from 4.7°C – 17.9°C in winter to 20.9°C – 36.4°C in summer. Temperatures are on average up to several degrees lower in the southern most parts of the bioregion.

Landform and soils

Landform is broadly characterised by extensive floodplains and a network of rivers and creeks that flow into the Darling River. Major rivers that feed into the Darling River upstream of Bourke include the Culgoa, Barwon, Gwydir, Namoi, Castlereagh, Macquarie and Bogan Rivers. Extensive alluvial deposits are associated with the Darling River. These deposits form extensive plains, with slopes of less than one degree to the west and south. The Darling Riverine Plains is noted for the many wetlands associated with the river system. These include the Macquarie Marshes (located on the lower Macquarie River near Warren), Narran Lakes (lakes and wetlands associated with the Narran River west of Walgett) and Talyawalka Anabranch and Teryawynia Creek (wetlands between Wilcannia and Menindee formed by the Talyawalka Anabranch of the Darling River and its distributary, Teryawynia Creek).

There are RAMSAR sites of international importance within the Darling Riverine Plains bioregion include Macquarie Marshes Nature Reserve, Gwydir Wetland and Narran Lakes Nature Reserve.

Soils in the region are mainly alluvial. The northern alluvial fans between Moree and Bourke consist of extensive and fertile plains. Sandy soils are found in linear belts along the older stream channels, sometimes with local source dunes on their border. These soils have low nutrient levels and drain rapidly. Texture contrast soils, often badly eroded, are found marginal to channels of all ages, and most of the plains are dominated by deposits of heavy dark-coloured clays. Many clay areas have gilgai micro-relief patterns, most crack extensively, and others are more or less permanently wet in swamplands.

Vegetation

There are two major riverine communities (river red gum [*Eucalyptus camaldulensis*] woodlands and black box [*Eucalyptus largiflorens*] woodlands) and vegetation that is associated with the drier areas away from waterways (semi-arid eucalypt woodlands).

River red gum woodlands occur along the fringes of the Darling River, adjacent flats and associated billabongs and swamps where flooding is common. River red gum forms an overstorey of up to 30 m. Black box, coolibah (*Eucalyptus coolabah*) and river coobah (*Acacia stenophylla*) may also occur. Lignum (*Muehlenbeckia florulenta*) is also common in the understorey. The ground layer is a mixture of mainly herbaceous species which vary seasonally and respond quickly to receding floods. Patches of cumbungi (*Typha* spp.) and rushes (*Juncus* spp.) may occur on the edge of the rivers, billabongs and lakes.

Black box and coolibah woodlands occur on alluvial plains that are subject to periodic inundation and associated minor and ephemeral creeks. These woodlands are extensively used for grazing, and the ground layer consists of Mitchell grass (*Astrebla* spp.), neverfail (*Eragrostis setifolia*) and bladder saltbush (*Atriplex vesicaria*), although if over-utilised they are often dominated by annual grasses and herbs, including many introduced species.

In low-lying areas in the south of the region, old man saltbush (*Atriplex nummularia*) occasionally forms the main shrub layer. Bladder saltbush and thorny saltbush *(Rhagodia spinescens*) may also occur, forming a shrubland with little or no overstorey. Occasionally canegrass (*Eragrostis australasica*) is a component of black box woodlands on swampy sites.

Semi-arid eucalypt woodlands occur on the drier sites away from watercourses, including poplar box (*Eucalyptus populnea*), red box (*Eucalyptus intertexta*) and silver-leaved ironbark (*Eucalyptus melanophloia*), along with other species such as white cypress pine (*Callitris glaucophylla*). On heavy soils there is usually limited shrub understorey and a ground layer dominated by grasses such as bunched kerosene grass (*Aristida contorta*) and speargrass (*Stipa* spp.).

On small areas of red earths, additional low trees include wilga (*Geijera parviflora*), belah (*Casuarina cristata*), ironwood (*Acacia excelsa*) and kurrajong (*Brachychiton populneus*). Shrubs such as broad-leaf hopbush (*Dodonaea viscosa*), turpentine bush (*Eremophila sturtii*), budda (*Eremophila mitchellii*) and punty bush (*Senna artemisioides*) may be dense where there has been a high level of disturbance from grazing and reduced fire regimes.

Land use and condition

The bioregion falls within the administrative areas of both the Western Division (i.e. leasehold) and the Central Division (mainly freehold). There are also a number of nature reserves in the region, including Kinchega National Park, Macquarie Marshes National Park, Neary Lake and Narran Lake Nature Reserves and Culgoa National Park.

The main grazing industries are sheep and cattle but the agricultural economy is dominated by dryland cropping and irrigated cotton, horticulture and other intensive enterprises. Intensive agriculture occurs in areas throughout the bioregion, including within the rangelands, and is based on the use of irrigation water from the Darling River and its tributaries. There are major irrigation areas around Bourke.

There is significant black opal mining based at Lightning Ridge and surrounding areas.

Overgrazing has been a significant cause of land degradation in the rangeland portion of the bioregion. Extensive clearing of marginal land has occurred in parts of the region in recent times, although this is now regulated more rigidly through regional planning and approval processes. The river systems and associated wetlands are extremely important aquatic environments for the conservation of native fish. A number of these species are endemic to the Murray–Darling system and their populations have declined with the changes brought about by the more intense use of water, together with declining water quality. The quality of the Darling River has come to public attention in the past decade with the occurrence of toxic algal blooms.

One of the major pest species in this bioregion is the feral pig, which favours the riverine and wetland habitats. Foxes and goats also occur in the bioregion. High populations of kangaroos can contribute significantly to total grazing pressure on pastoral leases.

Desert Uplands

The following description has been extracted from the workplan prepared by Eric Anderson and Peter Young for reporting on the Desert Uplands as a pilot region, with additional information provided by Richard Silcock. (Eric was one of the original Queensland members on the ACRIS Management Committee; Peter and Richard are continuing members.) Anderson and Young's written description, with relevant references, is repeated in Bastin (2005) as a publicly available document.

The Desert Uplands is situated in north-central inland Queensland, straddling the Great Dividing Range between the townships of Blackall and Pentland. The term 'desert' is usually associated with areas of little or no vegetation, but the Desert Uplands bioregion is thickly vegetated, and the term has been used because of the abundance of spinifex. Sandstone ranges and sand plains of Tertiary age dominate the region and distinguish it from the clay soils of the Mitchell Grass Plains to the west and more fertile soils of the Brigalow Belt to the east. To the north, the bioregion abuts the granite ranges and basalt tablelands of the Einasleigh Uplands. The sandstones of the Desert Uplands extend southwards into the Carnarvon Range area and beyond within the Brigalow Belt.

Climate

The region has a summer-dominant rainfall averaging between 350 mm and 600 mm per year. Rainfall variability is moderate to high throughout. The summer mean daily minimum and maximum temperatures for Barcaldine (southern part of the Desert Uplands) range from 23°C to 35.8°C. Equivalent winter mean temperatures for Barcaldine range from 7.7°C to 22.5°C.

Soils

Red and yellow earths are the dominant soils, covering about 90% of the region. These soils vary in depth, are low to very low in nutrients and prone to surface scalding. In the north, the very deep red sands form part of the intake beds of the Great Artesian Basin. There are also smaller areas of texture contrast and cracking clay soils.

Vegetation

The Desert Uplands form a key part of an inland corridor of eucalypt and acacia woodlands that extends from southern Cape York Peninsula to the north-west slopes of New South Wales. The biodiversity of the region, including both plants and animals, appears largely intact (Morgan et al. 2002). However, the biodiversity is poorly represented within the protected area network that comprises only 2.6% of the bioregion. The main reserves include White Mountains, Moorrinya, Cudmore and Forest Den National Parks.

In those southern parts where gidgee (*Acacia cambagei*) scrub originally grew on relatively fertile soils, most has been converted to buffel grass pastures which are highly regarded in the pastoral industry.

Land use

The region has traditionally been used mostly for cattle grazing because wild dogs are endemic and the region was east of the Dingo Barrier Fence. Significant proportions of wiregrasses in the pastures also made wool growing less attractive. However, adult wethers were often sent to desert country blocks on agistment from the Mitchell grasslands to the west during droughts.

The advent of buffel grass as a sown pasture species allowed large parts of the region to be profitably cleared and sown to highly productive perennial pastures. Where gidgee lands formed a significant proportion of the holding, this turned unprofitable holdings into economically sustainable businesses from the 1950s onwards. Development of buffel grass pastures was extended from the 1980s into the less fertile eucalypt woodlands and that has not been nearly as successful, ecologically and economically.

In the western section of the bioregion, many landholders derive management flexibility and profitability by running a ‘desert’ block in conjunction with a ‘downs’ (Mitchell grass) block. The desert block is the drought-relief country for sheep and the downs country is the production hub in all but the worst seasons. At the same time, cattle can be run on both land types, providing income diversity as well.

Resource condition

The faunal communities of the yellow jacket and ironbark woodlands have remained relatively intact. This appears to be due to relatively low impact from cattle grazing (probably in turn due to the poor forage value in these vegetation types, exacerbated by the presence of heartleaf poisonbush [*Gastrolobium grandiflorum*]). Alluvial systems in the north-west of the region are also relatively undisturbed and support a range of arboreal animals, including koalas. The large ephemeral lakes, in particular Lakes Buchanan and Galilee, are important habitats for waterbird breeding.

While most of the Desert Uplands remains in a relatively natural condition, the overall resource condition is considered to be fair and declining (NLWRA 2001). In 1991 approximately 55% of the pastoral resources of the bioregion (the soils and their associated pastures) were assessed as being in good condition, 25% had deteriorated somewhat and 20% were degraded (Tothill and Gillies 1992). The deteriorated country was considered able to be stabilised or rehabilitated through appropriate grazing management strategies, while the degraded resources would require major works or land use change to effect recovery. Some of the regional ecosystems of limited extent, such as those associated with the lacustrine features, have become badly degraded through the impact of unrestricted grazing.

Victoria River District (VRD)

The VRD Pastoral District is 134,005 km^2 in area and is situated in the north-west of the Northern Territory, about 500 km south-west of Darwin. The extent of the VRD Pastoral District is defined by a combination of catchment, tenure and social boundaries. It stretches 450 km north–south from the Joseph Bonaparte Gulf to the Tanami Desert, and 325 km east–west from the Sturt Plateau to the border with Western Australia.

The region's climate is semi-arid tropical, with rainfall concentrated in the wet-season months between November and April. Though rainfall varies from year to year, there is a distinct gradient of decreasing mean annual falls from 850 mm in the north to less than 500 mm in southern areas (see Karfs and Trueman 2005 for references). The total population of the VRD Pastoral District is 2303 (ABS 2004), comprised of sparsely scattered small towns and communities, of which Dagaragu-Kalkaringi is the largest, with 620 residents. Land use is divided between pastoral, Indigenous, national parks and the Defence Force, with pastoralism the dominant land use. At about twice the size of Tasmania and with a small population, the region is truly an area of vast open space.

History of settlement

Aboriginal people inhabited the VRD Pastoral District prior to the arrival of European explorers in 1839 and have continued to have a strong cultural and spiritual relationship with the land. It is probable that Aboriginal people used fire to manage the land, contributing to the maintenance of an open savanna woodland and grassland. Aboriginal people were later involved in pastoralism and many continue to work in this industry today. Currently, Aboriginal-run cattle stations comprise about 10% of land in the VRD Pastoral District.

Stokes and Wickham made the first formal European exploration of the VRD Pastoral District, from the sea, in 1839. In 1855–56, the North Australian Exploring Expedition led by Augustus Gregory was the first European party to follow the Victoria River to its source. Alexander Forrest further explored the region in 1879 and was impressed with its pastoral value. Following on from Gregory and Forrest, the 'last frontier' of the Australian continent was opened to pastoralism in 1883 with the settlement of Victoria River Downs station. By the 1920s, virtually all the useful land was under grazing, though the area remained a remote outpost for pastoralists up to the 1960s, surviving generally low market prices with few boom periods. Property management was essentially free range, with cattle spreading widely during the wet, but congregating around large permanent waterholes along the major rivers towards the latter part of the dry.

Substantial changes occurred in the pastoral industry during the 1960s, with investment in property infrastructure, construction of beef roads, and use of road trains, which improved the capacity to move large numbers of cattle quickly. The 1980s national BTEC program reduced the number of wild cattle, introduced Brahman bloodlines on an extensive scale and improved animal husbandry and land management practices (e.g. with fencing to control grazing of river frontage). The VRD Pastoral District was declared free of tuberculosis in 1997. This disease-free status and change of breed (from Shorthorn to Brahman) increased market opportunities and profitability, particularly through the expanding live cattle trade into South-East Asia.

Climate

The VRD Pastoral District lies in the semi-arid monsoonal tropics and experiences hot, humid wet seasons and warm to cool dry seasons. The mean maximum wet-season temperature is 36°C and the mean minimum dry-season temperature is 12°C. Annual rainfall ranges from over 850 mm in the north to less than 500 mm in the south, with nearly all the rainfall occurring between November and April.

The long-term rainfall record from three recording stations over the last century shows a marked change in rainfall (Karfs and Trueman 2005). Mean annual rainfall at the three recording stations is Bradshaw 853 mm, Limbunya 621 mm and Victoria River Downs 651 mm. Prior to about 1972, rainfall was generally less than the long-term average. More favourable seasons began with exceptional rainfall in the mid 1970s. During the last two decades, the period 1983–1992 was approximately equal to the long-term (100-year) average, whereas the period 1993–2004 had rainfall averaging 200 mm (20–30%) above the long-term average at all three recording stations.

Geology and geomorphology

Most of the VRD Pastoral District is less than 300 m above sea level, with a few areas reaching elevations of more than 600 m. Nearly half of the area is rugged country with considerable outcrop and shallow, stony soils. The remaining land consists of gently undulating lateritic surfaces, erosional plains formed by the weathering of underlying rock, and alluvial plains associated with major stream valleys and coastal environments. The Ord and Victoria Rivers are the main catchments of the region, emptying into the Joseph Bonaparte Gulf to the north. Two other coastal draining catchments are associated with the Keep and Fitzmaurice Rivers. The remaining catchment is an internal system emptying southwards into the inland deserts. Most of the coastal-flowing rivers maintain perennial waterholes, with the duration of intermittent waterholes being largely dependent on wet-season rainfall.

Soils

Clear relationships exist between soils and the parent material, drainage and climate in the VRD Pastoral District (Karfs and Trueman 2005). Well-drained, steep hilly country with rock outcrop tends to have shallow skeletal soils. Deeper soils (2–3 m depth) are largely confined to poorly drained, flatter country. Chromosols are commonly found in the channel banks and levees of major drainage lines. These soils have high pastoral productivity but are typically very susceptible to erosion. On the gentle slopes of the Sturt Plateau, soils are generally leached and deeply weathered, comprising red and yellow earths and lateritic podzolic soils. Colluvial slopes are generally associated with duplex soils, and level non-lateritic plains, with grey-coloured cracking clays.

Vegetation

Woodlands with grassy understoreys typify the vegetation, except in the lowest-rainfall areas in the south. Trees are generally low, less than 10 m, with tree density decreasing towards the south from woodlands to open woodlands. In the northern VRD Pastoral District the dominant tree species are northern box (*Eucalyptus tectifica*) on light-textured soils and stringybark–bloodwood (*E. tetrodonta*) on lateritic soils. To the south, snappy gum (*E. brevifolia*) becomes dominant on lateritic and sandy soils, and inland bloodwood (*E. terminalis*) and southern box (*E. argillacea*) on skeletal calcareous and volcanic soils. Cracking clay soils (vertosols) are virtually treeless, with only sparse communities of bauhinia (*Lysiphyllum cunninghamii*), nutwood (*Terminalia arostrata*) and rosewood (*T. volucris*).

Tall grasses are the dominant understorey in the northern VRD Pastoral District, where annual and perennial *Sorghum* species are a typical ground cover of eucalypt woodlands. The perennials Queensland bluegrass (*Dichanthium* spp.) and golden beard grass (*Chrysopogon fallax*) are usually found on the northern plains country. In the south, spinifex is dominant on the poorer sandy and lateritic soils. Black soil plains in the south of the district support a variety of perennial tussock grasses including Mitchell grass (*Astrebla* spp.), while on calcareous soils, limestone grass (*Enneapogon* spp.) is prevalent.

The major watercourses are normally lined with tall gum trees (*E. camaldulensis* and other eucalypts) and paperbarks (*Melaleuca* spp.). Coastal estuaries and inlets are lined with mangroves that are generally backed by salt and samphire flats. Vegetation in the extreme south of the VRD Pastoral District is characterised by shrubland, with spinifex dominant in the ground layer.

Contemporary land use

Land use in the VRD Pastoral District, as defined by land tenure, is broadly made up of pastoral (59% of area), Aboriginal land (20%), national park (10%) and Defence (7%). The major parts of the unfenced areas of the VRD Pastoral District are in national parks and Aboriginal lands, with pastoral lands being mostly fenced.

It has been estimated that greater than 60% of the VRD Pastoral District is suitable for grazing, given improvements in infrastructure, breed type, technology and markets (Stockwell and Andison 1996). The most productive land is generally the downs or gently undulating country developed on basalt, alluvium and residual clay lithologies – considered resilient, and supporting various perennial grass communities. As early as the 1960s, ecologists (Perry 1960, 1970) described the patchy nature of VRD landscapes and commented that the space between perennial tussocks was commonly bare ground in low rainfall years and at the end of the dry season. In good years, these spaces were almost completely occupied by annuals, in particular Flinders grass (*Iseilema* spp.). Prolonged heavy grazing led to changes in species composition tending to feathertop wiregrass (*Aristida latifolia*) and also caused a greater number of smaller, juvenile tussocks to be produced. Excessively heavy grazing (e.g. such as that occurring near water points or holding paddocks) resulted in the removal of perennial tussocks and their replacement by annual grasses and forbs.

SECTION 2 – DRIVERS OF (BIOPHYSICAL) CHANGE

Rainfall, both the amount and its distribution through the growing season, has a profound effect on pasture growth and ground cover in the short term (seasonal quality) and in the change in vegetation over longer periods (several years) – e.g. tree–grass balance – and the role of fire as a management tool. Separating rainfall effects from management effects remains a fundamental problem in interpreting change in monitoring data. In some environments, particularly northern Australia, the frequency and intensity of fire can also have a strong influence on vegetation change. While we don't yet have a robust method for partitioning seasonal (and fire) effects from those of management, the following interpretative framework (adapted from that provided by Ian Watson and Paul Novelly, WA Department of Agriculture) allows some degree of separation.

Seasonal conditions versus grazing

Determining causality for change in rangelands is always difficult. Major drivers of change include seasonal conditions, grazing pressure (both stocking rate per amount of feed and factors such as distance to water) and fire. Conversely, the demographic inertia of longer-lived vegetation species may resist change that could otherwise occur with seasonal variation in rainfall and short-term grazing effects. For each of the major drivers of vegetation change, there are many nuances, making it difficult to provide simple summaries of the driver. For example, seasonal conditions cannot be simply summarised by examining total rainfall, since the timing, frequency and intensity of rainfall help determine its effect, as does the rainfall during preceding and successive periods of interest. Finally, the interactions between the major drivers serve to produce changes in rangelands. Many of these are poorly understood at the research level and are therefore difficult to determine at the monitoring level.

For the vegetation indicators found on WARMS shrubland sites, the principal mechanisms of change include seasonal conditions and grazing pressure. The main indicators of change on shrubland sites are density and change in the canopy area of long-lived shrubs.

Table 3 provides a conceptual model of how to disentangle the impacts of seasonal conditions and grazing and, possibly, the interactions between seasonal conditions and change. Should there be a decline in the indicator during favourable seasonal conditions (above-average rainfall), then that would suggest that some other factor, probably grazing, had an influence on the change. Conversely, should there be an improvement under unfavourable seasonal conditions (below-average rainfall) then that would suggest that the grazing impact has been minimal. These cells in Table 3 are emphasised with red and green colours (a 'red light' for deleterious change and a 'green light' for favourable change). Other changes are more neutral and are indicated by 'softer' or no colouring.

In general, if there has been an improvement then it is possible to say that the grazing impact did not override the seasonal impact.

Table 3 Conceptual matrix to help judge attribution between seasonal conditions and grazing

Seasonal conditions	Condition/Attribute		
	Decline	No change	Improvement
Above average	XX	X	~
Average	X	~	√
Below average	~	√	√√

Notes:

- For the purpose of explanation here, the quality of seasonal conditions is based on the amount of rainfall in the growth season(s) prior to the monitoring period compared with the long-term record. (Further explanation is provided below.)
- Columns report the percentage of monitoring sites where reported attributes of vegetation (or landscape) are unchanged, have improved or declined.
- In this schematic, XX denotes adverse decline when seasonal conditions would suggest that improvement should have occurred. Conversely, √√ shows improvement when past seasons would indicate clear potential for decline.

With some monitoring systems, other pieces of evidence can be used to build a case for causality.

- For example, WARMS records attributes of relatively long-lived species which are minimally affected by recent seasonal conditions, and it is better positioned to dissociate long-term change from seasonally driven change. Negative changes are less likely to be due to unfavourable seasons alone than is the case with annual or ephemeral species. Where fire is not an obvious cause, the loss of longer-lived species over short time periods is likely to implicate grazing.
- If species known to be negatively affected by grazing (i.e. decreasers) exhibit different dynamics to those species known to be unaffected (intermediate) or positively affected (increasers), then that would suggest that grazing is having an impact. This assumes that seasonal conditions alone have the same impact on decreaser, increaser and intermediate species.

Ranking seasonal conditions

There are a number of approaches for ranking the quality of seasonal conditions contributing to vegetation attributes measured at monitoring sites. These include:

1. Historic rainfall of recording stations distributed through each reporting region – as described on following pages.

2. Aussie-GRASS simulated annual pasture growth (or cover) for the period 1890 to 2003 – processed in a similar way to historic rainfall as described below. Data were supplied by John Carter (Queensland Department Natural Resources and Mines, QNRM) for bioregions covering the various reporting regions. We evaluated these data but decided to use rainfall because:

   - Rainfall recording stations provided greater spatial flexibility in assigning the data from groups of monitoring sites to particular seasonal rankings. (At our request, the Aussie-GRASS data were supplied at the resolution of bioregions [apart from NSW, where data were available for provinces, or sub-IBRAs, of the Darling Riverine Plains]. The bioregion simulations were deemed too coarse for some reporting regions where monitoring sites were often assessed in small groups over time with these site groups having relatively limited geographic extent.)

   - The Aussie-GRASS data at this stage are not always calibrated and we considered that there was some doubt in how well the simulated output matched reality in some regions.

3. Images and statistics of seasonal quality derived from data of the Advanced Very High Resolution Radiometer (AVHRR) carried on-board National Oceanographic and Aeronautic Administration (NOAA) satellites. AVHRR data were processed by ERIN (see http://www.deh.gov.au/erin/ndvi/index.html). These images are demonstrated for the Gascoyne–Murchison region in Appendix 1. We elected not to use the ERIN procedure for assigning seasonal quality (described at http://www.deh.gov.au/erin/ndvi/procedure.html#seasonal) because of:

   - Limited historic context – i.e. images available since 1992.

   - The relative nature of seasonal quality index values – the Normalised Difference Vegetation Index (NDVI)-based value of each 1.1 km^2 pixel is compared against itself rather than being scaled in absolute terms (such as rainfall or Aussie-GRASS simulated pasture growth).

An example – seasonal quality in the Gascoyne–Murchison

1. Twelve recording stations (Figure 2) were selected from *Rainman v4.3* and the monthly rainfall data extracted to a spreadsheet. Rainfall statistics from these 12 stations are summarised in Table 4.

2. Annual rainfall amounts (and other variants as appropriate, e.g. winter rainfall, summer [wet season] rainfall in the VRD and Desert Uplands) were then arranged in ascending order and ranked from the lowest to highest amount.

3. This ordering was used to assign 'tercile' ranks to total rainfall for each defined period. The lowest one-third of recordings was considered to constitute 'below-average' seasonal conditions, the middle one-third was considered 'average' and the highest one-third 'above-average'.

4. Recent seasonal conditions (1990–2003) were then summarised across all locations (Table 5).

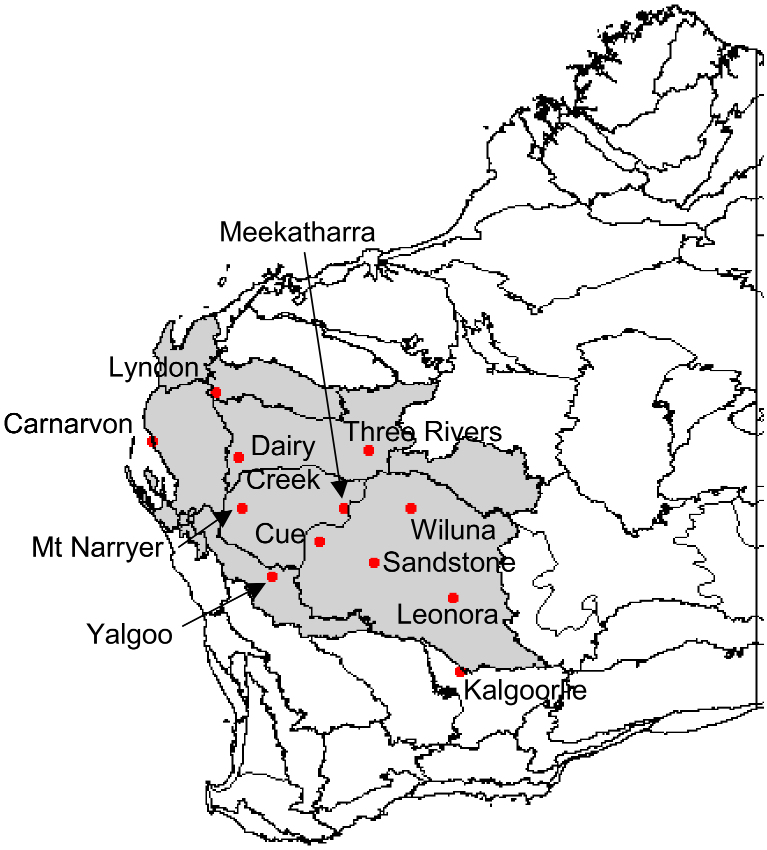


Figure 2 Location of rainfall recording stations used in the Gascoyne–Murchison region to assign seasonal quality

Table 4 Summary statistics of rainfall data from selected recording stations in the Gascoyne–Murchison region

Station	Recording period	No. of years	Annual rainfall (mm) [1]	
			Mean	Median
Carnarvon	1883–2003	121	228.5	207
Cue	1895–2003	109	232.2	217
Dairy Creek	1901–2003	103	208.0	187
Kalgoorlie	1896–2003	108	259.5	242
Leonora	1898–2003	106	233.1	220
Lyndon	1899–2003	105	265.8	249
Meekatharra	1908–2003	96	237.1	229
Mount Narryer	1900–2003	104	197.9	184
Sandstone	1905–2003	99	246.5	225
Three Rivers	1908–2003	96	229.2	204
Wiluna	1899–2003	105	257.0	221
Yalgoo	1897–2003	107	254.2	240

[1] Rainfall amounts for winter and summer periods were also examined for their effectiveness in assigning seasonal quality.

5. Each reporting region then used an appropriate 'prior period' to assign the overall seasonal quality prevailing prior to each monitoring period.

   - For the Gascoyne–Murchison (WA) shrubland sites and Gawler (SA) regions, this period was five years, because change for most biophysical-related questions (Question 1, Question 2 and Question 3, also Question 5 for Gascoyne–Murchison) is based on longer-lived perennial shrubs and the recording frequency (in WA at least) is on a five-year basis. The period was three years for WARMS grassland sites.

   - For the Victoria River District (NT) and Desert Uplands (Qld), the preceding summer wet season was used because of its predominant influence on the perennial grasses being reported.

   - For the Darling Riverine Plains (NSW), rainfall in the year preceding the annual assessments was used.

6. The proximity of sites to recording stations was then used to select the most appropriate seasonal ranking for the data being reported from each site.

Table 5 Ranking of seasonal quality in recent years based on annual rainfall of selected recording stations in the Gascoyne–Murchison region

Year	Recording station											
	Carn	Cue	DCk	Kal	Leon	Lynd	Meek	Mt N	Sand	3 Riv	Wil	Yalg
1990	59	34	62	75	70	56	46	48	60	74	54	88
1991	77	7	51	16	40	24	13	65	22	18	8	40
1992	75	107	56	100	99	61	87	85	94	80	86	107
1993	40	63	26	88	81	55	30	66	47	31	46	51
1994	27	24	34	58	10	47	5	20	24	11	22	23
1995	80	101	73	106	100	91	71	49	96	86	103	73
1996	104	64	74	50	89	84	62	61	83	71	92	99
1997	100	96	102	57	87	92	84	67	82	93	100	93
1998	111	97	97	82	77	83	85	88	88	78	93	70
1999	81	90	93	97	64	93	79	96	73	90	87	83
2000	105	104	88	105	103	105	96	97	92	81	102	52
2001	5	81	29	47	98	51	70	70	84	53	83	66
2002	19	20	11	27	39	15	40	19	38	59	73	43
2003	12	68	42	85	79	10	53	34	53	69	71	18

Notes:

- The number in each row (i.e. year) is the rank of that year's total rainfall for that recording station (column) among all years.

- The colour scheme is such that red cells represent rainfall amounts in the lowest tercile (considered to be below-average seasonal quality); green, the middle tercile (average season); and blue, the highest tercile (above average).

- This is an example only and is used to demonstrate the procedure used. The actual assignation of seasonal quality used for shrubland sites by Watson et al. (2005) for the Gascoyne–Murchison was derived from an index based on both winter rainfall and total rainfall in each of the five years prior to the year in which the site was recorded.

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SECTION 3 – DATASETS

The main datasets used for reporting are summarised in Table 6. Of the datasets with national extent:

- ERIN analysed change in the forest cover of each of the reporting regions for ACRIS. Forest cover was provided by the Australian Greenhouse Office and was originally derived from their National Carbon Accounting System multi-temporal Landsat database (spanning 30 years from 1972 to 2002). (These data were not released for the Gascoyne–Murchison region due to data quality issues.)

- ERIN provided their images of seasonal quality to ACRIS under a data license agreement. Gary Bastin extracted regional images and accompanying summary statistics and provided these to each State/NT coordinator to assist their reporting.

- John Carter from the Queensland Department of Natural Resources and Mines supplied the Aussie-GRASS data and Gary distributed regional output and statistical summaries as appropriate.

- In consultation with reporting region coordinators, Gary extracted rainfall (Rainman) data for nominated stations and ranked the 'quality' of recent seasonal conditions (1990–2002) to assist in the understanding and reporting of change. Each year (or growing season where there is a distinct wet period, e.g. Victoria River District) was described as 'below average' 'average' or 'above average' based on the tercile ranking of all rainfall records (generally >100). (See Table 5 as an example.)

- Rex Porter, Australian Bureau of Statistics, provided a socio-economic profile of each region, based on ABS and Australian Bureau of Agriculture and Resource Economics (ABARE) data, for Question 4. This work was done for ACRIS under a contract between ABS and the National Land and Water Resources Audit (with funding from the Department of Agriculture, Fisheries and Forestry).

Table 6 Primary datasets used for reporting on pilot regions

Extent	Domain	
	Biophysical (Q1–3 and 5)	Socio-economic (Q4)
National (data layers have national coverage but only analysed for pilot regions)	• Rainfall (ex *Rainman* + *Streamflow v4*) • Seasonal quality (ERIN yearly images of 'NDVI flush' – see http://www.deh.gov.au/erin/ndvi/index.html) • Aussie-GRASS simulated yearly total standing dry matter, green growth and cover • AGO change in forest cover	• ABS Census of Population and Housing (1991, 1996, 2001) • ABS Agricultural Census 2001 • ABARE farm surveys

Extent	Domain	
	Biophysical (Q1–3 and 5)	Socio-economic (Q4)
Regional		
Gascoyne–Murchison (WA)	• 700 shrubland sites installed 1994–99 and reassessed 1999–2004 and 71 grassland sites installed between 1994 and 2001 and reassessed 1999–2002. Of these, 40 grassland sites were assessed three times (WARMS) • Regional range condition surveys • Status and trend of threatened species and communities	• Participation in Ecological Management Understanding program • Change in tenure and land use (particularly conservation) • Changed land management practices from GMS
Gawler (SA)	• 179 (of 1933) pastoral monitoring sites established 1990–93 and reassessed in 2001–02 • Surveyed status of plant and animal species • Major fire events	• Change in land use • Change in property values
Darling Riverine Plains (NSW)	• 45 Northern Floodplain Rangeland Assessment Program (RAP) sites assessed annually 1992–2003 • Aerial kangaroo surveys • Extent of clearing from satellite imagery	• Conversion of grazing land to cropping • Change in property values
Desert Uplands (Qld)	• 34 QGraze sites assessed at various times during 1992–2004 • Recent regional trends at 440 GrassCheck sites (data not available at site level) • SLATS (Landsat TM) database – clearing and cover trends • Environmental Protection Agency (EPA) repeat surveys of flora and fauna	• Outcomes from the Desert Uplands Build-up and Development Strategy
Victoria River District (NT)	• Range condition assessments at 254 Tier 1 sites (1993 and 1998–2003) • Landsat-derived cover change analysis at paddock scale • Landscape function assessments at 33 Tier 2 sites • Exclosure-scale to regional-scale studies of woody layer and pasture dynamics • Fire regimes	• Trends in cattle numbers and turnoff • Change in land ownership and property values • Residency of pastoral company managers • Indigenous Natural Resource Management (NRM) involvement

SECTION 4 – CHANGE IN CRITICAL STOCK FORAGE PRODUCTIVITY (QUESTION 1)

Summary

- This question has been answered with a combination of nationally consistent simulated data (Aussie-GRASS total standing dry matter) and vegetation data collected at monitoring sites in each region. Note that Aussie-GRASS simulates likely pasture availability given preceding rainfall (and other environmental factors), not that which is actually present. Effectively, it is used here as an index of seasonal quality to provide an estimate of likely pasture biomass. It also allows comparisons between regions.

- The Aussie-GRASS data highlight the importance of rainfall for pasture growth (and availability). Across the rangelands, yearly total standing dry matter was much higher in subtropical northern Australia (particularly bioregions in the VRD) compared with the more arid south (Gawler bioregion, biomass generally low throughout). Within regions, higher biomass was present in wetter years or shortly thereafter.

  - The Ord–Victoria Plains bioregion (partly representative of the VRD) had increasing biomass from 1992 to 2000, generally consistent with above-average rainfall during this period. Above-average wet-season rainfalls have continued into the first part of the current decade, but simulated standing dry matter has decreased. This may reflect increased fire frequency as a result of these wetter years.

  - There was distinct cycling in simulated biomass for the Desert Uplands, with high values indicated in 1991 and 2000–01, coinciding with wetter years, and low simulated forage availability in the very dry years of the mid 1990s (1993–96) and again in 2002 and 2003.

  - There was marked year-to-year variation in total standing dry matter for the Darling Riverine Plains.

  - Simulated biomass in the Murchison bioregion (part of the Gascoyne–Murchison) increased progressively in wetter years between 1994 and 2000. Biomass then declined with deteriorating seasonal conditions from 2001 onwards.

- To the extent possible, attributes of vegetation at ground sites that are damped against short-term climate variability were used to report change. For the Gascoyne–Murchison and Gawler regions, reporting was based on either population measures or the density of decreaser shrub species – i.e. longer-lived palatable perennials that are known to decrease with regular grazing. For the Darling Riverine Plains, Desert Uplands and Gascoyne–Murchison (grassland sites), we used frequency (of occurrence) of 2P grasses. Data for the Victoria River District were more qualitative – based on the change in assessed condition at monitoring sites.

- Major trends from fixed monitoring sites were:

- In the Gascoyne–Murchison, there was general improvement in the shrublands throughout the reporting period, shown by increased occurrence and population of decreaser shrubs at the majority of monitoring sites (681 of 700 shrubland sites had decreaser species). Change on predominantly grassland country was more variable – 7 (of 40) sites showed continuous improvement in perennial grass frequency over two intervals of monitoring. A similar proportion (6 of 40 sites) had a continuous decline in frequency, while the majority (the remaining 27 sites) had decreased frequency in the second recording interval (a period of deteriorating seasonal conditions).

- Based on resampling of 179 pastoral monitoring sites in the Gawler bioregion, there were both increases and decreases in the density of perennial decreaser species. Bladder saltbush (*Atriplex vesicaria*) generally increased in density across the region. The density of pearl bluebush (*Maireana sedifolia*) and low bluebush (*M. astrotricha*), both long-lived perennials, remained stable through the monitoring period. The highly palatable bandicoot grass (*Monochather paradoxa*) significantly decreased in density over the bioregion. The density of mulga (*Acacia aneura*) increased at monitoring sites, by an average of 1.6 plants per site.

- From 45 sites on the Northern Floodplains of the Darling Riverine Plains bioregion, the frequency of 2P (palatable and perennial) grasses increased for most species at most sites between 1992 and 2000, a period of generally favourable seasons. Frequency of these grasses has decreased with drought conditions prevailing since 2001.

- Thirty-four of 48 QGraze sites in the Desert Uplands had a suitable monitoring record for data analysis. The averaged frequency of 3P (palatable, perennial and productive) grasses was relatively low between 1992 and 1997, under very dry conditions (but higher than that recorded at Rangeland Assessment Program sites in the Darling Riverine Plains because of higher and more consistent summer rainfall). 3P grass frequency then increased in the late 1990s in a wetter period, was maintained at moderate levels until 2002 and declined, under recent drought conditions, to a level near the starting point in 1992.

- From qualitative assessments made at 254 Tier 1 sites in the Victoria River District, approximately 10% more sites were in good condition at the end of the reporting period (i.e. had improved from fair condition) and there was no increase in the number of poor condition sites.

- We used a matrix filter of seasonal quality by direction of change at each site that sought to separate grazing effects from rainfall. Within regions:

  - Twenty percent of Gascoyne–Murchison shrubland sites had an increasing density of decreaser shrubs in a period of below-average seasons – interpreted as a positive effect of grazing management. Of concern, 15% of sites had a declining density of decreaser shrubs during a period of above-average rainfall. The remaining sites showed trends consistent with that expected for the rainfall amounts received prior to site assessment, i.e. shrub density either remained stable throughout, increased following above-average rainfall or decreased in periods of below-average rainfall.

- Two-thirds of sites in the Gawler bioregion reassessed following average seasonal conditions had an increased density of decreaser perennial species. Following below-average rainfall, half of the reassessed sites had an improved density of decreaser species. Approximately one-third of sites had a reduced density at this time.

- Seven percent of sites on the Northern Floodplains of the Darling Riverine Plains showed an increasing frequency of 2P grasses in below-average seasons (suggesting positive grazing management). Of concern, 17% of sites had a declining frequency of 2P grasses during above-average seasons. Frequency changes at the remaining sites conformed with that expected for the rainfall preceding the site assessment.

- In the Desert Uplands, 11% of sites had a declining frequency of 3P grasses in a period of above-average rainfall. The remaining sites showed trends consistent with that expected for the rainfall amounts received prior to site assessment.

- All sites either remained stable or improved in condition in the Victoria River District, the expected result given the above-average rainfall received through most of the reporting period.

Data used to answer Question 1

Data used in each reporting region to answer Question 1 are summarised in Table 7.

Table 7 Datasets used to answer Question 1

Region	Dataset	Derived indices
All	Aussie-GRASS • Total standing dry matter – simulated yearly biomass to indicate seasonal variation and likely impact on biomass. Also provides between-region comparisons of productivity for context purposes (Note: Dataset simulates change based on rainfall and other factors, it does not show actual change)	
Gascoyne–Murchison	WARMS • Demography of perennial shrubs that are known to **decrease** under grazing (700 shrubland sites) • Frequency of perennial grasses that are known to decrease under grazing (total of 71 grassland sites)	• Occurrence ratio (OR) – number of sites each species found on at first (t_1) and last (t_2) assessments • Recruitment rate – measure of whether the shrub population is replacing itself. Calculated as: *no recruits at* t_2 */ population size at* t_1 • Population growth rate (PGR). Calculated as: *pop'n size at* t_2 */ pop'n size at* t_1 • Change in frequency between t_2 and t_1
Gawler	• Density of decreaser palatable perennials (chenopods and grasses) measured in Jessup transects at 179 sites	• Population growth rate (as used by WARMS) – percentage of sites showing increase, no real change and decrease
Darling Riverine Plains	• Density of chenopods and other perennials in fixed belt transects at 45 RAP sites • Frequency of 2P grasses at 45 RAP sites • Reporting focussed on Northern Floodplain range type in north-east of bioregion	• Percentage of sites showing increase, no real change and decrease for specified reporting periods
Desert Uplands	• Frequency of 3P grasses at 34 QGraze sites • More general regional change indicated by GrassCheck monitoring	• % of QGraze sites showing increase, no real change and decrease for specified reporting periods • GrassCheck data not available at site level. General trends reported by Ken Dixon in Bastin (2005)
Victoria River District	• Assessed condition score at Tier 1 sites Assessment based largely on pasture availability and quality (particularly species composition)	• Percentage of Tier 1 sites with same or changed assessed condition rating (i.e. no change, improvement or decline)

Aussie-GRASS simulated forage availability

Simulated total standing dry matter for the Gawler (SA), Darling Riverine Plains (NSW) and Desert Uplands (Qld) bioregions and a single bioregion from the Victoria River District (Ord–Victoria Plains) and Gascoyne–Murchison (Murchison) is shown in Figure 3. Graphed data extend a little beyond the nominated reporting period (i.e. 1992–2002). The dashed lines show the average long-term (1890–2003) simulated biomass for each bioregion. Note that these graphs **do not** show actual change in annual biomass for each bioregion. Rather, they indicate **expected** (i.e. simulated) total standing dry matter based largely on rainfall. Each graph shows the average biomass for the bioregion and this may conceal considerable spatial variation related to rainfall variability, soil differences and other parameters used by Aussie-GRASS. Despite these caveats, the simulated data are valuable because they are consistent across large areas and provide an objective basis for determining whether actual biomass diverged from expected levels. Of particular note, the graphs powerfully demonstrate regional differences and the magnitude of year-to-year variation of individual bioregions.

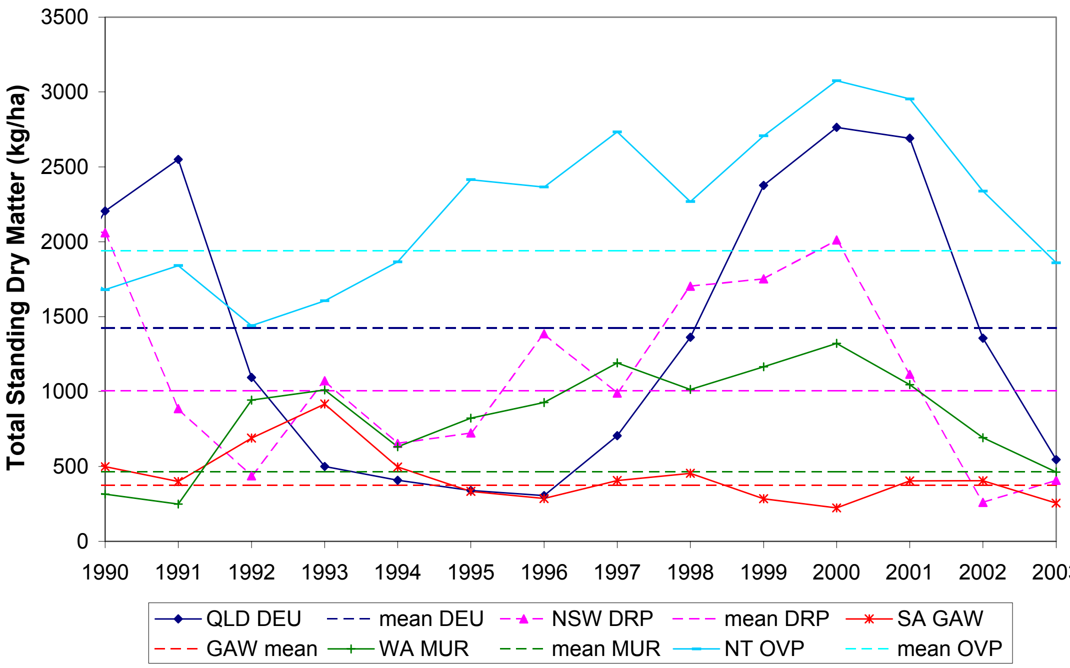

Figure 3 Aussie-GRASS simulated yearly total standing dry matter and the long-term (1890–2003) mean for selected bioregions

DEU = Desert Uplands, DRP = Darling Riverine Plains, GAW = Gawler, MUR = Murchison, OVP = Ord–Victoria Plains

This Aussie-GRASS product indicates that:

- The Ord–Victoria Plains (partly representative of the Victoria River District) had the highest simulated biomass. This bioregion showed generally increasing biomass from 1992 to 2000, which is generally consistent with above-average rainfall during this period. (The 1997–98 wet season had reduced rainfall and simulated standing dry matter decreased slightly in 1998.) Above-average wet-season rainfalls have continued into the first part of the current decade, but simulated standing dry matter has decreased. This may reflect the greatly increased fire frequency and area burnt that has accompanied these wetter years (Karfs and Trueman 2005).

- There was a strong cyclic nature in the simulated biomass for the Desert Uplands during the reporting period (1992–2002). High values were indicated in 1991 and 2000–01, coinciding with wetter years. The very dry years of the mid 1990s (1993–96) and again in 2002 and 2003 resulted in low simulated forage availability. This cyclic behaviour probably reflects shorter-term (El Nino – Southern Oscillation) and longer term (Inter-decadal Pacific Oscillation) climate variability (McKeon et al. 2004). The bioregion is part of north-eastern Queenland that was identified in the 1950s as having an exceptionally high degree of unreliability in its seasonal rainfall by world standards.

- Compared with the two northern bioregions, the Gawler bioregion had generally low simulated total standing biomass through the reporting period. Simulated biomass was relatively higher in 1992–93 and close to historical lows in 2000 and 2003.

- There was marked year-to-year variation in total standing dry matter for the Darling Riverine Plains. Simulated biomass was well above the long-term average in 1990 and 1998–2000. There was a particularly sharp decline in indicated forage availability with the onset of the recent drought (2001–02).

- Simulated biomass in the Murchison bioregion increased progressively from 1994 to 2000 and then declined, indicating wetter years and then deteriorating seasonal conditions. Predicted levels of standing dry matter throughout the reporting period were generally well above the simulated long-term mean.

Results of regional monitoring activity

The change in critical stock forage productivity detected by regional monitoring is summarised in Table 8. The reported change is based on repeat measurements or observations of vegetation attributes at fixed ground sites.

Table 8 Change in stock forage productivity detected by ground-based monitoring

Region	Measured or observed change
Gascoyne–Murchison	For decreasers (i.e. perennial species known to decrease with grazing) Decreasers found on 681 of 700 shrubland sites: • Occurrence ratio = 1.1 (i.e. more sites with species at t_2 compared with t_1) • Increase in shrub population at sites (population growth rate = 1.37) • Evidence of recruitment for 47 (of 48) species On 42 grassland sites: • 8 sites showed an increase in frequency of perennial grasses known to decrease with grazing, 12 sites recorded a decline in the frequency of decreaser perennial grasses, frequency of decreaser perennial grasses was relatively unchanged on the remaining 22 sites
Gawler	Density of decreaser perennial species measurements in Jessup transects at 179 sites: • Increase in density at two-thirds of sites reassessed following average seasons and half of sites reassessed after poorer seasons • Increase in density of bladder saltbush (*Atriplex vesicaria*) was common – primarily in the southern portion of the bioregion • Significant recruitment of mulga (*Acacia aneura*) at 14 of the 22 sites where mulga was present. Mulga survival has been adversely impacted by recurring fire across the northern area of the bioregion since the 1970s • Densities of 2P bandicoot grass (*Monochather paradoxa*) and mulga grass (*Thyridolepis mitchelliana*) significantly reduced at 11 of the 14 pastoral monitoring sites where these species occurred
Darling Riverine Plains	Chenopod bush density at 45 Northern Floodplain sites: • Density averaged across all sites declined initially (1992 to 1993), probably due to mortality of juvenile bushes. Density then remained fairly stable across most of the floodplain sites until 2002. Substantial recruitment in the Bogan–Macquarie province in 2000–02 following high rainfall in 2000 increased bush density averaged across all sites • Bladder saltbush (*Atriplex vesicaria*), a pastorally valuable species, contributed most to bush recruitment in the Bogan–Macquarie province. Lignum (*Muehlenbeckia* spp.) also increased and is now of some concern because it harbours feral pigs • Palatable cottonbush (*Maireana aphylla*) and old man saltbush (*A. nummularia*) had generally low densities where present (<~2000 bushes/ha) but showed up to fourfold differences in density through the reporting period Frequency of 2P grasses at 45 Northern Floodplain sites: • There was a broad range of 2P grass frequencies on RAP sites. A few sites had moderate and higher frequencies (>30%) in most years and many sites had quite low frequencies (<15%)

Region	Measured or observed change
	• 2P grass frequency increased with the favourable season of 2000 when averaged across sites. Most sites still had quite low frequencies and the increase was less on sites with higher frequencies of 2P grasses • 2P frequency decreased on average with drought conditions following 2000. Some sites retained moderate frequencies (up to 55% 2P frequency) • Curly Mitchell grass (*Astrebla lappacea*) and neverfail (*Eragrostis* spp.) were dominant perennial grasses. Averaged across sites, Mitchell grass frequency was fairly stable over the reporting period (in the range of 6–11%, increasing slightly with good summer rainfall in 2000). Several less abundant 2P grasses had increased frequencies with favourable summer rainfalls prior to the 2001–02 drought
Desert Uplands	Frequency of 3P grasses from 34 QGraze sites reassessed at various times: • Frequency averaged across sites was relatively low (~50%) until 1997. It then increased to a peak average value of 76.5% in 1999. 3P frequency was maintained at ≥65% until 2002 and then declined to ~50% in 2004 (Note that these frequencies were generally higher than for RAP sites in the Darling Riverine Plains, probably because of higher and more consistent summer rainfall) • Using a minimum threshold of 65% frequency (i.e. a 3P grass present in approximately two-thirds of quadrats assessed at each site): – 3 of 21 sites had >65% frequency in the drier period 1992–95 – 17 of 27 sites had >65% frequency during the wetter period 1999–2001 – one of 5 sites exceeded 65% frequency in the dry period 2003–04 • 7 of 27 sites had >35% increase in 3P grass frequency between repeat assessments made somewhere in the period 1992 to 2001 (a drier then wetter period)
Victoria River District	Condition assessments at 254 Tier 1 sites: • Approximately 10% more sites in good condition at second assessment • No increase in number of poor condition sites For major land types: • Small increase in number of sites in good condition for Alluvial Plain and Basalt Plain land types • Small decrease in number of Relic Clay Plain sites in good condition

Rainfall as a contributor to detected change

Using the framework outlined in Section 2 and illustrated in Table 3 for assigning quality of seasonal conditions, the following tables attempt to partition rainfall and grazing management effects on vegetation change reported in Table 8.

Gascoyne–Murchison

WARMS shrubland sites

Table 9 Percentage of WARMS shrubland sites where the population growth rate (i.e. density) of shrubs known to decrease with grazing declined, remained stable or improved under prevailing seasonal conditions in the five years prior to reassessment

Seasonal conditions	# Sites	Decline	No change [1]	Improvement
Above average	412	15	13	72
Average	163	37	20	43
Below average	106	60	20	20

[1] Population growth rate between 0.95 and 1.05 (i.e. shrub density at reassessment within 95% and 105% of previous measurement). Accordingly, 'decline' has PGR <0.95 (density <95%) and 'improvement' has PGR >1.05 (density >105%).

WARMS grassland sites

Table 10 Percentage of WARMS grassland sites where the frequency of perennial grasses known to decrease with grazing declined, remained stable or improved under prevailing seasonal conditions in the three years prior to reassessment

Seasonal conditions	# Sites	Decline	No change [1]	Improvement
Above average	42	29	52	19
Average	–			
Below average	–			

[1] A tolerance of ±10% was used to categorise 'no change'.

These summaries of the WARMS data show that a reasonable proportion of sites showed changes in the population of decreaser shrubs and the frequency of decreaser perennial grasses that were counter to the trend expected given seasonal conditions prior to reassessment. That is, about one-sixth of shrubland sites and ~30% of grassland sites assessed following above-average seasons had a reduced population of shrubs or perennial grass frequency compared with the preceding assessment (no change or increase expected). This suggests that grazing management (or some other unexplained factor) was having an adverse impact on the survival of these key forage species. Conversely, one-fifth of sites showed an increase in shrub population following below-average rainfall (no change or decrease expected), suggesting that grazing management was promoting shrub survival (or recruitment).

Gawler bioregion

The results of partitioning recent rainfall history (i.e. seasonal quality) on the direction of change at sites for the Gawler bioregion are shown in Table 11.

Table 11 Percentage of SA pastoral monitoring sites where the density of perennial species known to decrease with grazing declined, remained stable or improved under prevailing seasonal conditions in the five years prior to reassessment

Seasonal conditions	# Sites	Decline	No change [1]	Improvement
Above average	n/a			
Average (2001)	104	11	25	64
Below average (2002)	75	36	13	51

[1] A tolerance of ±10% was used to categorise 'no change'.

The results summarised above at the site level indicate an encouraging trend. Almost two-thirds of sites had a higher density of decreaser perennial species when reassessed following a period of average rainfall (i.e. in 2001). Half of the sites assessed the next year (2002) following poorer seasonal conditions similarly had an improved density of decreaser perennial species.

Darling Riverine Plains bioregion

RAP sites have been assessed annually. Based on the historical rainfall record for Brewarrina (approximately central to Northern Floodplain sites used for reporting), the period 1992–94 was ranked as 'average', 1995 to 2000 ranked 'above average' and 2001–2002 scored 'below average'. The frequency of the dominant perennial grass *Astrebla lappacea* and the frequency of combined 2P grasses were averaged at each site for the period 1992–94 and 1995–2001. The change in (averaged) frequency at each site between 1992–94 and 1995–2001 represents change through a period of above-average rainfall. Similarly, change for the period 1995–2001 to the discrete year of 2002 represents change for a period of below-average rainfall (Table 12).

Table 12 Percentage of RAP Northern Floodplain sites where the frequency of the dominant perennial grass *Astrebla lappacea* and combined 2P grasses declined, remained stable or improved under prevailing seasonal conditions prior to annual reassessments

Seasonal conditions	Species	# Sites	Decline	No change [1]	Improvement
Above average	*A. lappacea*	24	21	58	21
	2P grasses	41	17	68	15
Average	*A. lappacea*	0	na	na	na
	2P grasses	0	na	na	na
Below average	*A. lappacea*	24	17	54	29
	2P grasses	41	15	78	7

[1] A tolerance of ±10% was used to categorise 'no change'.

Desert Uplands bioregion

Most QGraze sites have been assessed several times, but at irregular intervals, since 1992. Sites were initially established by staff of the former Queensland Department of Primary Industries (DPI) to expand rangeland monitoring in the Desert Uplands but regular DPI monitoring activity largely ceased in 1999. QNRM has continued recent monitoring activity with their GrassCheck sites – which includes some QGraze sites, data from which are available for ACRIS reporting. QNRM monitoring is done as part of the Desert Uplands Build-Up and Development Strategy, with sites on participating stations monitored for three years. Thus, across the Desert Uplands bioregion, some sites 'move' into the monitoring program, are assessed for three years and then monitoring of these sites may be discontinued.

Because of this rolling program, it was difficult to align individual recording dates and intervening periods with seasonal conditions (Table 13). The QGraze data also show an apparent lag between rainfall amount and its effect on recorded frequency of 3P grasses. For example, 2002 was a very dry year but reduced 3P grass frequency was expressed in the 2003 and 2004 data rather than 2002. Given these difficulties, Bastin (2005) assigned seasonal condition rankings on the basis that:

- 1992 to 1995 were years of below-average rainfall.
- Rainfall amount increased on average across the bioregion between 1996 and 1998 – assigned years of average rainfall. Recorded change between 1992–95 and 1996–98 is summarised in the 'average' row of Table 13.
- 1999 and, particularly, 2000 were wetter years (above-average seasons). Because higher frequencies of 3P grasses persisted into 2001, this year was also assigned as 'above average' (Table 13), although the rainfall data indicate drier conditions.

  There are two groups of sites included in each row of the table:
  – sites assessed between 1992 and 1995 and then not assessed again until sometime

in the period 1999–2001 (6 sites)
– sites assessed in the period 1996–98 and again between 1999 and 2001 (21 sites)

- 2002 was a very dry year. This and following years (2003, 2004) were labelled 'below average'. Only three QGraze sites were assessed by QNRM during this period, with most of their monitoring activity concentrating on GrassCheck sites (data not publicly available but general trends reported by Ken Dixon in Bastin 2005).

- Degree of change at each site in Table 13 was assigned as:
– 'decline', where frequency of 3P grasses decreased by >10% between successive sequences of seasonal conditions
– 'no change', where frequency of 3P grasses changed by <10% between successive sequences of seasonal conditions – considered as probable sampling variation between assessments (and also possibly measurement error)
– 'improvement', where frequency of 3P grasses increased by >10% between successive sequences of seasonal conditions

Table 13 Percentage of QGraze monitoring sites where the frequency of 3P grasses declined, remained stable or improved under prevailing seasonal conditions prior to, and at the time of, various assessments

Seasonal conditions	Period	# Sites	Decline	No change [1]	Improvement
Above average	1999–2001	27	11	30	59
Average	1992–1995 to 1996–98	12	17	58	25
Below average	1992–95 to 2002–04	3	33	67	0

[1] A tolerance of ±10% was used to categorise 'no change'.

Victoria River District

The Victoria River District has experienced mainly above-average wet seasons throughout the reporting period. Based on assessed range condition, most sites have remained stable and a small percentage has improved (Table 14). While we could reasonably expect greater improvement under such favourable seasons, actual improvement is restricted because many sites were rated in the highest category at their first assessment (see footnote to table).

Table 14 Percentage of Tier 1 monitoring sites declining, remaining stable or improving in condition under different seasonal conditions between their first and last assessments

Seasonal conditions	Land type	# Sites	Decline	No change [1]	Improvement
Above average	All	254		94	6
	Alluvial Plain	35		71	29
	Basalt Plain	106		94	6
	Relic Clay Plain	61	3	97	
Average	All				
	Alluvial Plain				
	Basalt Plain				
	Relic Clay Plain				
Below average	All				
	Alluvial Plain				
	Basalt Plain				
	Relic Clay Plain				

[1] This may be an excessively harsh assessment. Sixty-five percent of all sites were in good condition at the initial assessment, and on the three-step condition rating used (i.e. good, fair and poor), could make no further improvement. Similarly, 46% of Alluvial Plain sites, 55% of Basalt Plain sites and 95% of Relic Clay Plain sites were in good condition at their first assessment.

Ability to report change in critical stock forage productivity

1. There is a large variation in methods, objectivity and precision of data used to answer the question of critical stock forage productivity. All regions have used repeat assessments at fixed ground sites. Methods vary from qualitative assessment of condition at Tier 1 sites (Victoria River District) to precise measurements of plant demography at WARMS shrubland sites (Gascoyne–Murchison).

2. Repeat measurements and observations at fixed sites are valuable for reporting change at these defined locations; however, the restricted spatial sampling associated with ground-based monitoring means that the data, and interpreted results, are probably more indicative of change across the whole region, rather than representative.

   Ground-based sites can provide a representative sample and be indicative of the whole landscape provided that:
   (1) all parts of the landscape are sampled, and
   (2) the sample adequately indicates what is happening on the rest of the landscape, given the representative stratification.

Most monitoring programs use explicit stratification procedures to place sites in preferred landscape (or vegetation) types and at specified distances from water, and thus cannot report change in other parts of the landscape. In fairness, though, most (and probably all) monitoring programs emphasise pastoral production, so site placement, and hence monitoring activity, is focussed on landscapes important for long-term pastoral productivity.

3. Seasonal conditions, expressed mainly through rainfall, are the fundamental driver of vegetation change. This makes it very difficult to quantitatively separate the effects of grazing management (or mismanagement) as a driver of change, even using the matrix structure above. Some monitoring systems better dampen the effects of shorter-term rainfall variability in reporting change, both by design and through the nature of the vegetation being sampled. WARMS shrubland monitoring specifically focusses on the demography of perennial shrubs, species that are reasonably long-lived and that do not appreciably respond to shorter-term rainfall variability. Thus WARMS shrubland sites have a greater ability than some other monitoring systems to report change in critical stock forage productivity related to grazing management by concentrating on species known to decrease with grazing. Shrub density data collected within fixed (Jessup) transects in the Gawler bioregion have some similarities with WARMS data and were amenable to similar analysis to better differentiate seasonal from grazing effects. Frequency data (QGraze, RAP and WARMS grassland sites) are more sensitive to shorter-term seasonal variation. For these three monitoring systems, we restricted analysis to the data of perennial and palatable grasses (for WARMS, species known to decrease with grazing) to try and dampen the effects of shorter term seasonal variability. Even so, the QGraze frequency data are still affected by the time of monitoring in relation to rainfall and fire effects (Ken Dixon pers. comm.).

4. The QGraze data provided additional challenges, as many sites had variable monitoring intervals and frequencies. QGraze monitoring is no longer conducted systematically across regions as is the case in other States and the NT. Queensland Department of Natural Resources, Mines and Energy (QNRM) continue to monitor in parts of the Desert Uplands at the single-property scale, rather than systematically across the whole region. Fortunately, they were able to extend the monitoring record for some QGraze sites, but data from their allied GrassCheck monitoring program are confidential at the site level and could only be reported as regional averages across sites.

5. The VRD Tier 1 data were less quantitative (i.e. change in assessed condition ratings) than data from other regions. However, these data are still valid for Question 1 because there is a distinct focus on production in ranking site condition. Specific criteria are used to guide the assignment of condition ranks and pastoral officers undergo training to minimise operator variability. Still, confidence in the ability of this monitoring system to report change would be strengthened with knowledge of the level of repeatability among observers and of any drift in their assessments over time.

6. Fire, and mainly wildfire, could be a factor in reported change (in Tier 1 assessed condition) for the VRD. Fire-scar mapping from satellite imagery showed a marked increase in the percentage area burnt annually from 1994 to 2003 compared to a more subdued fire pattern in the 1980s (Karfs and Trueman 2005). Based on NOAA AVHRR imagery, the average area burnt each year from 1995 to 2003 was 29,000

km^2. Fire histories are not available for Tier 1 sites but it is likely that some (perhaps many) of the 284 sites were burnt at least once during the reporting period. Apart from some QGraze sites in the Desert Uplands (number unknown), contemporary fire was not a factor in reported vegetation change for other regions. Karfs and Trueman (2005) report that fire effects on vegetation were often not apparent following wet-season rainfall (e.g. their Landsat-derived fire history mosaic was often used to infer that Tier 2 ground sites had been burnt – data used to answer following questions). Where fire was implicated with vegetation change, it was more in relation to cover (Question 5) and vegetation-derived indices of landscape function (Question 3) than change in pasture composition (Question 1). My assessment is that the increased incidence of fire in the VRD in the later stages of the reporting period probably meant that some (perhaps many) Tier 1 sites were burnt. However, the extended period of wetter years probably meant that any fire had a minimal effect on small changes in condition (and inferred critical stock forage productivity) reported from Tier 1 monitoring sites.

7. Some of the preceding comments may be relevant to any assessment of individual monitoring systems for their efficacy in reporting change in critical stock forage productivity (to the extent that this is a legitimate question to ask of each monitoring program). Such questioning might include: ‘Are they providing the answers required?’ ‘Is modification necessary?’

SECTION 5 – CHANGE IN NATIVE PLANT (AND ANIMAL) SPECIES (QUESTION 2)

Summary

- This question was framed to extend our reporting ability upon a small component of biodiversity. The question was deliberately restricted to change in plant species, recognising that monitoring data to report change in a broader suite of biodiversity are, as yet, restricted in the rangelands.

- Data describing density, frequency, richness and diversity (number) of species collected at pastoral monitoring sites are the main information sources for answering this question.

- Where suitable additional data were available, we expanded the question to report change in native animal species. The best available dataset at this stage is a repeat biological survey (from the 1970s) in the Emerald district (adjacent to the south-eastern edge of Desert Uplands, reported by McCosker et al. in press).

- Comprehensive flora and fauna surveys have been conducted in some regions, mainly at the bioregion level. At this stage, these are once-off datasets. If (and hopefully as) these surveys are repeated in the future, our capacity to report change will increase considerably.

- The main changes in native plant species from pastoral monitoring programs were:

  - A general increase in shrub density at WARMS shrubland sites in the Gascoyne–Murchison region. Recruitment was recorded for most species (137 of 139) across the region.

  - Perennial shrub species richness remained the same or increased on 80% of WARMS shrubland sites. When only decreaser species were considered, the corresponding figure was 83%, suggesting that the changes in richness of decreasers were similar to other species.

  - At (40) WARMS grassland monitoring sites, trends in the frequency of all perennials, and perennial grasses, were less consistent. About 15% of sites had declining frequency of both functional groups throughout the reporting period (based on two reassessments). Seventy percent of sites had a decreased frequency of both groups between the second and third assessments, the third assessment having followed a period of lower rainfall.

  - Species richness on grassland sites remained the same or increased on 63% of sites over the first assessment interval and on 55% of sites over the second reassessment interval. Only 7.5% of sites showed a decline in species richness over both reassessment intervals.

  - The density of chenopods and other perennial species increased at the majority of 179 pastoral monitoring sites in the Gawler bioregion. Separated into components:

– the density of long-lived chenopods remained stable
– there was a reduction in the density of perennial grasses in the northern area of the bioregion following below-average seasonal conditions.

- There was overall stability in pasture species diversity in the Darling Riverine Plains based on the annual number of species recorded at 45 Northern Floodplain sites. There was greater diversity in those years with higher rainfall and higher pasture biomass (1995 and 2000). On average, there was greater than 20 species per site, peaking at 40-plus species in the wetter year of 2000. On average, less than five exotic pasture species were recorded at sites and there was little change in this number through the reporting period.

- At 14 QGraze sites in the Desert Uplands assessed at least twice to 2001, there was a high frequency of native pasture species throughout and a small increase in their presence over time. There was a generally low frequency of exotic herbage species and, again, a small increase over time.

- The qualitative nature of condition assessments at Tier 1 sites in the VRD did not allow reporting of change in native plant species. However, other sources of information are used below to report likely changes.

- Probable changes in native plant species derived from other information sources:

  - Baseline surveys have been conducted in the Gawler bioregion to establish the presence and absence of species. Seven plant and 14 fauna species are listed as nationally threatened. Four ecological communities are considered threatened at the State level. Intended re-surveys should assist in identifying any change in these at-risk species and communities.

  - The status of flora and fauna species, and communities, has similarly been reported in the Gascoyne–Murchison. There are 18 wetlands of national significance. The region has one threatened ecological community and 112 ecosystems are considered at risk. Of the ecosystems, 2% are considered to be improving (at less risk) and 41% declining (risk increasing). At the species level, the conservation status of the mallee fowl is considered to have improved.

  - Analysis of satellite imagery shows that there has been a large expansion of cereal cropping into the rangelands component of the Darling Riverine Plains (115% increase between 1992 and 2003 – from 84,845 ha to 183,461 ha). As part of this expansion, extensive clearing of woodland tree cover has occurred, with coolibah, black box and myall woodlands now considered to be endangered communities within this bioregion.

  - Similarly, extensive tree clearing has occurred in parts of the Desert Uplands (reported with SLATS data in Section 8, see Table 33). The repeat of a 1973–76 biological survey in 2001–02 in the Emerald area (adjacent to the southern Desert Uplands) (McCosker et al. in press) showed that:
    – tree clearing increased from 13% to 59% of the area of Emerald Shire over the period
    – there was a major reduction in the number of waterbirds (attributable to drier seasons)

– there were significant increases for typically grassland birds and significant decreases for typically woodland birds
– there were declines for some native mammal species and three native frog species, and
– there was a major increase in the cane toad.

- Though not part of McCosker and colleagues' survey, anecdotal evidence would show a major increase in parthenium weed in southern parts of the Desert Uplands region with clay soils.

- Episodic wildfire, generally following wetter years, is considered a threat to some native plant species in the Gawler bioregion. Extensive areas of mulga were killed by wildfire in the mid 1970s, with subsequent regeneration hindered by rabbits.

- Annual surveys of kangaroo densities in parts of the southern rangelands should allow trends to be reported. In western NSW, the density of red kangaroos appears to have generally increased (peak density of ~16 / km^2 on two survey blocks in 2003). Kangaroo densities then declined sharply in 2004. However, changes in survey methodology in 1998 and 2003 make direct comparisons of survey numbers problematic.

  The density of grey kangaroos decreased between 1993 and 1995 and then progressively increased to 2001 on two survey blocks (peak density of ~42 / km^2 on one block) before declining sharply (to ~9 / km^2) in 2003. As for red kangaroos, changes in survey methodology make direct comparisons invalid.

- Air photo interpretation, exclosures and historic photos show woody thickening in parts of the Victoria River District. Examples include:

  1. From analysis of air photography across the VRD from the 1950s to 1990s (Fensham and Fairfax 2003)
  – a 2% regional increase in average cover (from 11.5% to 13.5%)
  – regional average shrub cover increased from 1.3% to 2.0%
  – thickening was more apparent on more open country (e.g. downs and alluvial)
  – thickening was more rapid in the latter part of the reporting period.

  2. Historical pairs of landscape photos and archival material across the VRD illustrate distinct increases in woody vegetation, particularly in alluvial and sandstone hill land types (Lewis 2002).

- In summary, plant species data collected at pastoral monitoring sites in most regions show changes in density, richness and diversity of native species through the reporting period. For shorter-lived species, these changes appear to be mainly driven by seasonal variation. Where data are available, there appears to have been no (or negligible) increase in the number of exotic pasture species.

  Other data sources, mainly survey but also research results, provide examples of how Question 2 might be answered with a broader information base in the future.

Data used to answer Question 2

Data used in each reporting region to answer Question 2 are summarised in Table 15. Although the focus question was confined to native plant species, we have included information on fauna where available to demonstrate that there is now some capacity to address change in biodiversity more broadly.

Table 15 Datasets used to answer Question 2

Region	Dataset	Derived indices
Gascoyne–Murchison	WARMS • Demography of native perennial shrubs (700 shrubland sites) • Frequency of perennial grasses (40 grassland sites) Other sources – e.g. status of wetlands of national significance, conservation status of plants and vertebrate fauna (see Watson et al. 2005)	• Occurrence ratio (OR) – number of sites each species found on at first (t_1) and last (t_2) assessments • Recruitment rate – measure of whether shrub population is replacing itself. Calculated as: *no recruits at* t_2 */ population size at* t_1 • Population growth rate (PGR). Calculated as: *population size at* t_2 */ population size at* t_1 • Species richness. Calculated as: *no species on site at* t_2 */ no species on site at* t_1
Gawler	• Density of chenopod shrubs and other perennials at 179 Pastoral Monitoring Program sites • Status of plants and animals from biological surveys • Incidence of wildfire as a threatening process	
Darling Riverine Plains	• Satellite remote sensing to monitor area of rangelands under cultivation for cereal cropping • Diversity of shrub (mainly chenopod) and herbage species at 45 Northern Floodplain RAP sites • Estimated kangaroo populations from aerial surveys	
Desert Uplands	• Frequency of native and exotic plant species at QGraze sites • Repeat fauna and flora surveys conducted by EPA • Extent of land clearing from SLATS and AGO databases	
Victoria River District	• Plot- to regional-scale vegetation change studies • Extent of land cleared • Use of exotic pasture species	

Results of regional monitoring activity

Change in native plant species detected by regional monitoring activity, and from other data sources where available, is summarised in Table 16. Change in native fauna is also reported where suitable data are available.

Table 16 Change in native plant (and animal) species

Region	Measured or observed change
Gascoyne–Murchison	From monitoring longer-lived perennial species at 700 shrubland sites: • Average occurrence ratio = 1.09 (i.e. more sites with species at t_2 compared with t_1). 82% of species had an occurrence ratio of >1 • Increase in shrub population at sites (average population growth rate = 1.31). 70% of sites had PGR >1.0, 87% of species had PGR >1.0 • Recruitment was commonplace – occurring at 99.4% of sites and for 98.6% (137 of 139) species • Species richness remained the same or increased on 80% of sites. The corresponding figure when only decreasers were considered was 80% On 40 grassland sites sampled three times between 1994 and 2002: • Seven sites had a decreased frequency of all perennials between the first and second, and second and third samplings. A further 28 sites had a decreased frequency between the second and third sampling. Note that generally drier seasonal conditions prevailed between the second and third assessments • Considering perennial grasses, six sites showed decreased frequency at both samplings, and 27 sites had decreased frequency between their second and third sampling. As above, generally drier seasonal conditions prevailed between the second and third assessments Status from other data sources (limited information on change): • There are 18 wetlands of national significance and 18 of sub-regional significance in the Gascoyne–Murchison • One threatened ecological community and 112 ecosystems are considered at risk. Of the ecosystems, 2% are considered to be improving (at less risk) and 41% declining (risk increasing) • Conservation status of one vertebrate species (mallee fowl) has improved • Three (of 225) bird species are considered threatened. Populations of 17% of species are considered to be declining and 23% to be increasing
Gawler	Limited suitable data available. From reassessment of 179 sites: • Density of perennial species increased at the majority of sites. Separated into components: – the density of long-lived chenopods remained stable – there was a reduction in the density of perennial grasses in the northern area of the bioregion following below-average seasonal conditions

Region	Measured or observed change
	Status information from other sources: • Baseline surveys conducted to establish presence and absence of species. Intended that surveys be repeated to determine change • At least nine plant, one bird and one reptile taxa are endemic to the bioregion, seven plant and 14 fauna species are nationally threatened, and four ecological communities are threatened at the State level • Episodic wildfire is a threatening process. The most significant recent fire period was 1974–75. Fire caused substantial tree death and there has been limited regeneration because of grazing, particularly by rabbits
Darling Riverine Plains	Expansion of cropping in the rangelands portion of the Northern Floodplains: • Satellite imagery used in the Resource Assessment and Monitoring System (RAMS) shows the area cropped increased by 115% between 1992 and 2003 (84,845 ha in 1992, 183,461 ha in 2003). Note that this is the area cropped, not necessarily cleared – more open areas are often cropped by working around clumps of trees. However, extensive clearing of woodland tree cover has occurred – coolibah, black box and myall woodlands are considered endangered communities • Cleared land not under crop generally grows annual grasses and weeds before slowly reverting to native grasses. Clearing and cropping has seen the spread of exotic weeds, e.g. rape (*Brassica rapa*) Shrub (mainly chenopod) and herbage species diversity at 45 Northern Floodplain sites: • Overall stability in pasture species diversity. Greater diversity in years with higher rainfall and higher pasture biomass (1995 and 2000). On average, >20 species per site, peaking at 40+ species in 2000 • On average, <5 exotic pasture species per site – and stable over reporting period • Diversity of chenopod (and other minor bush) species fairly stable – at ~2.5 species per site Survey of kangaroo populations: • Density of red kangaroos appears to have increased through the reporting period to about the year 2000 (peak density of ~16 / km^2 on two survey blocks in 2003). Kangaroo densities then declined sharply in 2004. Unfortunately, changes in survey methodology in 1998 and 2003 make direct comparisons of survey numbers problematic • Density of grey kangaroos decreased between 1993 and 1995 and then progressively increased to 2001 on two survey blocks (peak density of ~42 / km^2 on one block) before declining sharply (to ~9 / km^2) in 2003. As for red kangaroos, changes in survey methodology make direct comparisons invalid Change in broad-scale flooding regime: • There is preliminary evidence of reduced broad-scale flooding across the Northern Floodplains (Grant 2005) due to increased upstream extraction

Region	Measured or observed change
	of water for irrigation. This may adversely impact floodplain vegetation over large areas
Desert Uplands	Frequency of native and exotic herbage species at 14 QGraze sites assessed at least twice (to 2001): • High frequency of native species and small increase over time • Generally low frequency of exotic species and small increase over time Extensive tree clearing compared with other regions (see Section 8). Tree clearing is considered a threatening process for biodiversity: • Tree clearing extensive in the southern sector, but significant regrowth and thickening in the northern sector Repeat of a 1973–76 biological survey in 2001–02 in the Emerald area (adjacent to the southern Desert Uplands). Tree clearing increased from 13% to 59% of the area of Emerald Shire over this period. Results: • A major reduction in the number of waterbirds (attributable to drier seasons) • Significant increases for typically grassland birds and significant decreases for typically woodland birds (presumably related to clearing) • Decline for some native mammal species and 3 native frog species • Major increase in the cane toad Preliminary results from other faunal monitoring programs: • Wambiana grazing trial (northern Desert Uplands) – extreme grazing pressure appears to be adversely affecting vertebrate fauna • Woody thickening may not be that detrimental for biodiversity Extent of land clearing from remote sensing (SLATS database): • Substantial decline in wooded area across the bioregion since 1991 (detail presented in answer to Question 5) • Clearing in the 1999–2001 period accounted for 10.7% of all clearing in Queensland
Victoria River District	Vegetation change studies at various spatial scales: • Extensive analysis of air photography across the VRD from the 1950s to 1990s (Fensham and Fairfax 2003) – 2% regional increase in average cover (from 11.5% to 13.5%) – regional average shrub cover increased from 1.3% to 2.0% – thickening more apparent on more open country (e.g. downs and alluvial) – thickening more rapid in latter part of reporting period • Similar use of historical air photos has shown that an alluvial floodplain on Bradshaw Station has changed from being virtually treeless in 1948 to forest in the 1990s (Sharp and Whittaker 2003) • Substantial increase in vegetation cover (including establishment of perennial grasses and woody thickening) on small areas of calcareous red-soil plains at Victoria River Research Station (Bastin et al. 2003). Native tree species also thickened on adjacent areas of black soil

Region	Measured or observed change
	• Historical pairs of landscape photos and archival material across the VRD illustrate distinct increases in woody vegetation, particularly in alluvial and sandstone hill land types (Lewis 2002) Other types of information: • Negligible tree clearing (see Section 8) • Negligible introductions of exotic pasture species apart from rehabilitation projects, most notably the Ord Regeneration Project in the 1970s (Karfs and Trueman 2005)

Rainfall as a contributor to detected change

Where suitable data were available (WARMS sites, Gascoyne–Murchison; pastoral monitoring sites, Gawler, and RAP sites, Darling Riverine Plains), we used the seasonal quality by degree-of-change matrix of Section 2 to partition the influence of rainfall effects on change in native plant species.

Gascoyne–Murchison

WARMS shrubland sites

Table 17 Percentage of WARMS shrubland sites where the population growth rate (i.e. density) of shrubs declined, remained stable or improved under prevailing seasonal conditions in the five years prior to reassessment

Seasonal conditions	# Sites	Decline	No change [1]	Improvement
Above average	428	12	12	76
Average	166	28	27	45
Below average	106	57	21	22

[1] Population growth rate between 0.95 and 1.05 (i.e. shrub density at reassessment is within 95% and 105% of previous measurement). Accordingly, 'decline' has PGR <0.95 (density <95%) and 'improvement' has PGR >1.05 (density >105%).

Note that this summary is similar to that presented in Table 9 but includes all shrubs (cf decreaser shrubs in Table 9). About one-eighth of sites had a declining density of perennial shrubs when prior seasonal conditions indicated that an increase would be expected. More positively, almost one-quarter of sites had an increasing density following adverse seasonal conditions. As for Question 1, this suggests that grazing management was promoting shrub recruitment and survival.

WARMS grassland sites

Table 18 Percentage of WARMS grassland sites where the frequency of (i) all perennial species and (ii) perennial grasses declined, remained stable or improved under prevailing seasonal conditions in the three years prior to reassessment

Seasonal conditions	# Sites	Decline	No change [1]	Improvement
Above average				
All perennials	44	23	68	9
Perennial grasses	44	25	66	9
Average				
All perennials	–			
Perennial grasses	–			
Below average				
All perennials	–			
Perennial grasses	–			

[1] A tolerance of ±10% change in frequency was used to categorise 'no change'.

These data suggest a less encouraging trend for grassland sites compared with shrubland sites. One quarter of sites showed a decline in frequency of all perennials, and perennial grasses, following seasonal conditions that indicated frequencies should have been maintained or improved. In interpreting these data, it should be noted that perennial grasses are not as well buffered against shorter-term seasonal variability as shrubs and it may be that drier periods were experienced at some stage during the period of generally above-average rainfall. Additionally, the more palatable grasses on grassland sites are perhaps more likely to be appreciably grazed at some stage during better seasons than palatable shrubs.

Gawler bioregion

Changes in the density of perennial species at the site level are shown in Table 19.

Table 19 Percentage of SA pastoral monitoring sites where the density of perennial species declined, remained stable or improved under prevailing seasonal conditions in the five years prior to reassessment

Seasonal conditions	# Sites	Decline	No change [1]	Improvement
Above average	n/a			
Average (2001)	104	12	22	66
Below average (2002)	75	32	16	52

[1] A tolerance of ±10% was used to categorise 'no change'.

These results show that the density of perennial species increased at more than half of the sites through the reporting period, an encouraging result, as perennials contribute to more persistent vegetation. This would seem to benefit protection of the soil surface against erosion and improve landscape function (next section) and habitat for various fauna (provided the increase in density is not excessive, leading to non-natural thickening of perennial vegetation).

Darling Riverine Plains bioregion

As for Question 1, the period 1992–94 was ranked as 'average', 1995 to 2000, 'above average' and 2001–02, 'below average'. The number of pasture species present at each site was averaged for the period 1992–94 and 1995–2001. Change in the average species diversity at each site between 1992–94 and 1995–2001 represents change through a period of above-average rainfall. Similarly, change for the period 1995–2001 to the discrete year of 2002 represents change in a period of below-average rainfall (Table 20).

Table 20 Percentage of RAP Northern Floodplain sites where pasture species diversity declined, remained stable or improved under prevailing seasonal conditions prior to annual reassessments

Seasonal conditions	# Sites	Decline	No change [1]	Improvement
Above average	45	2	84	13
Average	0	na	na	na
Below average	45	51	47	2

1 A tolerance of ±5 species was used to categorise 'no change'.

The data indicate that when seasonal conditions declined from average to below average, more than 50% of sites experienced a decline in pasture-species diversity. Conversely, when seasonal conditions improved from average to above average, only 13% of sites had increased species diversity. Encouragingly, though, very few sites (2%) had reduced diversity during this period.

Ability to report change in native plant (and animal) species

1. There is currently a limited capacity to report change in native plant species within some reporting regions and, because of this limitation, to report change more broadly across regions. The best-equipped monitoring program to report change in native perennial species would appear to be WARMS in the Gascoyne–Murchison.

2. Pastoral monitoring programs were generally not designed to collect the specific data required to answer this question; therefore, this limited capacity is not surprising.

3. Most regions have a completed biological survey. It should be possible to report change as these surveys are repeated in the future, e.g. as demonstrated by a recently completed repeat survey adjacent to the Desert Uplands (McCosker et al. in press).

4. Although often limited in spatial extent, there is considerable value in results from long-term study sites (ranging from research plots to relocation of historical photo points). Photo pairs can powerfully indicate landscape change, often over longer time periods (e.g. Lewis 2002, McCullough et al. 2004). Longer-term research sites can provide important information about the change in plant and animal species and, in some cases, an improved understanding of the processes producing change. We need to be careful, though, in applying research results to larger areas, ensuring first that the research site is sufficiently representative of the area over which we want to extrapolate. Where representativeness is adequate, research results may provide an insight to, and improved understanding of, change across larger areas. At a larger scale, historic air photography has considerable value in quantifying change in woody cover (also appropriate to Question 5, Section 8).

5. Predation by cats and foxes is listed in regional reports as a common threat to the success of some fauna species (e.g. see Watson et al. 2005). Habitat disturbance caused by grazing is also listed for some regions.

6. There are regional differences in the occurrence and frequency of impacts that potentially disturb (threaten) native vegetation (and animal) species. These include:

   - Greater fire frequency in northern Australia, particularly the VRD and less so in the Desert Uplands, compared with the infrequent (episodic) occurrence of wildfire in the Gawler bioregion. Of probable greater significance (and impact) is an appreciably altered fire regime – e.g. fire suppression contributing to woody thickening. Infrequent fire can also have a long-term impact if post-fire conditions are not conducive to the re-establishment of fire-sensitive species – such as the suppression of mulga by rabbit (and sheep) browsing in the Gawler bioregion following fires in the mid 1970s (see DellaTorre 2005).

   - Extensive tree clearing in the Desert Uplands (see Section 8) and its apparent impact on native fauna (particularly some bird species [McCosker et al. in press]).

   - Change in land use from grazing to cropping on the Northern Floodplains of the Darling Riverine Plains, but little change in forest cover (Section 8) – with a probable (unquantified at this stage) impact on native vegetation and animal species.

7. It should be possible to identify the population trends of various kangaroo species from the annual surveys conducted in some States – but trend detection is hampered by changes in methodology (e.g. western NSW).

SECTION 6 – CHANGE IN LANDSCAPE FUNCTION (QUESTION 3)

Summary

- For monitoring and reporting purposes, landscape function is interpreted as the capacity of landscapes to capture and retain rainwater and nutrients as vital resources for plant growth. Formal assessment of landscape function has not traditionally been part of rangeland monitoring systems (except in WA since 1993). This question is designed to test our ability to report change in landscape function where suitable data exist and, in their absence, to test our resourcefulness in adapting surrogate data into suitable alternative indices.

- Data were available at a range of scales, but generally at the scale of fixed (ground) monitoring sites. Remote-sensed levels of cover provided additional information in the Victoria River District. For the Darling Riverine Plains, the concept of landscape function was extended beyond the local capture of rainwater to an altered flooding regime that now appears to be occurring across much of the bioregion.

- At monitoring sites, the most robust data came from formal landscape function assessment (LFA) taking place in the Gascoyne–Murchison and VRD. These data were reported at two levels:

  - Arrangement of perennial vegetation patches and other obstructions that facilitate resource capture. This was reported with a Resource Capture Index (RCI, Watson et al. 2005). RCI is calculated as the total length of resource capturing patches divided by the total length of transect measured. Higher values should mean an increased ability to capture and use water and nutrients for plant growth.

  - Soil surface condition indices, developed by Tongway (1994) and Tongway and Hindley (1995). Of these indices (stability, infiltration and nutrient cycling), Holm (2001) suggests that the Stability Index is the most damped against short-term seasonal variation.

- From formal LFA in the Gascoyne–Murchison (WARMS sites) and VRD (Tier 2 sites):

  - RCI remained stable or increased at 31% of 392 shrubland sites and 36% of 45 grassland sites in the Gascoyne–Murchison. This suggests that approximately two-thirds of all sites became more leaky, a result that is counter to the generally improving trend reported for Question 1 (critical stock forage productivity). RCI remained stable or increased at 66% of 32 sites in the VRD. Wildfires prior to the 2003 reassessment may have contributed to some of the decrease; although, several sites burnt at some stage in the three years prior to 2003 had increased RCI.

  - The Stability Index was stable or increased on 51% of 398 shrubland sites and 62% of 47 grassland sites in the Gascoyne–Murchison. Comparative results are not available for the VRD.

- Monitoring data that infer landscape function have been used in other regions in the absence of formal LFA.

  - In the Gawler bioregion, the Richards-Green Functionality Index (RGFI) (described in DellaTorre 2005) indicates that landscape function improved in the period 1990 to 2002 (data averaged across 179 sites, index improved from 2.11 to 1.97 – where 1 = 'highly functional' and 3 = 'poorly functioning').

  - Given the heavy-textured and relatively stable nature of soils in the Darling Riverine Plains (particularly the Northern Floodplain range type), the suitability of the soil surface for the establishment and growth of ground-layer vegetation is considered a suitable surrogate for landscape function assessment (Grant 2005). The extent of bare ground, eroded or sealed surfaces at monitoring sites decreased from the start of the reporting period (1992) to 2000 and then increased with drought conditions in 2001 and 2002. These changes are thought to be mainly seasonal. The frequency of perennial ground cover species remained relatively stable throughout (in the range of 12–22%). This suggests that any changes in landscape function are mainly seasonal.

  - An adapted form of the RGFI using the frequency of perennial herbage species and ground cover in the Desert Uplands showed an apparent improvement in landscape function between 1992 and 2001. This attempt to improvise LFA data is similar to that undertaken in the Darling Riverine Plains and, as with that region, the changes are considered to be mainly due to season.

  - From the broader coverage of 254 Tier 1 sites spread across the VRD, the small increase (8%) in occurrence of perennial grasses (as distinct from any substantial decrease) is inferred as stability in landscape function (Karfs and Trueman 2005).

- At larger scales of assessment:

  - The mean cover of Landsat pixels representing 21 Basalt Plains sites in the VRD was consistently higher and more stable between 1993 and 2003 compared with the previous decade. Extrapolating these results to the entire land type suggests that landscape function has improved on the Basalt Plains between 1983–92 and 1993–2003.

  - There now appears to be a substantially altered flooding regime in the NSW component of the Darling Riverine Plains bioregion as a result of upstream diversion of water for irrigation. For example:
    – The relative share of flood events with peaks around 60,000 ML/day at St George (Qld) that reach NSW has declined from an average of more than 50% prior to 1997 to only 20% in the 2004 event.
    – Analysis of satellite images shows that flooding in NSW was 88% (140,000 ha) less in 2004 compared with inundation produced by a similar event in 1988.
    This altered regime certainly means less floodwater available across large areas to grow ground-layer vegetation. It may also have implications for the longer-term redistribution of nutrients at the bioregion scale.

- There is a need for further testing of alternative approaches to reporting change in landscape function where formal LFA data are not available.

- It is desirable to link the different scales at which landscape function can potentially be reported – from point (i.e. site) to landscape. This linkage should include an improved understanding of landscape processes operating at the various scales.

Assessing landscape function

As outlined in Section 1, landscape function describes the capacity of landscapes to capture and retain rainwater and nutrients as resources for plant growth. There are established methods for LFA using ground data (Ludwig et al. 1997) and these have been implemented in the WARMS (Gascoyne–Murchison) and Tier 2 (VRD) monitoring programs. Methods are being developed for expanding the scale of these assessments with high to very high resolution remote sensing data (Ludwig et al. 2002 – aerial videography, Quickbird/Ikonos satellite imagery; Ludwig et al. in press – Landsat TM and similar satellite imagery) but these methods are not yet included in agency monitoring programs. The Richards-Green Functionality Index (Kraatz 2002) has been proposed as an indicator of landscape function where formal LFA is not conducted.

Data used to answer Question 3

Data used in each reporting region to answer this question are summarised in Table 21.

Table 21 Datasets used to answer Question 3

Region	Dataset	Derived indices
Gascoyne–Murchison	WARMS: • LFA assessments at 398 shrubland sites and 47 grassland sites	
Gawler	• Change in RGFI values at 179 sites	
Darling Riverine Plains	In the absence of formal LFA data, and in the context of the flat terrain, clay soils and low erosion hazard of the bioregion, the suitability of the soil surface as an environment for plant establishment and growth may be an adequate surrogate: • From 45 Northern Floodplains RAP sites, trends in extent of bare ground, sealing and erosion • Trends in frequency of perennial herbage species Change in flooding regime at bioregion scale: • Data on recent river flows and floods that indicate changes in the delivery of water and possibly nutrients to broad floodplain areas	
Desert Uplands	• Adapted form of RGFI (based on frequency of perennial herbage species and ground cover) at 14 QGraze sites that were assessed at least twice (to 2001)	
Victoria River District	Tier 2 sites: • LFA assessments at 32 sites (additional results for 21 Basalt Plains sites) • Time trace of 21 Basalt Plains sites derived from Landsat multi-temporal data Tier 1 sites: • Change in number (proportion) of sites where perennial grasses recorded	

Results of regional monitoring activity

Change in landscape function detected by regional monitoring activity is summarised in Table 22.

Table 22 Change in landscape function

Region	Measured or observed change
Gascoyne–Murchison	WARMS – RCI (total length of resource capturing patches divided by total length of transect measured). Higher values should mean an increased ability to capture and use rainwater and nutrients for plant growth • RCI remained the same or increased on 123 of 392 shrubland sites (i.e. 31%). RCI decreased on the other 269 sites • RCI remained the same or increased on 16 of 45 grassland sites (i.e. 36%). RCI decreased on the other 29 sites WARMS – Stability Index (derived from soil surface indicators and considered better damped against seasonal variation than compatriot nutrient cycling and infiltration indices). Higher values should mean increased soil surface stability • The Stability Index remained the same or increased on 201 of 398 shrubland sites (i.e. 51%). (The Infiltration Index [indicator of ability of rainfall to infiltrate the soil] remained the same or increased on 189 sites [i.e. 47%]. The Nutrient Cycling Index was stable or increased at 142 sites [i.e. 36%]) • Comparative figures for 47 grassland sites were: – Stability Index – stable or increased at 29 sites (62% of all sites) – Infiltration Index – stable or increased at 25 sites (53% of all sites) – Nutrient Cycling Index – stable or increased at 24 sites (51% of sites)
Gawler	RGFI using condition ratings at 179 pastoral monitoring sites: • Small improvement in landscape function averaged across all sites (from 2.11 at first assessment in the period 1990–93 to 1.97 in 2001–02) Note that a score of 1 = 'highly functional' and 3 = 'poorly functioning'
Darling Riverine Plains	From 45 Northern Floodplain RAP sites, seasonal variation in the extent of bare, eroded or sealed surfaces and stability in the frequency of perennial ground cover species: • Decline in bare, eroded or sealed surfaces from 51% in 1993 to 25% in 2000 (3-year rolling averages). Changes mainly attributed to better seasonal conditions. Using data for individual years, there was an increase in this less desirable soil surface state with drought conditions in 2001–02 • Frequency of perennials within the range of 12–22%, considered stable. Most of the above change in bare ground (i.e. inverse of ground cover) attributable to annuals

Region	Measured or observed change
	Reduced flooding: • Comparison of the 1988 and 2004 events shows much-reduced flow peaks, total volumes and flooding in the bioregion compared with previous events of similar magnitude. For example, the relative share of flood events with peaks around 60,000 ML/day at St George (Qld) that reached NSW has declined from an average of more than 50% prior to 1997 to only 20% in the 2004 event • Analysis of satellite images shows that flooding in NSW was 88% (140,000 ha) less in 2004 compared with inundation produced by a similar event in 1988
Desert Uplands	• Apparent improvement in landscape function between 1992 and 2001 based on an increase in the frequency of perennial herbage species and/or an increase in ground cover. This improvement is probably largely attributable to better seasonal conditions
Victoria River District	RCI derived from formal landscape function assessment at 32 Tier 2 sites: • Stable or increased index values at 21 sites (66%) in the period 1995–2003. Four of the 11 sites where a decrease occurred had been burnt sometime in the period 2000–03. (Although, countering this, 10 sites were burnt and showed either no change or an improvement in RCI) Formal LFA at 20 Basalt Plains (Tier 2) sites: • Stability or increase in RCI at 12 sites (60%) between 1995 and 2003 • Increase in other landscape function indicators (average patch width and length, and number of patches) between 1995 and 1999 in generally above-average seasons. Average patch width and length at sites then declined at the next assessment (2003) under continuing favourable seasons, presumably due to many sites being burnt between 1999 and 2003. Patch number also declined, but less dramatically Time trace in cover from Landsat satellite data: • The mean cover of pixels representing the 21 Basalt Plains sites was consistently higher and more stable in the period 1993–2003 compared with the previous decade. This stability in cover in recent years is interpreted as a satisfactory level of landscape function (Karfs and Trueman 2005). Extrapolating these site results to the land-type scale suggests that landscape function has improved in the Basalt Plains land type over the 10 years 1993–2003 compared with the previous 10 years, 1983–1992 Change in recorded occurrence of perennial plants at 254 Tier 1 sites: • Based on the number of perennial species within 50 m of a defined point, there was a small increase (8%) in the occurrence of perennial grasses at sites. This increase, as distinct from any substantial decrease, is inferred as stability in landscape function by Karfs and Trueman (2005)

Rainfall as a contributor to detected change

Where suitable data are available, we have used the seasonal quality by the degree-of-change matrix of Section 2 to better partition the influence of rainfall effects on a change in landscape function.

Gascoyne–Murchison

Resource Capture Index (RCI)

The Resource Capture Index indicates the proportion of the transect that is able to capture and regulate nutrient and water flow.

Seasonal conditions for shrubland sites are based on rainfall received in the five years prior to assessment, and for grassland sites, rainfall in the preceding three years.

Table 23 Percentage of WARMS sites where the RCI has declined, remained stable or improved under prevailing seasonal conditions prior to reassessment

Seasonal conditions	Site type	# Sites	Decline	No change [1]	Improvement
Above average	Shrubland	156	74	7	19
	Grassland	44	55	20	25
	Pooled [2]	*200*	*70*	*10*	*20*
Average	Shrubland	130	57	18	25
	Grassland	1	na	na	na
	Pooled	*131*	*na*	*na*	*na*
Below average	Shrubland	105	57	20	23
	Grassland	0	na	na	na
	Pooled	*105*	*na*	*na*	*na*

1 An RCI tolerance of ±0.1 was used to categorise 'no change'.

2 *Pooled* is the weighted average of the values from the shrubland and grassland sites.

Stability Index

The Stability Index is derived from a subset of soil surface condition indicators (Tongway 1994, Tongway and Hindley 1995) assessed as part of formal LFA. It represents the ability of the soil to withstand erosive forces and to reform after disturbance. In the WA rangelands, the Stability Index is considered to be relatively independent of shorter-term seasonal variability (Holm 2001).

As for the RCI, seasonal conditions for shrubland sites are based on rainfall received in the five years prior to assessment, and for grassland sites, rainfall in the preceding three years.

Table 24 Percentage of WARMS sites where the Stability Index has declined, remained stable or improved under prevailing seasonal conditions prior to reassessment

Seasonal conditions	Site type	# Sites	Decline	No change [1]	Improvement
Above average	Shrubland	162	13	53	34
	Grassland	46	15	50	34
	Pooled	*208*	*13*	*52*	*34*
Average	Shrubland	131	15	73	13
	Grassland	1	na	na	na
	Pooled	*132*	*na*	*na*	*na*
Below average	Shrubland	105	21	70	9
	Grassland	0	na	na	na
	Pooled	*105*	*na*	*na*	*na*

[1] A Stability Index tolerance of ±0.1 was used to categorise 'no change'.

The change in RCI values, as an indicator of landscape function, at both shrubland and grassland sites suggests some cause for concern (Table 23). Almost three-quarters of shrubland sites and more than half of grassland sites showed a decline in RCI following above-average seasonal conditions – when stability or improvement would have been expected. Encouragingly, one-fifth of shrubland sites and a quarter of grassland sites had an improved RCI value through this period. Also of encouragement, almost one-half of sites maintained or improved their RCI value in poorer seasons – when decline could have been expected.

Stability Index values were more constant at most sites through the reporting period (Table 24). Less than one-sixth of shrubland and grassland sites showed a decline in the index following better seasons – when stability or improvement in index values would have been the expected result. One-third of both site types improved during this period. Almost 80% of shrubland sites maintained or improved their Stability Index value in poor seasons.

Gawler bioregion

Changes in landscape function based on the RGFI are shown in Table 25.

Table 25 Percentage of pastoral monitoring sites in the Gawler bioregion where landscape function has declined, remained stable or improved under prevailing seasonal conditions in the five years prior to reassessment

Seasonal conditions	# Sites	Decline	No change [1]	Improvement
Above average	n/a			
Average (2001)	104	8	41	51
Below average (2002)	75	24	48	28

1 A tolerance of ±1 ranking was used to categorise 'no change'. (See DellaTorre 2005 for details)

These results are an encouraging indication of an improving trend in landscape function because they indicate that three-quarters of sites assessed in the below-average season of 2002 maintained or improved their Richards-Green Functionality Index value. Similarly, 92% of sites assessed the year before (following average seasons) had either stable or improved function.

Darling Riverine Plains bioregion

As well as reporting change in landscape function with soil surface and frequency data of perennial species as described in Table 22, Grant (2005) combined these data into an adapted form of the RGFI to calculate a landscape function value for each site. Changes in index values at the site level are shown in Table 26.

Table 26 Percentage of RAP monitoring sites where landscape function has declined, remained stable or improved under prevailing seasonal conditions prior to reassessment

Seasonal conditions	# Sites	Decline	No change [1]	Improvement
Above average	40	10	15	75
Average	n/a			
Below average	40	75	15	10

1 A tolerance of ±1 ranking of the RGFI was used to categorise 'no change'.

These site-level data suggest that seasonal conditions are primarily influencing index values: 75% of sites had improved functionality following above-average rainfall and a similar percentage showed reduced functionality in below-average seasons. Grazing management would appear to be having minimal impact on a change in landscape function – to the extent that the adapted RGFI (or input data to the index) is adequately representing landscape function in this bioregion.

Desert Uplands bioregion

Change in landscape function at QGraze sites is shown in Table 27. Landscape function is based on a modified form of the RGFI (frequency of perennial herbage species and ground cover).

Table 27 Percentage of QGraze monitoring sites where landscape function has declined, remained stable or improved under prevailing seasonal conditions prior to reassessment

Seasonal conditions	# Sites	Decline	No Change [1]	Improvement
Above average	6	0	50	50
Average	8	0	62	38
Below average	n/a			

[1] A threshold of ±5 units of modified RGFI was used to categorise 'no change'.

Based on the adapted functionality index, the change in landscape function at QGraze sites generally conformed with seasonal expectations. Slightly more than a third of sites had an improved index value when assessed following average seasonal conditions – an encouraging result. (Note, however, that few sites were assessed across the region.)

Victoria River District

As described in Table 22, several ways of reporting change in landscape function were used in the VRD (Tier 1 and Tier 2 ground sites, analysis of Landsat imagery surrounding sites and across land types). Here we are using RCI values derived from formal LFA procedures at Tier 2 sites to report site changes. The assessment period is 1995 to 2003.

Table 28 Percentage of Tier 2 monitoring sites where the RCI has declined, remained stable or improved under prevailing seasonal conditions prior to reassessment

Seasonal conditions	# Sites	Decline	No change [1]	Improvement
Above average	32	34	19	47
Average	n/a			
Below average	n/a			

[1] An RCI tolerance of ±0.1 was used to categorise 'no change'.

One-third of sites showed a decline in their RCI value when no change or an improvement would have reasonably been expected. As reported by Karfs and Trueman (2005), many of the Tier 2 sites were burnt at some stage. Fire effects on vegetation patch dimensions may partly explain the decline in site RCI values.

Ability to report change in landscape function

1. As for Question 1, the results for this question are largely based on the measured change at widely spaced (often few) but fixed sites. Thus we can report change over time for these points within each region but our ability to broaden these assessments to larger areas is dependent on the extent to which sites are representative of enlarged areas.

2. Based on the work of Holm (2001), the RCI and Stability Index appear useful for reporting change in landscape function from formal LFA data. The value of these indices is increased because they are reported to be relatively independent of shorter-term seasonal variability.

3. The RGFI and variants that are based on criteria such as ground cover (of various types) and frequency (or density) data appear to be less damped against seasonal variability. If possible, the robustness of the RGFI and variants should be increased to better separate possible grazing (management) effects on landscape function from that due to season.

4. It should be possible to test the utility of the RGFI (and variants) by comparing RGFI values with formal LFA at WARMS and Tier 2 sites.

5. Because existing monitoring sites cannot adequately represent entire regions, LFA-derived index values (such as the RCI and Stability Index) and other indicators of landscape function (RGFI and variants) reported for the whole region should be interpreted with caution. In turn, reported change between successive assessments should also be used carefully. It may be more sensible to clearly explain that we are reporting change as detected at (albeit few) sites than to 'smear' an average value (or some other statistic) across a whole region (as originally proposed for ACRIS reporting, Kraatz 2002).

6. There is potential to increase the scale at which landscape function is monitored. Karfs and Trueman (2005) have demonstrated a cover-based linkage between formal LFA and Landsat-derived index values at their Tier 2 sites. They infer LFA from their remote sensing analyses on the basis of stability in cover through time. There is probably scope to increase (i) the theoretical understanding of landscape function at larger (landscape) scales and (ii) the rigour with which assessments are made and conclusions drawn. To this end, Ludwig et al. (2002, in press) have developed methods for monitoring leakiness with various remotely sensed data (pixels at sub-metre to tens of metres resolution) and it would seem useful to have their methods tested for their effectiveness and practicality in monitoring changes in landscape function at hillslope to landscape scale.

7. The reported changes in flooding regime across much of the Northern Floodplains of the Darling Riverine Plains (Grant 2005) demonstrate that the concept of landscape function may also be useful at large landscape to bioregional scale. It would seem desirable to link the different scales at which landscape function can potentially be reported – from point (i.e. site) to landscape.

SECTION 7 – CAPACITY FOR CHANGE (QUESTION 4)

Summary

- Monitoring activity and the reporting of change in the rangelands has traditionally focussed on the biophysical environment. Question 4 was purposely framed by the ACRIS Management Committee to extend our reporting capacity in the area of socio-economics. The decisions and actions of people, especially pastoralists, are integral to the way in which the rangelands change. If government policy is to influence the direction and pace of change in land management practices, then we need to understand the capacity of people to understand and implement improved land management practices.

- The ABS was contracted to report statistics for each pilot region that could indicate capacity for change. They used their recent national census data (1991, 1996, 2001) and surveys by ABARE as source data.

- The census data are reported by Statistical Local Area (SLA). It was difficult for ABS to obtain good geographical alignment between component SLAs and the boundaries of some reporting regions. In this regard, the Darling Riverine Plains region includes population, production, and economic value figures for that part of the bioregion extending into southern Queensland. These figures are also heavily influenced by agricultural production in some of the bioregion outside of the rangelands.

  The Victoria River District had the best fit between SLAs and reporting regions (VRD = ~130,000 km^2, one component SLA = ~100,000 km^2). In contrast, the Gawler bioregion is ~120,000 km^2 while the component SLAs are ~400,000 km^2 and include agricultural areas with significant cereal production. Similar distortion occurs in the Darling Riverine Plains (noted above) and to a lesser degree in the Desert Uplands and Gascoyne–Murchison regions.

  Concordance procedures were used to minimise the effects of boundary mismatches on the population data but it was not possible for ABS to adjust the ABARE survey data to indicate agricultural production and its economic value reasonably accurately within most pilot regions.

- Headline statistics from the ABS analysis include:

  - The median age of farmers (pastoralists) is increasing in four regions (Gascoyne–Murchison, Gawler, Darling Riverine Plains and Desert Uplands). The median age of farmers in these regions was between 47 and 50 years in 2001, an increase from 44–46 years in 1991. In contrast, Victoria River District farmers (pastoralists) had a median age of 42 years in 2001, unchanged from 1996.

    Allied with an increasing median age, approximately three-quarters of farmers in the four regions were older than 40 (in 2001), with approximately one-quarter older than 60 years. Sixty percent of VRD pastoralists were older than 40 (down from 70% in 1996). Twelve percent of pastoralists were older than 60.

The younger age profile of VRD pastoralists is probably due to many being managers for pastoral companies. In the other four regions, most 'farmers' would own their farm (station).

- There was insufficient data to allow comparison of total family farm income. Where data were available, there was considerable sampling variability, meaning that reported figures should be interpreted cautiously. There was a twofold increase in three-year average income in the Darling Riverine Plains (1996–97, $41,137; 1999–2000, $83,600). Average farm income in the Desert Uplands was more stable and comparable with that for the Darling Riverine Plains in the latter period.

- There was insufficient data among regions on 'farms' with property plans to allow inter-regional comparisons.

- All regions apart from the VRD have a slowly increasing age-dependency ratio – i.e. an increasing proportion of younger and older people compared with the working-age population.

- Allied with the increasing age dependency ratio, all regions apart from the VRD are losing young people to other regions (i.e. negative net migration). Moving to larger regional centres or capital cities for secondary and tertiary education may partly account for this 'loss' of younger people. The loss has greater implications when young people find gainful employment outside of the region and are then less likely to return.

- Other regional differences in population trends from the ABS data include:

  - The population of the regions, from the 2001 Census, varied between ~2300 in the VRD to ~47,300 in the Darling Riverine Plains bioregion. Note that the Darling Riverine Plains figure is for the whole bioregion and includes towns in the more intensive agricultural zone such as Goondiwindi (Qld), Coonamble, Gilgandra, Warren and Nyngan.

    Regional populations declined in the Darling Riverine Plains and Desert Uplands between 1991–96 and 1996–2001. Elsewhere, the population increased between recent censuses, by as much as 17.6% between 1991 and 2001 in the VRD.

  - The VRD has a high proportion of the population identifying as Indigenous and this probably largely accounts for its increasing population, positive net migration of young Australians and decline in age-dependency ratio.

  - Mining is an important source of employment in the Gascoyne–Murchison and Gawler regions (26% and 12% of employment respectively). Government employment (including Defence) is important in the VRD (42%). Agriculture and allied industries are relatively important sources of employment in most regions (12–36%) but are minor in the Gawler bioregion (3%).

  - Generally, large property size relative to the area of the Gascoyne–Murchison, Gawler and VRD regions means that farmers/managers are a small proportion of the workforce (<8%) in these regions. Conversely, smaller properties in the Desert Uplands and Darling Riverine Plains accounts for a higher proportion of farmers/managers in the workforce (22% and 16% respectively). The proportion for the rangelands portion of the Darling Riverine Plains would probably be considerably lower (elevated here with the inclusion of more intensive agriculture within the bioregion).

- The generally poor correspondence between SLAs and region/bioregion boundaries skews the ABARE economic data such that inter-regional comparisons are not really valid. However, the data indicate that:

  - There are many more 'farms' in the Darling Riverine Plains and Desert Uplands and that these 'farms' are smaller than in the three other regions.

  - Properties in the Darling Riverine Plains and Desert Uplands have a lower estimated value of agricultural operations than elsewhere.

  - Beef (cattle and calves) is the main source of agricultural income in the VRD, Desert Uplands and Gascoyne–Murchison. Beef contributes significantly to income in the Gawler bioregion, along with wool (and sheep). Wool and sales of sheep and lambs also contribute considerably to the agricultural economy of the Gascoyne–Murchison.

    Crops account for three-quarters of the production value in the Darling Riverine Plains, mainly because of the contribution from more intensive agriculture in that area east of the Western Division boundary. Beef and wool make up most of the remainder.

    The inclusion of the Carnarvon horticultural precinct in constituent SLAs of the Gascoyne–Murchison shows that vegetables and fruit are an important component of the region's agricultural economy (19.3% of the estimated value of agricultural operations in 2000–01).

  - From recent ABARE surveys, the area fenced to protect country from grazing ranged from 190 km^2 in the VRD to 1,500 km^2 in the Gascoyne–Murchison. Additional figures through time are required to establish any trend. With the generally large area of rangeland paddocks, the length of fencing constructed to protect areas probably needs to be compared with the total length of new (or renovated) fencing during the same period to obtain an appreciation of whether these protected areas are significant. However, it is probably encouraging that areas in each region are now being fenced explicitly to 'protect from grazing'.

- Information extracted from reports compiled for pilot regions shows that for some regions there is changing land use (e.g. from pastoral to conservation in parts of the Gascoyne–Murchison), property values are generally increasing and there has been relatively high levels of participation in regional restructuring initiatives. In particular, programs within the Gascoyne–Murchison Strategy and the WA Government's Ecological Management Unit (well-known as 'EMU') have had considerable success in achieving change in the Gascoyne–Murchison region.

Background

Question 4 was designed to challenge and extend the capacity of ACRIS to report in the socio-economic domain. It recognises that people are an integral part of the rangelands, and particularly pastoralists, because their land management actions can have a profound effect on biophysical change. For government policy and related activity (e.g. research, development and extension) in the rangelands to be effective, we need to better understand the capacity of land managers to adopt and implement improved management practices. At the broadest level, Australian society should also have some understanding of the socio-economic profile of rangeland communities as background in forming their perceptions of how well the rangelands are currently managed.

Data used to answer Question 4

The main source of information for inter-regional comparison is the 'headline indicators' compiled by the ABS in their commissioned report to the National Land and Water Resources Audit (ABS 2004, available at <http://www.nlwra.gov.au/social_economic.htm>). These indicators were identified by Haberkorn et al. (2001) as being useful for informing rangeland management policy (Table 29). The headline indicators (summarised in Table 30) are complemented by other statistics that provide a broader view of the social and economic conditions of each region. In compiling these profiles, ABS used its own data from the Census of Population and Housing (1991, 1996 and 2001) and the Agricultural Census 2000–01, and the Australian Agricultural and Grazing Industry Survey conducted by ABARE.

Some ancillary information that has been extracted from the regional reports contributing to this synthesis is also presented for Question 4.

Table 29 Headline indicators reported by the Australian Bureau of Statistics

Indicator	Rationale for inclusion
Median age of farmers	Age statistics can help explain the likely desire of property owners/managers to remain on the property, their exposure to environmental concepts, their attitude towards stewardship and their adoption of different resource management practices.
Total family farm income	Level of income can explain potential opportunities to experiment with new sustainable management practices.
Farms with property management plans	Property management plans reflect the motivation to manage more sustainably, skills in management, and access to and use of different information for management decisions.
Age-dependency ratio	Provides a useful economic snapshot of the population structure/composition.
Net migration of young people	Net migration assists in understanding population changes, particularly in those beginning their careers, and those most able to be mobile and/or completing their education.

(Extracted from ABS4_Rangelands_profiles_prelims.pdf available at <http://www.nlwra.gov.au/social_economic.htm>)

Regional socio-economic profiles

The main points apparent from these profiles (Table 30) are:

- The median age of farmers (i.e. pastoral land managers) is increasing in four regions (Gascoyne–Murchison, Gawler, Darling Riverine Plains and Desert Uplands). 'Farmers' (i.e. pastoralists) are appreciably younger in the Victoria River District, as indicated by median age. This is probably because many are managers for pastoral companies, whereas in other regions most 'farmers' are owners.

- All regions apart from the VRD have a slowly increasing age-dependency ratio. This is the ratio of children and elderly people relative to a region's population that is of working age (15–64) and indicates the 'economic burden the productive portion of a population must carry' (from Haberkorn et al. 2001) – presumably, the higher the ratio, the greater the burden. This simple statistic could be misleading, though, as a high proportion of elderly people would seemingly have a different medium- to longer-term impact on a region's economy (and society) than a high proportion of children.

- The Victoria River District is the only region gaining young people (aged 15 to 24). Elsewhere, young people are leaving – at quite high rates in the Darling Riverine Plains, Desert Uplands and Gawler regions. It is unclear to what extent young people are leaving regions temporarily for secondary and tertiary level education as distinct from leaving permanently in search of satisfying employment.

- Regional populations declined in the Darling Riverine Plains and Desert Uplands between 1991–96 and 1996–2001. Elsewhere, the population increased between recent censuses, by as much as 17.6% between 1991 and 2001 in the VRD.

- The VRD has a high proportion of the population identifying as Indigenous and this probably largely accounts for its increasing population, positive net migration of young Australians and decline in age-dependency ratio. The higher birth rate of Indigenous people (not quantified by ABS) will also contribute to these statistics.

- Mining is an important source of employment in the Gascoyne–Murchison and Gawler regions. Government employment (including Defence) is important in the VRD. Agriculture and allied industries are relatively important sources of employment in most regions (12–36%) but are minor in the Gawler bioregion (3%).

- Allowing for the poor correspondence between component Statistical Local Areas (reporting units for socio-economic data) and pilot region boundaries:

  - There are many more 'farms' in the Darling Riverine Plains and Desert Uplands and 'farms' there are smaller than in the three other regions.

  - Properties in the Darling Riverine Plains and Desert Uplands have a lower estimated value of agricultural operations than elsewhere. (Note that for the Darling Riverine Plains, farms outside of the rangelands are included – i.e. more intensive agriculture east of the Western Division boundary.)

Table 30 Regional socio-economic profiles

Indicator type	Region				
	Gascoyne–Murchison	Gawler	Darling Riverine Plains	Desert Uplands	Victoria River District
Headline					
Median age of farmers	1991 – 44 years 1996 – 48 years 2001 – 48 years	1991 – 46 years 1996 – 47 years 2001 – 50 years	1991 – 44 years 1996 – 46 years 2001 – 48 years	1991 – 44 years 1996 – 47 years 2001 – 47 years	1991 – 35 years 1996 – 42 years 2001 – 42 years
Total family farm income	Not available for specified area	Not available for specified area	3-year average 1996–97 to 1998–99 – $41,137 3-year average 1999–2000 to 2001–02 – $83,600 *	3-year average 1996–97 to 1998–99 – $83,142 3-year average 1999–2000 to 2001–02 – $75,789 *	Not available for specified area
Farms with property management plans	Not available for specified area	Not available for specified area	1998–99 – 20% 2001–02 – 17% *	1998–99 – n/a 2001–02 – 48% *	Not available for specified area
Age-dependency ratio	1991 – 0.42 1996 – 0.39 2001 – 0.42	1991 – 0.49 1996 – 0.49 2001 – 0.48	1991 – 0.54 1996 – 0.55 2001 – 0.56	1991 – 0.53 1996 – 0.55 2001 – 0.57	1991 – 0.60 1996 – 0.63 2001 – 0.50
Net migration of young Australians	1996 – -4.3% 2001 – -11.1%	1996 – -11.3% 2001 – -15.1%	1996 – -21.3% 2001 – -18.3%	1996 – -11.2% 2001 – -16.4%	1996 – +9.0% 2001 – +7.8%

* ABS advises that data subject to high level of sampling variability and the estimate should be used with caution.

Indicator type	Region				
	Gascoyne–Murchison	Gawler	Darling Riverine Plains	Desert Uplands	Victoria River District
Social					
Population (Pop'n)	26,298 in 2001 2.0% increase on 1996 3.7% increase on 1991	20,371 in 2001 1.6% increase on 1996 4.1% increase on 1991	47,328 in 2001 2.7% decline from 1996 3.0% decline from 1991	3,737 in 2001 2.8% decline from 1996 4.3% decline from 1991	2,303 in 2001 7.6% increase on 1996 17.6% increase on 1991
Age (2001)	17% pop'n <15 yrs (20% in 1991) 13% pop'n >64 yrs (10% in 1991)	23% pop'n <15 yrs (26% in 1991) 9% pop'n >64 yrs (7% in 1991)	24% pop'n <15 yrs (26% in 1991) 12% pop'n >64 yrs (9% in 1991)	24% pop'n <15 yrs (25% in 1991) 12% pop'n >64 yrs (10% in 1991)	23% pop'n <15 yrs (27% in 1991) 5% pop'n >64 yrs (5% in 1991)
% Pop'n identifying as Indigenous (2001)	14% for region (WA 3% and Aust 2%)	11% for region (2% for SA and Aust)	18% for region (2% for NSW and Aust)	5% for region (Qld 3% and Aust 2%)	58% for region (NT 24% and Aust 2%)
Employment (2001)	12% in Ag/allied 26% in Mining 7% Farmers/managers 5% unemployed	3% in Ag/allied 12% in Mining 2% Farmers/managers 8% unemployed	31% in Ag/allied 11% in Retail trade 16% Farmers/managers 9% unemployed	36% in Ag/allied 10% in Retail trade 22% Farmers/managers 4% unemployed	22% in Ag/allied 42% in Govt/Defence 5% Farmers/managers 3% unemployed
Income (2001) (low <$300/week, high ≥$700/week)	34% with low income 31% with high income	37% with low income 23% with high income	41% with low income 16% with high income	40% with low income 17% with high income	54% with low income 13% with high income
Education (2001)	27% done Yr 12 11% left school by Yr 8	22% done Yr 12 11% left school by Yr 8	25% done Yr 12 14% left school by Yr 8	26% done Yr 12 17% left school by Yr 8	18% done Yr 12 21% left school by Yr 8
Computer and Internet use at home (2001)	24% computer use 23% Internet use	32% computer use 28% Internet use	26% computer use 20% Internet use	30% computer use 23% Internet use	9% computer use 10% Internet use

Indicator Type	Region				
	Gascoyne–Murchison	Gawler	Darling Riverine Plains	Desert Uplands	Victoria River District
Socio-demographics of farmers					
Age (farmers) (2001)	71% ≥40 yrs (70% in 1996) 23% ≥60 yrs (20% in 1996)	76% ≥40 yrs (68% in 1996) 26% ≥60 yrs (17% in 1996)	73% ≥40 yrs (68% in 1996) 23% ≥60 yrs (20% in 1996)	74% ≥40 yrs (70% in 1996) 22% ≥60 yrs (20% in 1996)	60% ≥40 yrs (70% in 1996) 12% ≥60 yrs (18% in 1996)
Income (farmers) (2001) (low <$300/week, high ≥$700/week)	18% high income (31% regional pop'n) 34% low income (34% regional pop'n)	20% high income (23% regional pop'n) 28% low income (37% regional pop'n)	31% high income (16% regional pop'n) 28% low income (41% regional pop'n)	29% high income (17% regional pop'n) 27% low income (40% whole pop'n)	24% high income (13% regional pop'n) 14% low income (54% whole pop'n)
Education (farmers) (2001) Level of qualification (2001)	33% done Yr 12 14% left school by Yr 8 22% had certificate or higher (region @ 33%)	30% done Yr 12 13% left school by Yr 8 26% had certificate or higher (region @ 28%)	38% done Yr 12 7% left school by Yr 8 31% had certificate or higher (region @ 24%)	26% done Yr 12 16% left school by Yr 8 18% had certificate or higher (region @ 21%)	26% done Yr 12 12% left school by Yr 8 43% had certificate or higher (region @ 21%)
Computer and Internet use at home by farmers (2001)	34% computer use 24% Internet use	37% computer use 22% Internet use	43% computer use 32% Internet use	38% computer use 24% Internet use	52% computer use 33% Internet use
Address changes (farmers) (2001)	75% at same address as 5 yrs ago (49% elsewhere Aust)	77% at same address as 5 yrs ago (49% elsewhere Aust)	78% at same address as 5 yrs ago (49% elsewhere Aust)	74% at same address as 5 yrs ago (49% elsewhere Aust)	62% at same address as 5 yrs ago (49% elsewhere Aust)

Indicator type	Region				
	Gascoyne–Murchison	Gawler	Darling Riverine Plains	Desert Uplands	Victoria River District
Agriculture and natural resource management (2001 data)					
Degree of correspondence [1]	60 m Ha SLAs = 43 m Ha	12 m Ha SLAs = 40 m Ha (i.e. prod^n figures very much overstated)	11 m Ha SLAs = 30 m Ha (i.e. prod^n figures probably overstated)	7 m Ha SLAs = 15.6 m Ha (i.e. prod^n figures probably overstated)	13 m Ha 1 SLA = 10 m Ha
Extent of agriculture	380 farms 40% of all farms vegetables and fruit 32% sheep, 14% beef 9% sheep and beef	193 non-irrigat. farms 82% of all farms beef and/or sheep 14% grain	3665 non-irrigat. farms 35% of all farms beef and/or sheep 25% mixed grain and beef/sheep	684 non-irrigat. farms 97% of all farms beef and/or sheep	38 farms 34 (90%) of all farms beef (and/or sheep)
Farm production value	16% with EVAO [2] >$500,000 43% with EVAO $150,000 – $500,000	18% with EVAO [2] >$500,000 48% with EVAO $150,000 – $500,000	22% with EVAO [2] >$500,000 37% with EVAO $150,000 – $500,000	25% with EVAO [2] >$500,000 47% with EVAO $150,000 – $500,000	63% with EVAO [2] >$500,000 11% with EVAO $150,000 – $500,000
Agricultural production	Cattle and calves $38.3m and 37% Wool 28.2m, 14%; Sheep/lambs 11%	Cattle and calves $29.7m and 43% Wool 30% Crops 17%	Crops $1.7 bn and 75% Cattle and calves 12% Wool 8%	Cattle and calves $221m and 85% Wool 10% Crops 2%	Cattle and calves $34.5m and 99.8% Pastures and grasses 0.2%
Area fenced to protect from grazing	1500 km^2 65% of this area fenced 'to protect creeks and rivers'	400 km^2 81% of this area fenced 'to protect other degraded areas'	1070 km^2 60% of this area fenced 'to protect all [3] other areas'	887 km^2 43% of this area fenced 'to protect all [3] other areas'	190 km^2 fenced 'to protect creeks and rivers'

1 Information from Agricultural Census of 2001. Data available at the level of Statistical Local Area (SLA), which do not closely align with bioregions (or reporting regions). Concordance procedures used to obtain the best fit possible. Figures in this row indicate discrepancy.

2 EVAO: Estimated value of agricultural operations.

3 from Agricultural Census of 2001 – 'all' presumably means other, non-specified, forms of protection.

Information from regional reports

Additional information (to that available from the ABS profiles) extracted from regional reports relevant to Question 4 is summarised in Table 31.

Table 31 Information on capacity for change extracted from regional reports

Region	Measured or observed change
Gascoyne–Murchison	Watson et al. (2005) have compiled a diversity of information related to capacity for change in the Gascoyne–Murchison. Highlights include: • Anecdotal and direct evidence that pastoralists destocked in response to the recent drought indicating increased capacity to manage drought • Of pastoralists surveyed as part of the GMS, 58% stated their capacity to manage had improved over the last 5 years, 25% said it had not changed and 17% said it had declined • Capacity for nature conservation has improved with the addition of 3.5M ha to the conservation estate within the GMS • Installation of 1,350 Total Grazing Management yards, covering about 10% of the artificial waters, has significantly improved pastoralists' capacity to manage total grazing pressure (i.e. livestock, ferals and native grazers) • Artesian bore capping and reticulation has drastically improved capacity to manage underground water resource, saving an estimated 8.35 GL of water per annum • EMU activity has helped pastoralists improve capacity to manage their land and achieve significant additional outcomes. EMU has engaged with managers of 15M ha operating ~70 pastoral businesses; contributed to altered pastoral management of several nationally listed wetlands and several examples of rare and/or threatened flora; and helped community-driven catchment, riparian and floodplain management and restoration projects • Capacity for diversification and the introduction of new or expanded industries has increased in the last few years. There has been a significant shift from wool production (Merinos) to cattle and/or a range of meat sheep (e.g. Damaras) and increased income from 'rangeland goats'. This has reduced reliance of income on wool but has also led to declining maintenance of infrastructure, particularly internal fencing
Gawler	• Total stock numbers for the Gawler and Kingoonya Soil Conservation Districts (pastoral administrative regions matching the bioregion) have fluctuated between ~250,000 and ~750,000 sheep equivalents. There are no clear trends – numbers fluctuate with seasonal conditions and commodity prices (with the lowest number present in the very dry year of 2002) • 11% change in pastoral land use (across 97 leases) between 1994 and 2003:

Region	Measured or observed change
	– 3 leases changed from pastoral to conservation – 4 pastoral leases changed stock breed as part of ongoing management – 3 leases have diversified into tourism • Insufficient property sales to accurately indicate change in property values through the reporting period. Average increase in unimproved value of 58% based on figures used by SA Department of Administrative and Information Services for calculating lease rental. (Note: This does not mean that improved value has increased by the same amount – see DellaTorre 2005.)
Darling Riverine Plains	Grant (2005) has summarised several significant socio-economic trends that influence the management of rangelands in this bioregion: • Declining profitability of wool growing through the reporting period has been compounded by small property size and increasing costs of production • Rising land values limit the options of landholders to increase property size as marginal returns from additional land do not cover its cost • Conversion of rangeland to cropping has been very important in maintaining the viability of grazing enterprises in the eastern part of the bioregion. There are few other options for diversification • Sheep numbers have declined across the region – due to both the declining profitability of wool growing and recent poor seasons • There is interest in off-park conservation. Projects covering the management of 12,000 ha for conservation outcomes are currently being implemented through the WEST 2000 Plus Enterprise Based Conservation project (a regional strategy for environmental, economic and social renewal in the Western Division of NSW)
Desert Uplands	Not addressed by Bastin (2005). A comment provided by Ken Dixon (QNRM, Emerald) was: • The Desert Uplands Build-Up and Development Strategy, through its support of property amalgamation, has produced an increase in average lot size. This may have reduced the risk of overgrazing, which was previously occurring due to inadequate property size Other comments provided by Richard Silcock (Qld member of ACRIS Management Committee): • The Desert Uplands Build-Up and Development Strategy has an active committee with a secretariat driving local communities to adopt new and improved land management and business strategies to enable sustainable use and development of their area. It has been going since 1994 and has a website <www.desertuplands.org.au> informing people about upcoming events and continuing projects to help them achieve their goals • The recent detailed map and description of the biophysical resources of the region by Lorimer (2003) and their publication on the Internet should boost regional capacity to meet current and future challenges. See <http://www.desertuplands.org.au/duslrad/index.html>

<table>
<tr><th>Region</th><th>Measured or observed change</th></tr>
<tr><td>Victoria River District</td><td>From Karfs and Trueman (2005)
Cattle population and turnoff:
1992, the start of our reporting period, coincided with an historic low for district cattle numbers (347,000) as part of the national BTEC program. This program essentially transformed pastoral management from largely cattle harvesting to one of controlled herds
Since 1992, cattle numbers have steadily increased to a peak population in 2003 of 545,000
Annual turnoff in the 1980s and early 1990s was affected by the BTEC program (average turnoff pre-1982 of 12% of total herd, increasing to 20% after 1982)
Despite the impact of BTEC, there has been a steady increase in the number turned off over the last 30 years
Current disease-free status and changing of breed to predominantly Brahman has facilitated increasing live exports to South-East Asia
Increasing value of land based on properties sold:
No increase in property values between 1991 and 1994. Unimproved capital value based on property sales then increased by 5% until 1997. In the ensuing six years to 2003, there has been an increase in property value (based on sales) of 35%. This increase probably relates to economic factors such as drought in other parts of Australia and demands from the Asian market
Change in company- and family-owned properties:
Increased company ownership in past 13 years – 1991: 14 (of 29) properties family owned; 2004: 8 properties family owned
Several company-owned stations have managers with 10+ years of district residency, so increasing corporate ownership may not mean loss of local management experience
Aboriginal people in natural resource management:
Indigenous Pastoral Project established to assist traditional owners in managing pastoral enterprises through training, advice and support
Has resulted in improved land management, particularly in the control of fires and feral animals</td></tr>
</table>

Ability to report capacity for change

1. The ABS data (regional profiles) have provided standardised data and facilitated inter-regional comparisons.

2. Despite access to consistent data, these profiles have still not allowed us to provide definitive answers on capacity for change. The data provide valuable insights into, and about, regions, but contain limited information to help us answer Question 4.

(Adapted comment by Richard Silcock:
It is a step to show us what we don't know and what we need to plan to get, to inform us, e.g. debt levels versus assets and income are the main limitations to financial and social prosperity. There was no information about health facilities and educational opportunities in the region. In my experience, these are critical issues required to attract women to remote regions and retain them. Access to the Internet etc is a sideshow to the health and welfare issues for many.)

3. Simple statistics such as membership of a landcare (or equivalent) group could be a useful indicator of capacity for change – presuming that membership implies a positive attitude towards improved land management practices.

4. Collectively, we (ACRIS) probably need to understand better the work of Haberkorn et al. (2001) and others (Gordon et al. 2001) completed under Audit 1 to define and test indicators of change. From there, we should have a better appreciation of 'data type' / indicator value in the ABS regional profiles.

5. Poor concordance between SLAs and our defined bio-geographic boundaries for some regions devalues some of the economic data. Merging biophysical and socio-economic data will probably continue to be difficult because they are often collected using different boundaries. This 'degrading' effect (for our purposes) seems to be most severe where intensive agriculture abuts the rangelands (or is interspersed through it and we are primarily interested in extensive [pastoral] land use). There are perhaps two issues for ACRIS here:

   - Work is currently being done by ABS and others to improve concordance procedures.
     (Further comment by Richard Silcock following a recent ABS-sponsored workshop in Brisbane:
     ABS is not intent on collecting NRM data but, rather, fitting normal census and agricultural survey questions to catchments and bioregions. So it is testing part of what is needed but questions are not designed to answer NRM issues.)

   - We need to better understand issues involved in both data collection and concordance and increase our ability to deal with (or minimise) their effects.

   (Note that the statistics of urban centres also influence summaries presented at the SLA and bioregional level. It would be desirable to know the extent to which the inclusion of urban centres affects values for rangeland areas.)

6. Some (perhaps most) of the NRM issues about which ABS and ABARE collect data appear to have limited relevance to the rangelands (with fencing for land/vegetation protection, improved management perhaps being the most relevant). The value to ACRIS of these NRM indicators may increase as the time series develops. We need to better understand the context of why the questions were asked and what the answers may mean in terms of on-ground action.

7. As with Question 2 (change in native plant species), this question has revealed a diversity of regionally relevant information (most notably for the Gascoyne–Murchison). The challenge has been to synthesise these regionally different datasets into coherent information that indicates capacity for change in the rangelands.

8. The opportunity to answer Question 4 has provided a valuable opportunity for ‘meta-collation’ and meta-analysis of data.
   (Comment by Ian Watson:
   Presumably this is the sort of thing that a good journalist (or consultant) does all the time, i.e. assemble disparate evidence and put together a story in which comparisons are made and main messages drawn out.)

9. The bottom line is that we (ACRIS) still have a limited capacity to answer Question 4 – but its existence has provided a useful learning exercise for us. We need to extend ourselves further in the domain of reporting socio-economic change in the rangelands.

SECTION 8 – CHANGE IN COVER (QUESTION 5)

Summary

- Theoretically, change in cover should be a simple question to answer, but, in practice, the answer depends on how cover is defined. As examples:

  - Land cover change analysis based on multi-temporal Landsat imagery in the Victoria River District reports change in total vegetation cover. Alternatively, a multiple regression bare ground index that monitors ground cover below minimum thresholds of woody cover is being tested in the Desert Uplands. (Results not reported here because the index is still developmental but trial products described in Bastin 2005.)

  - The AGO's National Carbon Accounting System reports change in forest cover where forest is defined as vegetation with 'a potential to reach a minimum 20% canopy cover, 2 m in height and minimum area of 0.2 ha'. In a similar vein but with a broader focus, the Queensland SLATS uses Landsat imagery to report change in 'wooded' vegetation. The SLATS threshold for wooded vegetation is foliage projected cover approximately greater than 7% (or >~12% crown cover, considerably less than AGO's definition of 'forest').

  - Agency monitoring systems generally measure ground cover and woody cover (where present) separately – but often using different techniques. For example, ground cover is measured in quadrats at both QGraze (Desert Uplands) and RAP (Darling Riverine Plains) sites, but using different estimation criteria. Crown cover of perennial shrubs is measured at WARMS shrubland sites (Gascoyne–Murchison) because of the focus on perennials.

- Remote sensing using satellite data could provide a synoptic view of cover changes across whole regions. At this stage it is routinely used as part of Tier 2 monitoring in the VRD.

- Question 5 is answered in this synthesis using the results of Aussie-GRASS simulated cover, Landsat-derived change in forest cover (both AGO and agency methods) and agency monitoring programs (mainly ground based).

- Aussie-GRASS simulations provide an indication of the likely levels of ground cover present for the different bioregions through time. As for biomass (Question 1, critical stock forage productivity), the simulations indicate likely cover levels through the reporting period – not the levels actually present.

  - The Ord–Victoria Plains bioregion (partly representing the VRD) had generally high levels of simulated cover throughout the reporting period, presumably largely due to generally favourable wet-season rainfall.

  - Conversely, the Gawler bioregion had generally low cover, particularly from 1995 onwards, reflecting the more arid nature of this region.

  - The Desert Uplands had a strong cyclical pattern in simulated cover. High cover was indicated prior to the start of our reporting period (1990 and 1991), reducing to low cover with the dry years between 1993 and 1997, then high cover in the wetter period of 1999–2001 and lower cover in recent drier years.

  - The Darling Riverine Plains (restricted to the predominantly rangeland provinces) also had marked fluctuation in simulated cover according to rainfall – low in 1992, generally increasing to 2000, and then falling sharply with the drier years from 2001 onwards.

  - Change in simulated cover in the Gascoyne–Murchison was more moderate – cover gradually increased between 1992 and 2000 and then substantially declined from 2000 to 2003 with lower rainfall.

- The Desert Uplands had significant change in forest cover, both during our reporting period (1992–2002) and extending back to the start of the Landsat record in 1972. AGO's methods allow for reporting of change in forest cover for those areas affected by human activity (i.e. does not include impacts such as forest fires). The reporting period is 1972 to 2002. ERIN (which did the analyses for ACRIS) had difficulty in validating AGO information for the Gascoyne–Murchison and excluded this region from their reporting to ACRIS. Additionally, images and other data sources released by AGO were incomplete for the VRD. From ERIN's analysis:

  - The most extensive change in forest cover has occurred in the Desert Uplands. In 1972 forests covered 19.4% of the bioregion, increasing to 25% in 2000. There has been significant regrowth during our reporting period (1992–2002), with an apparent net gain of 403 km^2 in forest area. There were major periods of deforestation (clearing) during the 1980–85, 1989–95 and 2000–2002 periods. Large areas of regrowth occurred between 1980 and 2000.

  - There has been a net loss of forest cover in the Darling Riverine Plains since 1972 (forest 5.4% of bioregion area in 1972, reducing to 2.2% in 2000). Major deforestation events occurred between 1973–75 and 1988–92.

  - There was minimal change in forest cover in the Gawler bioregion and Victoria River District. 11.3% of the Gawler bioregion was classified as forest in 1972, reducing to 11.0% in 2000. The area of forest for the VRD was not available. ERIN reports that areas of the VRD affected by deforestation and regrowth were relatively small. This is confirmed by NT Government monitoring that reports 0.28% (371 km^2) of the VRD was cleared during the period 1992–2003 (Karfs and Trueman 2005).

- The SLATS data show that extensive clearing of woody vegetation (as distinct from forest) has occurred in the Desert Uplands. Wooded area (foliage projected cover approximately >7%, equal to crown cover >12%) has decreased from 78.7% of the bioregion in 1991 to 73.0% in 2001 (a reduction of 3938 km^2). Clearing in the Desert Uplands in the latest SLATS reporting period (1999–2001) accounted for 10.7% of all clearing in Queensland. Almost all clearing was for increased pasture (i.e. grazing).

- Regional changes in cover obtained from agency pastoral monitoring programs appear to be largely related to rainfall. For vegetation cover, change occurs partly through the change in size of existing plants and partly due to the change in number of plants. Size change is particularly dependent on recent rainfall.

- In the Gascoyne–Murchison, canopy cover of perennial shrubs increased at 82% of 700 WARMS shrubland sites. The average cover increase per site was 50% and 95% of shrub species (across all sites) had increased cover. There was little difference between decreaser, intermediate and increaser species. Cover has progressively decreased with recent drier years.

- Similar results were obtained when the data were limited to shrubs less than 1.5 m high, in order to remove the effects of tall, relatively stable shrubs and trees like mulga. Canopy cover increased on 79% of sites, and for 98% of species, with an average increase per site of 71%.

- Crown cover of woody species has increased at 30% of 42 WARMS grassland sites assessed in 1999 and 2002.

- For the Gawler bioregion, there was a small (statistically non-significant) increase in the mean cover of perennials averaged across 179 sites. Within vegetation types, perennial cover decreased in the mulga–open woodland group of sites. Elsewhere, there was a significant increase in bare ground and a decrease in annuals and litter at 5 (of 11) vegetation groups. These changes were related mainly to seasonal variation.

- From 45 Northern Floodplain sites in the Darling Riverine Plains, ground cover generally increased with the better seasons between 1994 and 2000 and then decreased with ensuing drought conditions. Despite this decrease, all but one bioregion province (Bogan–Macquarie) had higher levels of ground cover at the end of the reporting period (2001–02) compared with the start (1992–94).

- Ground cover averaged across 34 QGraze sites in the Desert Uplands was relatively low (<40%) between 1994 and 1996, in 1998 and again in 2003. Cover was considerably higher (~50%) during the wetter period between 1999 and 2002.

- Cover averaged across 33 Tier 2 sites in the VRD increased from 33% in 1996 to 53% in 1999 and then declined to 44% in 2003. Wildfire is considered largely responsible for this decline in the latter part of the reporting period.

- At the larger scale in the VRD and based on an analysis of Landsat imagery, average cover levels on the Basalt Plains land type in larger paddocks (>80 km^2) was generally higher and more stable between 1993 and 2003 compared with the previous decade. Apart from the 1997–98 wet season, the latter decade was a wetter period.

Data used to answer Question 5

Data used in each reporting region to answer this question are summarised in Table 31.

Table 32 Datasets used to answer Question 5

Region	Dataset
All	Aussie-GRASS: • Fractional cover – simulated yearly cover as an indicator of seasonal variation (Note: As for Aussie-GRASS simulations of total standing dry matter [Question 1], this dataset simulates change based on regional rainfall and other factors; it does not show actual change). Because the data are consistent across large areas, they have the potential to show where actual cover levels differ from that which could be expected. AGO forest cover: • Change in forest cover derived from AGO's multi-temporal Landsat database compiled for their National Carbon Accounting System (analyses conducted for ACRIS by ERIN)
Gascoyne–Murchison	• Measured cover of perennial shrubs in fixed transects at 700 WARMS shrubland sites. Canopy cover of individual shrubs estimated as area of circle with radius half the measured width. • Crown cover of woody perennials taller than 1 m at 71 WARMS grassland sites
Gawler	• Cover measured by step pointing at 179 pastoral monitoring sites
Darling Riverine Plains	• Ranked estimates of cover type (pasture, litter, cryptogam) in quadrats at 45 Northern Floodplain RAP sites • Cover of chenopod shrubs at RAP sites • Canopy cover of trees and shrubs (not extensive in the Northern Floodplains)
Desert Uplands	• Ranked estimates of percentage ground cover in quadrats at QGraze sites • Estimates are by cover class
Victoria River District	• Cover (grass, forb, litter, shrub and tree) measured at 33 Tier 2 sites • Landsat-derived trends in average vegetation cover of Basalt Plains land type in large paddocks (>80 km^2)

Aussie-GRASS simulated cover

Simulated cover levels calculated on a yearly basis for the Gawler (SA), Darling Riverine Plains (NSW) and Desert Uplands (Qld) bioregions and a single bioregion from the Victoria River District (Ord–Victoria Plains) and Gascoyne–Murchison (Murchison) are shown in Figure 4. The dashed lines show the long-term (1890–2003) mean simulated cover for each bioregion. As for simulated total standing dry matter (Question 1, Figure 3), these graphs do not show actual change in cover for each bioregion. Rather, they indicate the expected (i.e. simulated) cover in each year. Additionally, because they are regional averages, they may conceal considerable spatial variation related to rainfall variability, soil differences and other parameters used by Aussie-GRASS. Nevertheless, the graphs powerfully demonstrate regional differences and the magnitude of year-to-year variation in the potential cover of bioregions.

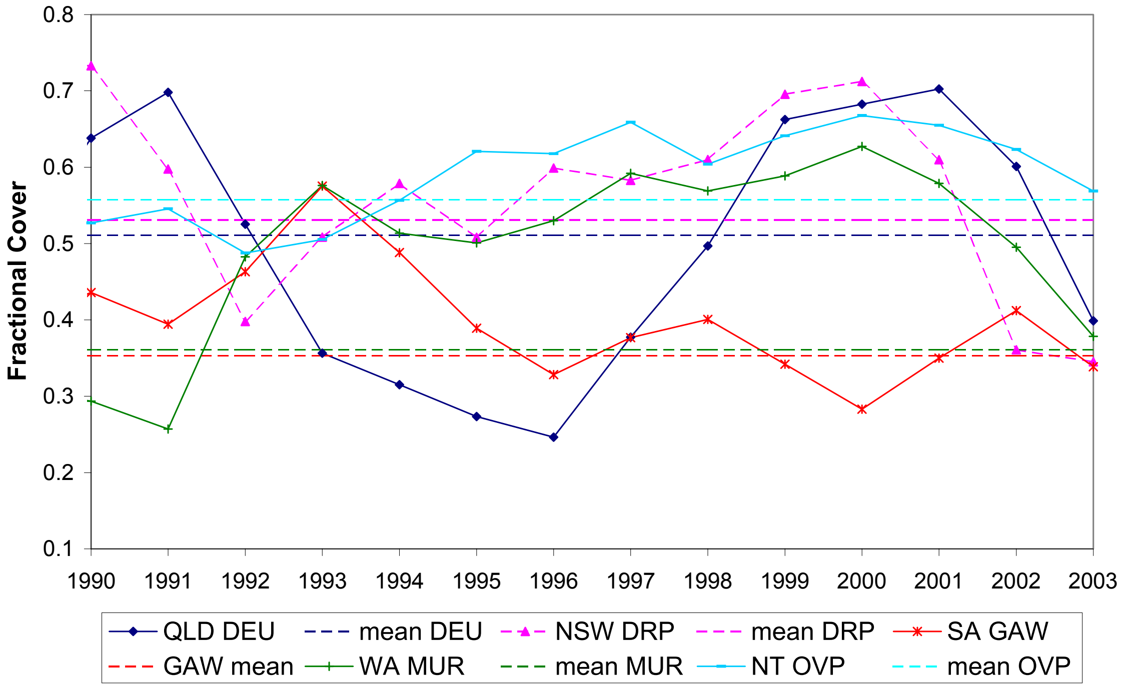

Figure 4 Simulated yearly fractional cover and the long-term (1890–2003) mean for bioregions produced by Aussie-GRASS

DEU = Desert Uplands, DRP = Darling Riverine Plains, GAW = Gawler, MUR = Murchison, OVP = Ord–Victoria Plains

There are obvious similarities between simulated cover and total standing dry matter (compare Figures 3 and 4), presumably due to relationships in the Aussie-GRASS model. The main features of simulated cover for the different regions through the reporting period are:

- The strong cyclic nature of simulated cover for the Desert Uplands during the reporting period. High values were indicated in 1991 and 1999–2001, coinciding with wetter years. The very dry years of the mid 1990s (1993–96) and again in 2002 and 2003 resulted in low simulated cover (in 2003). Some of the decline in cover between 1991 and 1996 may have been due to tree leaf-fall and death in the very dry years of this period. There were reports of significant tree death at this time and the semi-deciduous nature of eucalypts in this region means that there is considerable leaf drop (and decline in canopy cover) during sequences of dryer years. Conversely, leafing out of mature trees and thickening of saplings may have contributed to the increase in simulated cover in the latter 1990s and early part of this decade.

- The Darling Riverine Plains and Desert Uplands bioregions had the greatest fluctuations in modelled cover in recent years – for the Desert Uplands, from the highest to the lowest cover levels of all bioregions depicted. The Desert Uplands showed distinct periodicity in cover change, whereas there was greater year-to-year variation for the Darling Riverine Plains. Cover levels for both bioregions decreased sharply in recent years – between 2000 and 2002 for the Darling Riverine Plains and from 2001 to 2003 for the Desert Uplands. These decreases were due to drought conditions in both regions.

- The Gawler bioregion generally had the lowest simulated cover. Its long-term mean value was the lowest, just below that for the Murchison bioregion.

- Conversely, the Ord–Victoria Plains bioregion (part of VRD) had generally high simulated cover, and the highest long-term mean.

- Simulated cover for the Murchison bioregion (part of Gascoyne–Murchison) was generally well above its long-term mean value (because of extended periods of simulated below-average cover in the earlier twentieth century and an extended period of above-average rainfall in the mid to late 1990s). Modelled cover has decreased after 2000 in a similar manner to that of the Darling Riverine Plains and Desert Uplands – but not as sharply as for each of the latter bioregions.

AGO forest cover

The Australian Greenhouse Office has mapped forest change across Australia using 25 m and 50 m resolution Landsat imagery spanning the period 1972 to 2002. Change has been calculated over 11 epochs (image dates) measured through 10 transitions, varying between 1.21 and 4.96 years (see Department of the Environment and Heritage 2004 for more detail). The methods use a range of filters to limit the mapped change to human-induced change, excluding artefacts such as forest fires and tenures where forests are protected. AGO's National Carbon Accounting System analysis identifies land-use change for forests only.

AGO had not released details and maps of forest extent areas for the Victoria River District at the time of analysis, so ERIN was not able to provide a complete analysis of change in forest cover for this region. However, they did report the area of regrowth and deforestation for each epoch. Additionally, ERIN had difficulty in validating figures produced by the AGO for the Gascoyne–Murchison, and as these figures were not logical, ERIN excluded them from their report to ACRIS. Excluding the Gascoyne–Murchison, ERIN's summary of the area of regrowth and deforestation for each epoch is shown graphically in Figure 5.

Note that epochs represent time intervals ranging from 1.21 to 4.96 years. To correctly interpret trends over time, ERIN have normalised the data to a per-annum estimate by dividing the net epoch change by the duration of the epoch. Results are then expressed as average annual change for the epoch. Deforestation is defined as the loss of forest between measurements so that within each epoch a given area of land is not cleared or re-forested more than once.

Note also that deforestation and regrowth can occur multiple times on any one piece of land during the period 1973 to 2002. According to ERIN, the sum of clearing/regrowth over all epochs does not give a true estimate of net change over all epochs.

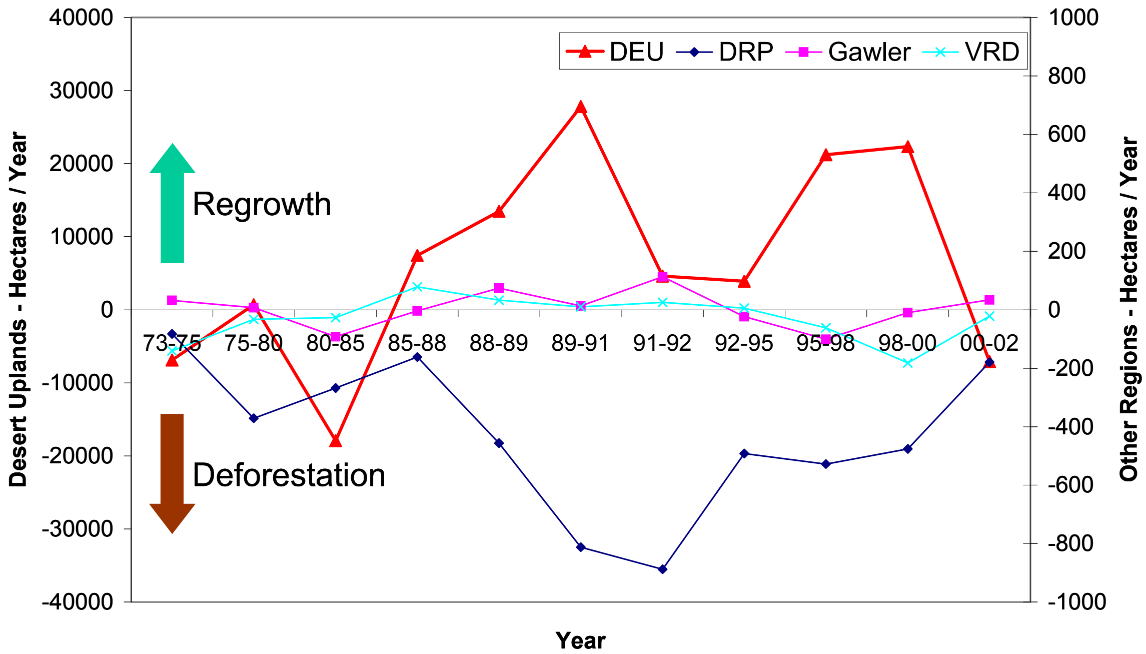

Figure 5 **Average yearly net change in forest cover within each epoch for reporting regions**

DEU = Desert Uplands, DRP = Darling Riverine Plains, VRD = Victoria River District

Note that the left-hand vertical scale applies to the Desert Uplands region. Figures for other regions should be scaled from the right-hand vertical axis. Figures above the zero line represent net average annual regrowth during that epoch. Conversely, figures below the zero line represent net average annual deforestation during that epoch.

The main features apparent from ERIN's analysis of the AGO data are:

- By far the most extensive change in forest cover has occurred in the Desert Uplands. In 1972 forests covered 19.4% of the bioregion (total area 70,322 km^2), with an increase in the area of forest to 25% of the region in 2000. There have been significant periods of regrowth during our reporting period (1992–2002), with an apparent net gain of 403 km^2 in forest area. Maps supplied by ERIN show that this increase was not uniformly distributed across the bioregion. Department of the Environment and Heritage (2004) reports that 'major deforestation events occurred in 1980–85, between 1989–95 and 2000–02. Large areas of regrowth occurred between 1980 and 2000'.

- Although the forest area for the Darling Riverine Plains is much smaller than the Desert Uplands, there has been a net loss of forest cover in this region. In 1972 forests covered 5.4% of the bioregion (bioregion area = 106,522 km^2) and reduced to 2.2% in 2000. Over this time the major deforestation events occurred between 1973 and 1975 and between 1988 and 1992. Although not shown in Figure 5, Department of the Environment and Heritage (2004) reports that a large amount of regrowth was evident between 1973 and 1975 followed by minimal regrowth up to 2002.

- Compared with the Desert Uplands and Darling Riverine Plains, there has been insignificant change in forest cover in the Gawler bioregion and Victoria River District. 11.3% of the Gawler bioregion (area = 123,726 km^2) was classified as forest in 1972, reducing to 11.0% in 2000. Forest-extent areas were not available for the VRD. Department of the Environment and Heritage (2004) reports (for the VRD) that 'areas affected by deforestation and regrowth are relatively small. The majority of deforestation occurred between 1973 and 1985 and between 1995 and 2002 and the majority of regrowth between 1985 and 1992. This pattern is reflected in the net change between deforestation and regrowth' (Figure 5).

Comparison with estimates by other agencies

Based on an analysis of Landsat data, Karfs and Trueman (2005) report that 370.7 km^2 have been cleared in the Victoria River District (0.28% of the region). Most of this was for pastoral infrastructure (tracks and fencing). Although this area cannot be directly compared with ERIN's analysis of the AGO forest data, it serves to show that clearing is insignificant in the VRD.

By comparison, SLATS data show that there has been a substantial decline in wooded area in the Desert Uplands since 1991 (Table 33, data extracted from Department of Natural Resources and Mines 2003). SLATS defines 'wooded' as woody vegetation with foliage projected cover (FPC) approximately >7% FPC (or >12% crown cover). Twelve percent FPC is approximately 20% crown cover, one of the criteria for defining AGO forest cover. Thus SLATS includes areas with lower levels of woody cover that would be excluded by AGO as being non-forest. Nevertheless, the SLATS data further emphasise the decline in woody cover in the Desert Uplands.

Clearing in the Desert Uplands in the latest reporting period (1999–2001) accounted for 10.7% of all clearing in Queensland (Department of Natural Resources and Mines 2003). Almost all clearing was for increased pasture (i.e. grazing) but it may include a large proportion of retreated regrowth from earlier clearing cycles, e.g. gidgee regrowth.

Table 33 Extent of woody vegetation at various time periods in the Desert Uplands bioregion, derived from the SLATS database

Year	Wooded area (km^2) [1]	% of total
1991	54,210	78.7
1995	52,736	76.6
1997	52,024	75.6
1999	51,289	74.5
2001	50,272	73.0
Total area of bioregion	68,843	

1 'Wooded' area has woody vegetation with FPC approximately >7% FPC (or >12% crown cover).

Results of regional monitoring activity

The change in cover detected by agency monitoring programs for the 1992–2002 reporting period is summarised in Table 34. For the Gascoyne–Murchison, Gawler, Darling Riverine Plains and Desert Uplands, reported change is based on repeat measurements of vegetation attributes at fixed ground sites. Ground sites and remote sensing, at paddock scale, are used to report cover change in the Victoria River District.

Table 34 Change in cover detected by agency monitoring programs

Region	Measured or observed change
Gascoyne–Murchison	On 700 WARMS shrubland sites: • When all data were used, regardless of height, cover of perennial shrubs increased on 82% of sites. Average increase per site was 50% and cover increased for 95% of species • The increases for decreaser, increaser and intermediate species were approximately similar • When the data were filtered to include only those shrubs less than 1.5 m in height (to remove the effect of large, relatively stable shrubs like mulga), the cover of perennial shrubs increased on 79% of sites. The average increase per site was 71% and cover increased for 98% of species. • Cover progressively decreased with the dry years from 2000 onwards. Decreaser species declined in cover more so than increaser and intermediate species. On 42 WARMS grassland sites: • Crown cover of woody species increased at 30 sites measured sometime

Region	Measured or observed change
	between 1997–99 and 2000–02 (mostly 1999 and 2002) • Crown cover decreased at 10 sites during this time period
Gawler	Step point measurements at 179 sites: • There was a small (non-significant) increase in cover of perennial species averaged across all sites • The majority of sites maintained their cover through the reporting period (all components combined) • Statistically significant reduction in cover of perennial species for the 'mulga over perennial and annual grasses' vegetation type • Significant increase in bare ground and a decrease in cover of annuals and litter at sites in five (of 11) vegetation groups • These changes were mainly attributed to seasonal conditions at the time of measurement
Darling Riverine Plains	Ranked cover score in quadrats at 45 Northern Floodplain RAP sites: • General trend of increasing cover with better seasons between 1994 and 2000 then a decrease with drought (e.g. ~80% average cover in 2000, 40% in 2002). However, in all bioregion provinces except Bogan–Macquarie, cover in the 2001–02 drought was higher than in the 1992–94 period • Cryptogam cover was generally less than 5% throughout. Although low, this is considered satisfactory for these grey cracking clay floodplain soils (Grant 2005) • Very low levels of recorded erosion (<2%) indicating soil stability • Thickets of juvenile coolibah (*Eucalyptus coolabah*) and black box (*E. largiflorens*) are common on more frequently flooded parts of the floodplains. Woody species were not significant at most RAP sites. On 15 representative sites, average canopy cover increased by 31% from 1.56% to 2.04%
Desert Uplands	Ranked percentage ground cover in quadrats at 34 QGraze sites reassessed at various times: • Cover, averaged across sites, was relatively low (<40%) between 1994 and 1996, and in 1998 and 2003. Between 1999 and 2002, cover was considerably higher (~50%) • Three of 21 sites had >50% cover in the drier years at the start of the reporting period (1992–95); 14 of 27 sites had >50% cover in the wetter years 1999–2001 and one of five sites exceeded 50% cover in the dry years 2003–04 • These trends are indicative only. Ground cover is estimated as a rank score and there are two broad classes either side of the 50% cover. Cover estimates are affected by the amount of time since rainfall, the amount of leaf fall and fire

Region	Measured or observed change
Victoria River District	Vegetation cover measured at 33 Tier 2 sites between 1995 and 2003: • Cover, averaged across sites, increased from 33% in 1996 to 53% in 1999 and then declined to 44% in 2003. Fire is considered largely responsible for the cover decline in 2003 Landsat-derived cover change on Basalt Plains land type: • Basalt Plains occupy ~40% of the Ord–Victoria Plains bioregion. Average cover on this land type in paddocks >80 km^2 was generally higher and more stable between 1993–2003 compared with the previous decade. (Apart from the 1997–98 wet season, the latter decade was a wetter period) • There were two modes of behaviour in cover for paddocks following the poor 1991–92 wet season (see Figure 6): (i) 31 (of 50) paddocks appeared to display greater resilience by reaching a relatively stable plateau of maximum average cover in the following year (ii) 19 (of 50) paddocks took longer to reach peak average cover, and their cover level remained below that of more resilient paddocks • The trend in cover has been one of stability for paddocks with greater resilience (see (i) above), and increasing for the indicated less resilient paddocks (see (ii) above)

Figure 6 illustrates the procedure used to assign a 'resilience score' for selected paddocks in the Victoria River District. Karfs and Trueman (2005) analysed yearly cover change in 50 'large' paddocks (area >80 km^2) within the Basalt Plains land type of the Ord–Victoria Plains bioregion. Their data for a sample of the paddocks show that:

- Average paddock cover in the period 1993–2003 was generally higher than in the preceding decade (black dashed line). The cover index was either Landsat MSS band 2 or TM band 3 (i.e. red band) with images acquired in August or September following each summer wet season.

- Cover declined sharply following the poor wet season of 1991–92.

- In the following wet season (1992–93), there appeared to be two modes of cover response (grey-shaded box):

    - Good cover response ('green' paddocks with higher resilience), where average cover appeared to plateau at a relatively stable level (apart from the poorer wet season of 1997–98).

    - Lower cover response ('red' paddocks with lower resilience), where average cover increased more slowly and generally remained below the average of all paddocks.

- During the period 1993–2003, the trend in cover was stable for the higher-resilience ('green') paddocks, and increasing for the seemingly less-resilient ('red') paddocks.

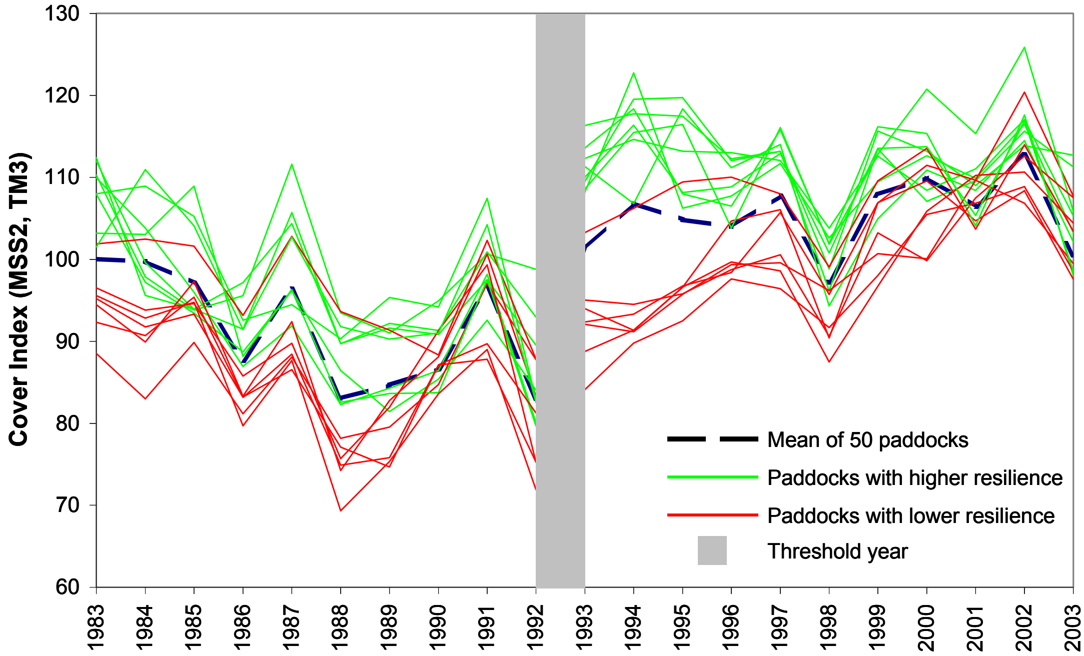

Figure 6 **Yearly time traces of average cover on Basalt Plains combined land type in selected paddocks of greater than 80 km^2.**

(Figure adapted from Karfs and Trueman 2005.)

Rainfall as a contributor to detected change

Using the framework outlined in Section 2 and illustrated in Table 3, the following tables attempt to partition rainfall effects on vegetation change reported in Table 34.

Gascoyne–Murchison

WARMS shrubland sites

Table 35 **Percentage of WARMS shrubland sites where cover of shrubs declined, remained stable or improved under prevailing seasonal conditions in the five years prior to reassessment**

Seasonal conditions	# Sites	Decline	No change [1]	Improvement
Above average	428	3	4	93
Average	166	20	25	54
Below average	106	58	15	26

[1] Cover threshold of ±10% was used for the 'no change' category.

The data were filtered to exclude shrubs >1.5 m high, to remove the influence of large, relatively stable tall shrubs and trees, such as mulga.

WARMS grassland sites

Table 36 **Percentage of WARMS grassland sites where the cover ratio of woody perennial species changed between 1997–1999 and 2000–2002**

Cover ratio is the ratio of crown cover in the period 2000–02 to that of 1997–99.

Seasonal conditions	# Sites	Decline	No change [1]	Improvement
Above average	42	21	14	64
Average	–			
Below average	–			

[1] Cover threshold of ±10% was used to categorise 'no change'.
– i.e. 0.90 ≤ Crown Ratio <1.10

Change in shrub cover at shrubland sites appears to largely accord with antecedent rainfall. The majority of sites measured following above-average seasons had increased shrub cover – the expected result. One-quarter of sites assessed following below-average seasonal conditions also had increased shrub cover, going against the expected trend of cover loss. During this same adverse period, a little more than half of the sites assessed lost shrub cover – conforming with expectations.

While most grassland sites maintained or improved their level of woody cover following above-average seasons, one-fifth of sites showed a decline in woody cover – suggesting that factors other than rainfall were responsible for the decline.

Gawler bioregion

The change in total cover at monitoring sites reassessed through the reporting period is summarised in Table 37. 'Total cover' is all cover categories excluding bare ground.

Table 37 **Percentage of pastoral monitoring sites in the Gawler bioregion where total cover declined, remained stable or improved under prevailing seasonal conditions in the five years prior to reassessment**

Seasonal conditions	# Sites	Decline	No change [1]	Improvement
Above average	n/a			
Average (2001)	104	8	88	4
Below average (2002)	75	4	87	9

[1] A tolerance of ±10% in total cover was used to categorise 'no change'.

These results indicate that the majority of sites maintained their cover through the reporting period – largely conforming with the expected result.

Darling Riverine Plains bioregion

Northern Floodplain RAP sites have been assessed annually. We have used the same procedure as for Question 1 (Table 12, page 65) to partition change in cover at sites according to prior seasonal conditions. That is, change in (averaged) cover at each site between 1992–94 and 1995–2001 represents change through a period of above-average rainfall and change for the period 1995–2001 to 2002 represents change for a period of below-average rainfall.

Table 38 Percentage of RAP Northern Floodplain sites where ground cover declined, remained stable or improved under prevailing seasonal conditions prior to annual reassessments

Seasonal conditions	# Sites	Decline	No change [1]	Improvement
Above average	44	2	30	68
Average				
Below average	44	77	18	5

[1] A tolerance of ±10% was used to categorise 'no change'.

Cover changes recorded at RAP sites appear, to some extent, to be damped against seasonal variability, with cover remaining stable at 18% of sites despite below-average rainfall, and improving at a further 5% of sites. With improving seasonal conditions, cover improved at two-thirds of sites and remained stable at almost one-third of sites.

Desert Uplands bioregion

A similar procedure to that described for Question 1, 3P grass frequency (Table 13, page 66) was used to partition seasonal effects on cover from possible management effects (Table 39). Briefly:

- Change in ground cover between 1992–95 and 1996–98 is summarised in the 'average' (seasonal conditions) row of Table 39.
- The period 1999 to 2001 was assigned 'above average' and two groups of sites were included in this row of Table 39:
  – Sites assessed between 1992–95 and then not assessed again until sometime in the period 1999–2001 (6 sites)
  – Sites assessed in the period 1996–98 and again between 1999 and 2001 (21 sites).

- 2002 to 2004 was labelled a ‘below average’ period (3 QGraze sites assessed by QNRM during this period).

Table 39 Percentage of QGraze monitoring sites where ground cover declined, remained stable or improved under prevailing seasonal conditions prior to, and at the time of, various assessments

Seasonal conditions	Period	# Sites	Decline	No change [1]	Improvement
Above average	1999–2001	27	0	37	63
Average	1992–95 to 1996–98	12	25	33	42
Below average	1992–95 to 2002–04	3	67	33	0

[1] Cover threshold of ±10% was used to categorise ‘no change’.

These data conform to pastures that are performing to their peak potential under moderate to heavy grazing pressure. In good seasons two-thirds of the pastures showed an obvious improvement in ground cover and one-third maintained historic cover levels. In a run of poor seasons, no sites had substantially improved cover and two-thirds showed an obvious drop in cover.

Victoria River District

Two season-by-change matrices are shown for cover data in the VRD. The first (Table 40) seeks to partition the influence of wet-season rainfall on cover change at Tier 2 monitoring sites (ground data). The second (Table 41) reports change at the paddock scale based on average cover levels, determined from Landsat data, for the Basalt Plains land type from 1993 onwards (as illustrated in Figure 6).

Table 40 Percentage of Tier 2 monitoring sites where cover declined, remained stable or improved under above-average seasonal conditions experienced between 1996 and 2003

Seasonal conditions	Period	# Sites	Decline	No change [1]	Improvement
Above average	1996 to 1999	33	9	18	73
	1999 to 2003	33	46 [2]	33	21
	1996 to 2003	33	12 [2]	39	49

[1] Cover threshold of ±20% for 'no change' category – based on standard deviations of cover variability among sites for each year (1996 – 14.8%, 1999 – 20.9%, 2003 – 21.4%).

[2] Cover decline mainly attributable to fire as a result of fuel accumulation during the extended period of above-average wet-season rainfall.

The Tier 2 remote sensing–based Land Cover Change Assessment method determines trends in cover change through time. It is necessary to categorise the rate of cover change as well as the direction. Karfs and colleagues have developed methods for this (see Karfs and Trueman 2005) but here it is presented in simplified form because the VRD experienced increasing cover under favourable seasons during the national reporting period (1993–2003, Figure 6). Paddocks displayed two modes of cover increase during the majority of this period. One group had apparently greater resilience by reaching a plateau of near-maximum average cover in 1993, one year after the poor wet season of 1991–92. Cover also increased for the second group, but much more slowly (since 1983, paddocks in this group always had average cover levels lower than the first group – see Figure 6). Because average cover increased in all paddocks, it is inappropriate to partition paddocks into columns of 'decline', 'no change' and 'improving'. Rather, a slightly modified version of the schema for ground data is used, but the paddocks are categorised in terms of direction and **rate** of cover change (Table 41, extra column added). This approach to partitioning seasonal effects needs further testing, particularly with regard to cover change in poorer seasons. In Table 41 the rate of cover increase after a poor year is used (i.e. 1991–92 wet season as a threshold) but this may not always be appropriate.

Table 41 Percentage of paddocks showing different directions and rates of change in average cover on the Basalt Plains land type

Seasonal conditions	# Paddocks	Rapid decline	Slow decline	Slow improvement	Rapid improvement
Above average	50	not likely	0	38	62
Average					
Below average					not likely

Note:
Cover is based on Landsat MSS band 2 or TM band 3. Paddocks are >80 km^2 in area.

Ability to report change in cover

1. Although 'cover' is a seemingly simple property of vegetation, it is measured and reported in different ways by the different jurisdictional monitoring programs.

   For example, WARMS shrubland monitoring (Gascoyne–Murchison) reports on more persistent cover as calculated from the circular area of shrubs in fixed transects. This form of cover measurement is less affected by short-term seasonal variation (e.g. time of year at which measurements are made in relation to rainfall and grazing).

   QGraze (Desert Uplands) uses ranks of percentage cover in quadrats to estimate ground cover (tree basal area is measured and reported separately with TRAPS; few data are available for the Desert Uplands and not reported here). QGraze cover measurements seem potentially prone to short-term variation, due to events such as leaf fall (Ken Dixon, pers. comm.).

   The NSW Range Assessment Program uses a quadrat-based approach but a different ranking system (akin to dry-weight rank) to estimate soil surface cover (vegetation, cryptogam, erosion etc).

   Cover (ground layer and woody) is estimated with a combination of methods at Tier 2 sites (VRD). Short-term variability could affect estimates of ground cover but this is reduced by monitoring at approximately the same time each year (i.e. approximately similar time since end of growing season).

   The SA Pastoral Monitoring Program (Gawler bioregion) uses the step point method to obtain a fairly rapid estimate of cover type (perennials, annual and litter, bare and other [including stones and lichen]).

   Both RAP quadrat-based and SA step point estimates of cover will reflect seasonal conditions (e.g. time since rainfall). RAP seeks to reduce the effect by monitoring at the end of the expected growing season. For the Gawler bioregion, perennial cover should be less affected by seasonal variation than annuals and litter.

2. The differences in monitoring methods mean that it is not possible to make direct comparisons among regions. However, there are some emergent similarities – mainly that cover (as reported) increases in better seasons and decreases in poorer seasons. The VRD goes against this trend where cover has decreased at the most recent recording (2003) under continuing good seasons. This is presumed to be due to the influence of wildfire in fragmenting perennial grass tussocks and consuming litter.

3. As is the case for Question 1 (critical stock forage productivity) and Question 3 (landscape function), repeat measurements at sites provide a good indication of change for these fixed areas. To the extent that sites are representative of broader areas (e.g. land types), it is probable that reported change in cover can be extrapolated to larger areas (landscapes). Some programs have a restricted spatial distribution of sites (QGraze, RAP, Tier 2 ground sites) and it is likely that sites inadequately report cover change across the whole of these regions. In all cases, the logistics of ground-based monitoring means that there are landscape types (and/or component landscape elements) that are inadequately monitored. In some cases, this may matter for overall landscape stability (e.g. maintenance of cover to minimise erosion) and maintenance of landscape and ecosystem function. Typical (and possibly critical) areas within

bioregions that may fail to be adequately monitored include break-of-slope and riparian areas.

4. Allied with monitoring of cover to check on landscape stability (e.g. adequate cover to minimise erosion) is the time of year at which assessments are made. Cover is most important at times of high erosive forces, be they wind or rain. In most regions of northern Australia, this is at the end of an often-prolonged dry period (i.e. pre-wet season). Thus, monitoring sites at the end of the wet season (e.g. to assist plant identification) may over-estimate the 'practical' cover value. (Conversely, the timing may be reversed in southern Australia – plant identification is easiest in spring following winter rain but cover levels are critical in late summer and autumn.)

5. In contrast, remote sensing can provide the 'global' view – provided the results are sufficiently ground-truthed to assure their validity. Cover indices are a fairly standard product from satellite data and the image archive, particularly for Landsat, allows retrospective monitoring of cover. Landsat MSS and TM data have provided a more comprehensive view of cover change for part of the VRD ('core' area, Karfs and Trueman 2005) while data for a shorter time period are available for a larger area of the VRD (results available in Karfs and Trueman 2005 but not cited here). The Queensland Department of Natural Resources and Mines is expanding Landsat-based analysis of cover change into the Desert Uplands with their 'multiple regression bare ground index' and SLATS database (preliminary results illustrated in Bastin 2005). The Queensland Environmental Protection Agency intends using this index with Land Cover Change Analysis to determine change in land condition. However, neither method is yet sufficiently proven to report publicly on cover (and land condition) change.

6. Remote sensing–based methods should be seriously considered for any future expanded reporting of cover change by ACRIS, if such cover data are shown to link well with landscape process rates such as runoff, erosion or vegetation biomass. More research needs to be done to quantify the degree to which cover changes within each year and to develop relationships between cover at different times of the growing cycle and under different climatic sequences.

SECTION 9 – CONCLUDING REMARKS

This section aims to integrate, in a highly summarised form, information provided in answer to each of the five questions, and comments on institutional capacity for reporting change in the rangelands at larger scale. It contains the following components:

- An assessment of the quality and appropriateness of various data assembled to answer each question.
- A synthesis of our approach to meta-analysis of data and information used to compile this national report.
- A synthesis of key issues for expanded reporting by ACRIS.
- An appraisal of the capacity of States and the NT to undertake further reporting of change at larger scale.

Quality of answers to questions

The following assessment is adapted from that used by the Intergovernmental Panel on Climate Change, where they assign a descriptive 'confidence' level to their reporting. We have based our 'confidence limits' on:

- Relevance of data to the question.
- Data quality based on methodology and presentation (e.g. how well the data represent change at the site scale).
- Spatial adequacy (or representativeness). Site data cannot provide total representation but their adequacy can be compared through criteria such as number of land types present that are sampled, site density per land type, consistency of sampling distance with respect to water etc.
- Temporal adequacy – even annual assessments will have limitations in adequately representing seasonal trends.

A draft template for assessing the above criteria has been provided by Russell Grant (Table 42). The detail in individual cells needs to be agreed upon and this could be a worthwhile exercise for the ACRIS Management Committee. When agreed upon, these criteria (or suitably adapted ones) should provide improved transparency in assigning confidence limits.

Table 42 Criteria for assigning confidence limits to data types used in reporting change

Component	Rank for assigning confidence limit		
	High	Medium	Low
Relevance	Actual measurement	Index of surrogate	Data type inappropriate
Data quality	Transect/quadrat based	Surrogate measurement	Qualitative assessment
Spatial adequacy	Remotely sensed	Sampling density >X (specify X)	Sampling density <X (specify X)
Temporal adequacy	<3 yearly cycle?	3–5 year cycle?	>5 yearly cycle?

In the absence of specified criteria for all cells in Table 42, I have made a more subjective assessment based mainly on the relevance and spatial adequacy of listed information sources to each question (Table 43). This assessment uses a three-rank scoring system (high, medium or low) for relevance and four ranks for spatial adequacy (very high, high, medium or low). The rankings are highly qualitative. However, the scoring system should serve to differentiate the quality of information sources, in that a monitoring system that delivers highly relevant data with very high spatial density obviously provides a more reliable (i.e. confident) answer than one that is rated low for both criteria. (I have not included a quality assessment for temporal frequency in Table 43 because most monitoring systems have two data points [time 1 and time 2]. I have noted where more temporally frequent data are available.)

A quick look through the table reveals that remotely sensed data with wide area coverage (i.e. available for the entire area of each region) score most highly for 'spatial adequacy'. Data collected at ground sites generally scored moderate to high (low for QGraze sites because of the generally small number with suitable repeat assessments). Pastoral monitoring systems generally provide suitable data (and information) for answering Question 1 (change in critical stock forage productivity) and Question 5 (change in cover). Their performance varies for Question 3 (change in landscape function) with the information being most relevant where formal landscape function is assessed and scoring lower where vegetation and soil surface attributes are transformed to an index that may represent landscape function. Not surprisingly, data from pastoral monitoring systems do not rank as highly relevant in answering Question 2 (change in native species) – highlighting the need for more dedicated or tailored systems for monitoring components of biodiversity.

Table 43 Quality rankings of information sources used to answer Questions 1 to 5

Region	Information source	Relevance to question	Spatial adequacy
Q1: Change in critical stock forage productivity			
All	Aussie-GRASS – simulated total standing dry matter	Moderate provides seasonal context but not actual change	High
Gascoyne–Murchison	WARMS shrubland sites – density of decreaser shrub species	High	Moderate to high
	WARMS grassland sites – frequency of decreaser perennial grasses	High	Moderate to high
Gawler	Pastoral monitoring sites – density of decreaser perennial chenopods and grasses	High	Moderate (10% sample of all available sites)
Darling Riverine Plains	Northern Floodplain RAP sites – frequency of 2P grasses	High	Moderate (high temporal frequency)
	Northern Floodplain RAP sites – density of palatable chenopod species	High	Moderate
Desert Uplands	QGraze sites – frequency of 3P grasses	High	Low
	GrassCheck sites – frequency of desirable grasses, pasture yield (presented in regional report, not this synthesis – data confidential and not able to track change at site level)	Low to moderate (site data not available)	Moderate
VRD	Tier 1 sites – assessed condition score	Moderate	Moderate to high
Q2: Change in native plant (and animal) species			
Gascoyne–Murchison	WARMS shrubland sites – density of shrubs	Moderate	Moderate to high
	WARMS grassland sites – frequency of perennial grasses	Moderate	Moderate to high
	WARMS shrubland and grassland sites – species richness	Moderate	Moderate to high
Gawler	Pastoral monitoring sites – density of perennial chenopods, other shrubs and grasses	Moderate	Moderate (10% sample of all available sites)
Darling Riverine Plains	Northern Floodplain RAP sites – diversity of chenopod and herbage species	Moderate	Moderate (high temporal frequency)
	Satellite-based monitoring of area under cultivation	Moderate	High

Region	Information source	Relevance to question	Spatial adequacy
	Aerial surveys of kangaroo populations	Moderate but difficult to establish trends because of changing methodology	Moderate to high
Desert Uplands	QGraze sites – frequency of native and exotic plant species	Moderate	Low
	EPA – repeat flora and fauna surveys	High	Low
	SLATS – extent of tree clearing	Moderate	Very high
VRD	Plot (experimental) to regional-scale studies of vegetation change	Moderate to high	Low to moderate
	Extent of land clearing	Moderate	Very high
	Use of exotic pasture species	Moderate	Low
Q3: Change in landscape function			
Gascoyne–Murchison	WARMS sites – formal landscape function assessment	High	Moderate to high
Gawler	Pastoral monitoring sites – change in RGFI	Moderate	Moderate (10% sample)
Darling Riverine Plains	Northern Floodplain RAP sites – adapted form of RGFI	Moderate? (further testing needed)	Moderate (high temporal frequency)
	At landscape scale, altered flooding regime resulting from upstream water diversions	Moderate	High
Desert Uplands	QGraze sites – adapted form of RGFI	Moderate? (further testing needed)	Low
VRD	Tier 2 sites – formal LFA	High	Low
	Tier 2 remote sensing – time traces of cover at landscape scale	Moderate	Very high
	Tier 1 sites – change in proportion of sites where perennial grasses recorded	Moderate? (further testing needed)	Moderate to high
Q4: Capacity for change			
All	ABS regional socio-economic profiles	Moderate	High
Gascoyne–Murchison	Change in livestock numbers	Moderate	High – all pastoral leases
	Expansion of conservation estate	Moderate	Moderate
	Participation by pastoralists in EMU (improved ecological understanding)	Moderate to high	Moderate
	Financial indicators of pastoral production from regional benchmarking	Moderate to high	Moderate

Region	Information source	Relevance to question	Spatial adequacy
Gawler	Change in sheep numbers	Moderate	High – all pastoral leases
	Change in land use	Moderate	High – all pastoral leases
	Change in unimproved capital value	Low to moderate	High all pastoral leases
Darling Riverine Plains	Expansion of cropping (change in land use)	High	Very high (from remote sensing)
	Change in stock numbers	Moderate	High – all pastoral leases
	Change in land values	Low to moderate	High – if region-wide
Desert Uplands	Comments with regard to Desert Uplands Build-up and Development Strategy	Low to moderate	Low to moderate
VRD	Change in cattle numbers and turnoff	Moderate	High – region-wide
	Change in value of properties sold	Low to moderate	Low
	Change in proportion of company- and family-owned stations	Moderate	Moderate – region wide
	Number of Aboriginal people engaged in natural resource management	Moderate to high	Low
Q5: Change in cover			
All	Aussie-GRASS – simulated cover	Moderate – provides seasonal context but not actual change	High
	AGO – change in forest cover	Moderate – limited area of forest in rangelands	High – difficulty validating Gascoyne–Murchison results
Gascoyne–Murchison	WARMS shrubland sites – canopy cover of shrubs	Moderate – cover of shrubs only	Moderate to high
	WARMS grassland sites – crown cover of woody species	Moderate – woody species only	Moderate to high
Gawler	Pastoral monitoring sites – cover by type	High	Moderate (10% sample)
Darling Riverine Plains	Northern Floodplain RAP sites – estimated ground cover, cover of chenopods and woody species	High	Moderate (high temporal frequency)
Desert	QGraze sites – estimated ground cover	High	Low

Region	Information source	Relevance to question	Spatial adequacy
Uplands	SLATS – extent of tree clearing	High	Very high
	SLATS – index of ground cover	Moderate (developmental product)	Very high
VRD	Tier 2 sites – cover by type	High	Low
	Tier 2 remote sensing – time traces of cover at landscape scale	High	High

Concluding comments on meta-analysis

In Section 1 ‘Approach in answering questions’ (page 31), we introduced the concept of ‘meta-analysis’ for comparing results to the five questions among the five regions. To reiterate, this meta-analysis was necessary because of the diversity of answers generated from different datasets. These differences arise because of:

- Environmental differences among regions across Australia’s rangelands – expressed through different climates and levels of variability, soil differences and related vegetation communities.

- Differences in (pastoral) land use in terms of inherent productivity, type of grazing animal and intensity of use.

- The different purposes of institutional monitoring systems giving rise to different data collection methods, data types and reporting methods.

These differences will persist and it is important that we continue to refine and improve our methods for meta-analysis and synthesis for national-level reporting of change in the rangelands. However, we should also accept that because of the diversity of climates, landscapes and land uses across the rangelands, it may often be inappropriate to report results at a highly integrated level if such reporting loses regional relevance. In support of this, Stafford Smith et al. (2000) have argued that rangeland policy should recognise and accommodate the diversity of the rangelands.

Figure 7 schematically summarises the meta-analysis procedure used in this report – in a sense, our ‘state of play’ with meta-analysis. The intent with further reporting should be to improve the objectivity, rigour and transparency of meta-analysis by:

- Increasing (where possible) the quantitative nature, spatial extent and similarity of data types used for reporting among regions.

- Improving our competency and sophistication in using meta-analysis techniques.

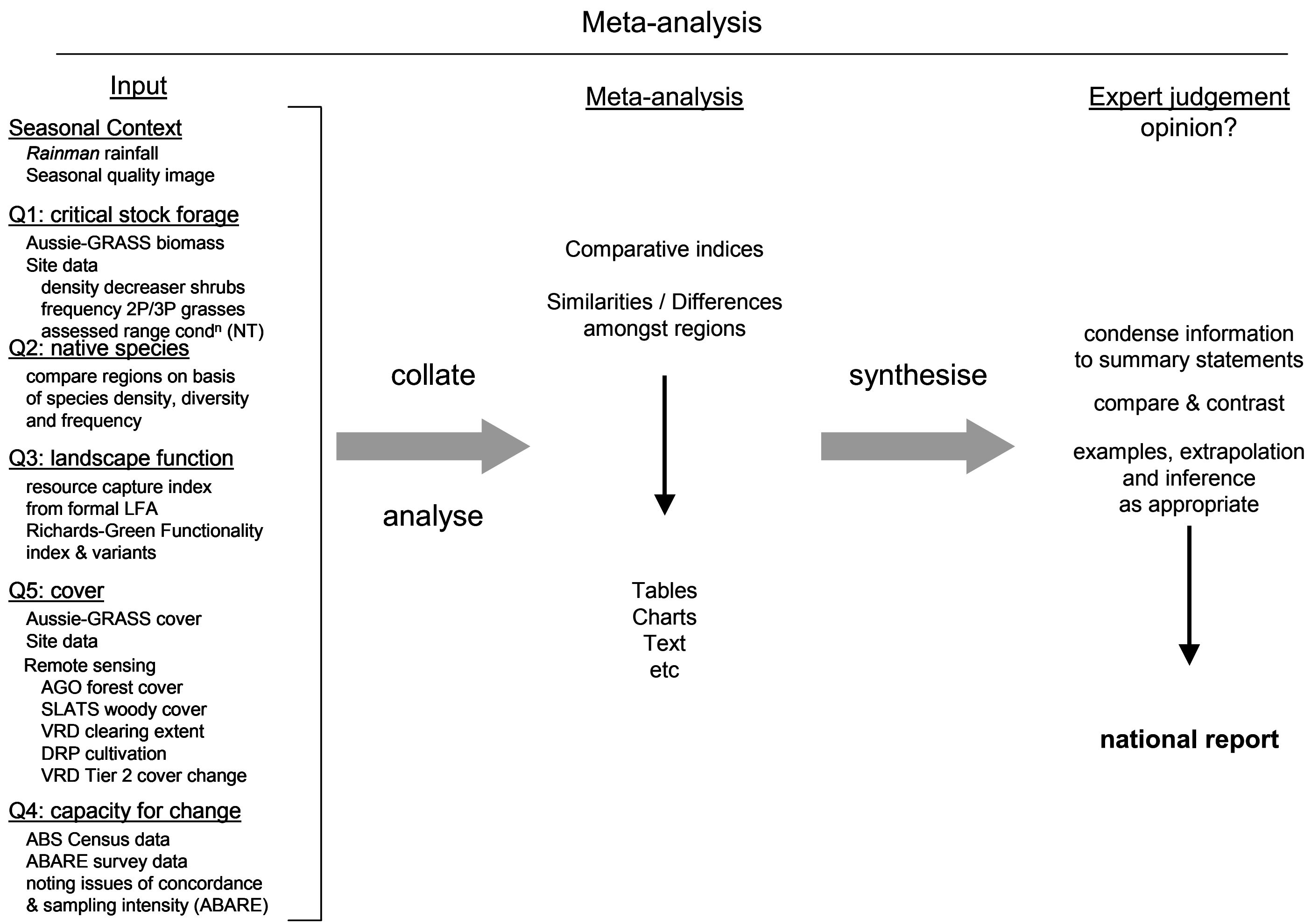

Figure 7 **Schematic summary of meta-analysis**

Key issues for further reporting

The following comments are sourced from discussion among members of the ACRIS Management Committee and Management Unit as reports for pilot regions and this synthesis were being finalised. It contains an assessment of achievements (lessons learnt) from having conducted this activity and issues that affect the capacity for expanded reporting.

Achievements

- Compilation by participants of regional reports that met the requirements of ACRIS reporting and had additional value to government agencies and other interest groups within jurisdictions by providing a more substantive account of the region. This was the case for all regions except the Desert Uplands, where reporting was conducted by the Management Unit and focussed closely on only the four biophysical questions (Questions 1, 2, 3 and 5). Reports compiled for the other four regions should have an increased utility because they deliver value to multiple stakeholders.

- The matrix of seasonal quality by direction of change as a filter for sharpening management effects on natural resources. We still have some learning to do on how to best implement this filter across all regions, and there are still considerable challenges in quantifying the extent to which grazing (and other management) is a driver of change, but this is a worthy first step in the partitioning process.

- Our first steps in understanding and using meta-analysis to integrate and synthesise different, and often disparate, datasets (as described above). We still have some way to go to improve our techniques for meta-analysis and integration of differing information but now have a better understanding of some of the steps required for improvement.

  Statistical techniques that identify outliers leading to the legitimate discounting of their influence on the overall result may increase the robustness of future syntheses.

  Fortunately there are some parallels in methodology among monitoring systems that assist in the comparison of results – for example:

  - Frequency of perennial grasses (Rangeland Assessment Program, NSW; QGraze, Qld; and WARMS grassland sites, WA).

  - Density of shrubs, especially chenopod (WARMS shrubland sites, WA; Jessup transects, SA; and RAP, NSW). The SA chenopod data are amenable to some of the demographic analyses developed for WARMS. QGraze would include such density counts but sites used to date have not contained fodder shrubs.

Issues affecting current and further reporting

The most critical issues for expanded (even continued) reporting by ACRIS relate to the availability of suitable data and institutional capacity. These issues are described in greater detail under 'logistical issues' below.

General issues related to monitoring

- There are considerable (often vast) differences in scale and resolution of data used for reporting – but data collection methods are generally focussed at the point (i.e. site) scale. Remote sensing using the expanding archive of standardised satellite imagery should be able to contribute more to reporting change, provided analysis techniques are used to account for seasonal variation (e.g. land cover change analysis, grazing gradient analysis) and sufficient resources are available for ground truthing results and training agency personnel. Examples of standardised image archives include the SLATS database in Queensland, AGO's Landsat database for monitoring change in forest cover (images and some products are becoming increasingly available to government agencies and the public) and the NOAA AVHRR archive.

- Inevitably, there is varying rigour in the data of pastoral monitoring systems – mainly because each serves a different purpose and was developed with that purpose in mind. In terms of extracting trends due to grazing management, the WARMS shrubland system is perhaps the most rigorous (focussing on the demography of longer-lived shrubs and perennial grasses).

  Tier 1 monitoring in the NT collects rapid visual assessments of range condition similar to Stocktake in Queensland, the Land Condition Index method in South Australia and Range Condition Assessments in Western Australia. For rapid monitoring techniques, repeatability among observers and accuracy of plant identification are known issues, with reliability dependent on the skill and knowledge of the observer. Thus it is a marked change in the number of sites moving between condition classes over time that is of significance for rapid land condition monitoring. Obviously it is not possible to drill into recorded assessments to extract detailed information for direct comparison with more quantitative data from other jurisdictional monitoring programs. Nevertheless, less accurate but spatially robust rapid monitoring data have value to ACRIS. For example, the NT's Tier 1 system provides independent evidence of current conditions and vegetation change that is used as a 'reality check' for remote sensing–based analyses, and is the only systematic ground monitoring data set for all NT pastoral leases.

- Differences in spatial extent (coverage) of pastoral monitoring programs and the frequency of reassessment. The pilot regions were selected partly because they represented the best monitoring datasets available. Thus, capacity to report over larger areas for some jurisdictions is likely to be diminished (discussed further below). Equally, infrequent monitoring through time decreases our ability to confidently report change through time.

- Change in survey methodology over time diminishes the value of the monitoring record. This is illustrated by the difficulty in validly comparing the results of kangaroo survey data in western NSW. Changing methodology will likely be a continuing ‘hazard’ for reporting bodies like ACRIS.

- ACRIS doesn’t yet have access to suitable monitoring data to adequately report change in biodiversity. However, we can probably get a bit smarter in tracking down and reporting relevant information where available. The pilots unearthed substantial survey activity in the various regions, although rarely was this activity systematic or repeated so as to build a monitoring record. Our challenge in the absence of better monitoring data is to synthesise these various information sources into a coherent and accurate assessment of change (as best we can) while also recognising their limitations.

- We need to expand our ability and confidence in the socio-economic domain. Perhaps the best way of growing our capacity in this area is through the continued use of targeted questions (as in Question 4 for the current activity), commissioned analysis and reporting (e.g. further contracts with the Australian Bureau of Statistics or Bureau of Rural Sciences) and in repeating and extending the purpose-built survey developed during the first phase of the National Land and Water Resources Audit.

Logistical issues

- The absence of systematic public-domain ground-based monitoring in Queensland, especially in recent years, makes regional syntheses difficult. (GrassCheck monitoring is occurring in the Desert Uplands but the results at the site level are confidential. Monitoring of some TRAPS sites is occurring as part of funding for other projects but currently there is no systematic QGraze monitoring.)

  Similar uncertainty exists for the continued monitoring of RAP sites in western NSW with the establishment of catchment management authorities and their differing regional priorities. Although the core agency (Department of Infrastructure, Planning and Natural Resources) remains responsible for monitoring, the program is highly dependent on the involvement of the catchment authorities in field assessments.

  There are similar concerns about continued levels of support for WARMS monitoring in the WA rangelands. Ian Watson reports that in 2005 it will only be possible to meet 50% of the sampling schedule in the Pilbara and southern rangelands.

  These three examples indicate declining State institutional commitment to, and support of, ongoing regional environmental monitoring.

- Identified people are needed within agencies with the skills, experience and time to undertake expanded reporting. An alternative is the outsourcing of data collation, analysis and reporting to suitable consultants. Consultancies may be more convenient and efficient in the short term but detract from building agency human-resource skills for continued input to ACRIS. Without adequate agency capacity, archiving, continuity and use of the data could also run into difficulties.

Technical

- ACRIS needs to keep working on methods for effectively separating climate, grazing and fire as causes of change in biophysical data.

- We need to deal adequately with spatial variability in data across (bio)regions – both point (ground-based) and remote sensing data. We should resist the temptation to simply collapse data to the mean. It may be that in some cases, a meta-analysis statement based on the known complexity of the data and consideration of other input by 'experts' (local knowledge etc.) is preferable to collapsing the data into a mean so as to produce a table, or some other numerical summary. (This approach should be considered, even if the numerical approach seems a more rigorous approach at the time for keeping results at the data level for the sake of purity.)

- ACRIS should explore ways of effectively reporting change in landscape function in the absence of formal (LFA) data – e.g. the RGFI and possible variants. The Richards-Green Functionality Index currently requires that subjective condition ratings be assigned as input. Approaches that provide greater transparency and less subjective input may be more appropriate if they can produce robust useful results. We probably have some opportunity to develop and test alternative indices of landscape function using the formal LFA data from WARMS (WA) and NT Tier 2 as input.

- The interpretative usefulness of current cover estimates with respect to resource degradation or improvement is in question. If the data do not refer to the time of greatest vulnerability, what confidence do we have in moderating/modelling the raw data to make it applicable to that critical time, before or after the time of data acquisition?

- There could be better linkages across data of different scales within bioregions. For example, possible change in landscape function was reported at two scales for the Northern Floodplains of the Darling Riverine Plains (NSW) – at point level with RAP site data and at regional scale with flood data. Are there linkages and relationships between the two datasets? What implications do the altered flooding regimes have for the maintenance of landscape function at the site to paddock level? It would be interesting (and hopefully insightful) to explore the relationships between these point and regional-scale data.

Other comments

- Responses to Questions 2 and 4 demonstrated participants' ingenuity in accessing diverse data. While this is commendable, there is a downside in that diversity can produce inconsistency of data and results among regions, thus making comparisons difficult.

Institutional capacity for further reporting

At the March 2005 Management Committee meeting in Dubbo, we made an assessment of jurisdictional capacity to undertake expanded reporting against the ACRIS reporting products described in *Rangelands – Tracking Changes*. The assessment is summarised in Table 44. It forms the basis of discussions with individual States and the NT for the development of jurisdictional workplans that are intended to achieve reporting of change for as much of the rangelands as possible. Also included at the end of the table are additional national level datasets considered integral to expanded reporting.

Table 44 Assessment of jurisdictional capacity to contribute to reporting of change via *Tracking Changes* products

Theme	*Tracking Changes* product	Measure	Capacity for reporting	
			Now [1]	Into the future
Probable products				
Landscape/Ecosystem (including soil)	2 Expanded landscape assessment (change in landscape function)	Landscape function assessment	Yes: WA – via WARMS and formal LFA NT – limited number of sites (currently 94 sites in the VRD and Sturt Plateau) SA – via RGFI (mainly in sheep-grazed rangelands). Limited number of reassessments (second round about to start) NSW – via RAP data and RGFI Qld: Possible via RGFI at QGraze sites but limited number of sites and most lacking recent assessment	Dependent on maintaining current monitoring activity Only if QGraze monitoring is reactivated and number of sites expanded
		Cover for protecting against soil erosion – site-based and remote sensing	Yes: Qld (some regions) via SLATS and bare ground index. All of rangelands for woody cover NT – most of pastoral leases with Tier 2 R/S NSW – via RAP sites WA – via WARMS sites SA – step pointing at pastoral monitoring sites (mainly sheep country and limited reassessments) May be feasible to do national assessment using AGO Landsat database	Possibly expanding capacity in Qld as SLATS bare ground index is more widely applied Elsewhere, dependent on maintaining current activity
		Plant density and frequency	Yes: WA – using WARMS SA – Jessup transects at pastoral monitoring sites (mainly sheep country and limited number of reassessments) NSW – RAP sites Qld: QGraze sites – but limited number and most lacking recent assessment NT: Limited – network of Tier 1 sites but quantitative vegetation data not collected	As above, maintain existing activity and expand QGraze activity in Qld Need to collect suitable data in NT

Theme	*Tracking Changes* product	Measure	Capacity for reporting		
			Now [1]		Into the future
	Additional (national) products	Dust Watch (Griffith University)	Yes	For much of rangelands and expanding	Yes
		Dust Storm Index (Bureau of Meteorology)	Yes	All of Australia (but noting that it is limited point-based data, often on the coast [e.g. Pt Hedland, Carnarvon, Broome etc] – but used to represent the rangelands inland)	Yes
	4 Regional resource condition assessments	Lease assessments (including Land Condition Index SA)	Yes No	WA, SA and NT Qld and NSW	As for 'now' cell
Biodiversity	12 Interpretation and reporting of clearing extent	Change in forest extent (AGO, NVIS data)	Yes	National product (forest definition of 20% canopy cover may mean limited applicability in the rangelands)	Yes – while AGO continues to update database and analyses
		Other remote sensing and ground data	Yes	Qld – SLATS database NT – using remote sensing NSW – Resource Assessment and Monitoring System	Probable for Qld, NT and NSW?
	3 Biodiversity monitoring and analysis	Native species diversity (or richness) (perennials)	Yes Qld No	WA, SA and NSW Limited to restricted set of QGraze sites NT (required information not collected at Tier 1 sites)	As for 'now' cell

Theme	*Tracking Changes* product	Measure	Capacity for reporting	
			Now [1]	Into the future
Sustainable management	2 Collate, interpret and report on currently collected pastoral estate information	Various – focussing on pastoral production (e.g. palatable composition)	Yes WA, NSW, NT SA Mainly in sheep-grazed rangelands (second complete round of lease assessments about to start) Qld QGraze sites suitable – but limited number and most lacking recent assessment	Yes – If maintain existing activity and expand QGraze activity in Qld Problematic that activity can be maintained for some States
	4 Updating of national photographic record	Photos	Yes All States and NT	Yes
	6 Predicting and managing pasture availability (Aussie-GRASS)	Simulated biomass and cover (plus other products if required)	Yes National product	Yes
	9 Fire	Extent, frequency and timing of fire	Yes Possible national product with ongoing development of satellite mapping/monitoring and associated databases	Yes

1 Collation, analysis and reporting by December 2006 for a national report by mid 2007.

Theme	*Tracking Changes* product	Measure	Capacity for reporting		
			Now [1]		Into the future
Possible products					
Water	Distribution of water points	Spatial database of waterpoint locations	Yes	Process for reporting needs further investigation	Yes
Biodiversity	3 Biodiversity monitoring and analysis	Contextual floristics (NVIS) May include 'condition' in future	Yes	Possible national product (requires further investigation)	Yes – if NVIS suitable
Biodiversity	3 Biodiversity monitoring and analysis	Collating biodiversity audits and surveys	??	Variable across jurisdictions – needs further investigation to determine value for national reporting	Possible expanding capacity?
Social/Economic	Changes in land value	Property sales Lease valuations etc	Yes	Further investigation and documentation of procedures for reporting required	Presumably yes??
Sustainable management	8 Total grazing pressure assessment (split into domestic and non-domestic [or even further into feral and native]. Note: strictly speaking, the data are not grazing pressure but some estimate of stocking rate or abundance per area)	Domestic livestock Kangaroos Goats Ferals (NT)	Yes Yes SA NT Note:	Various forms of estimate for all States and NT? Qld, SA, NSW and WA from aerial surveys Through Operation Bounceback (parts of SA) Nationally – possibly from 5-yearly ABS surveys Repeat aerial surveys Further investigation on feasibility of reporting required	??

Theme	*Tracking Changes* product	Measure	Capacity for reporting		
			Now [1]		Into the future
Additional national products					
Climate	7 Australia-wide interpretation of seasonal characteristics	*Rainman* Aussie-GRASS ERIN seasonal quality Other	Yes	Compile and distribute to States and NT as service by ACRIS Management Unit	Yes
Social/Economic	10 Australia-wide collation, interpretation and change in land use and tenure	From State and NT cadastre and databases	Yes	Our understanding is that this is being compiled as a NLWRA (Audit) product. ACRIS has a role in assisting to define categories (of tenure and use) for reporting to maximise utility (categories should include Indigenous land use, leases purchased by conservation groups, mining, Defence etc)	Yes
Water	1 Surface and groundwater information to report on water resource sustainability	Water resource data	No	Water is a major issue on the national agenda. ACRIS should keep a watching brief on reporting activity. If areas are missed / inadequately reported, ACRIS should consider picking these up	As for 'now' cell

[1] Collation, analysis and reporting by December 2006 for a national report by mid 2007.

Assessment made at Dubbo meeting of the ACRIS Management Committee (8–9 March 2005)

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ACRONYMS

2P (grasses)	Palatable and perennial (grasses)
3P (grasses)	Palatable, perennial and productive (grasses)
ABARE	Australian Bureau of Agriculture and Resource Economics
ABS	Australian Bureau of Statistics
ACRIS	Australian Collaborative Rangeland Information System
AGO	Australian Greenhouse Office
Aussie-GRASS	Australian Grassland and Rangeland Assessment by Spatial Stimulation
BTEC	Brucellosis and Tuberculosis Eradication Campaign
CRC	Cooperative Research Centre
DEU	Desert Uplands
DPI	Queensland Department of Primary Industries (Now Queensland Department of Primary Industries and Fisheries [QDPIF])
EMU	Ecological Management Unit
EPA	Environmental Protection Agency
ERIN	Environmental Resources Information Network
EVAO	Estimated Value of Agricultural Operations
FPC	Foliage protected cover
GMS	Gascoyne Murchison Strategy
GrassCheck	Pasture monitoring system for Queensland graziers
GS1	Geraldton Sandplain 1 (Edel) province of bioregion
IBRA	Interim Biogeographic Regionalisation of Australia
LFA	Landscape function analysis
NCAS	National Carbon Accounting System (of the Australian Greenhouse Office)
NDVI	Normalised Difference Vegetation Index
NLWRA	National Land and Water Resources Audit
NOAA AVHRR	NOAA – National Oceanographic and Aeronautic Administration AVHRR – Advanced Very High Resolution Radiometer
NRM	Natural Resource Management
NVIS	National Vegetation Information System
OR	Occurrence Ratio
PGR	Population Growth Rate
QDPIF	Queensland Department of Primary Industries and Fisheries (Previously Department of Primary Industries [DPI])

QGraze	Vegetation and soil monitoring system operated by QDPIF
QNRM	Queensland Department of Natural Resources & Mines
RAMS	Resource Assessment and Monitoring System
RAMSAR	International conservation agreement for the protection of wetland birds and their habitats
RAP	Rangeland Assessment Program
RCI	Resource Capture Index
RGFI	Richards-Green Functionality Index
SLA	Statistical Local Area
SLATS	Statewide Landcover and Trees Study
TRAPS	Tree Recording and Processing System
VRD	Victoria River District
WARMS	Western Australian Rangeland Monitoring System
WEST 2000	and WEST 2000 Plus – Regional strategy for environmental, economic and social renewal in the Western Division of NSW

APPENDIX 1 – ERIN IMAGES OF SEASONAL QUALITY

Background

The ERIN products, based on NDVI derived from continental NOAA AVHRR imagery, were proposed as contextual information to help interpret change measured on the ground and detected with higher resolution satellite data (e.g. Landsat). The product is described in *Rangelands – Tracking Changes* (Product 7, pp 64-7 and <http://audit.ea.gov.au/ANRA/rangelands/rangelands_frame.cfm?region_type=AUS&region_code=AUS&info=impact>).

Source data

Yearly images of seasonal quality for the period 1992 to 2003 were provided by ERIN. An example image can be seen at <http://www.deh.gov.au/erin/ndvi/images/seasqual/pdfrl02c.html>.

A description of the seasonal quality image product is available at <http://www.deh.gov.au/erin/ndvi/images/seasqual/pdfrl02c.html> and is reproduced below:

Seasonal quality analysis

"The hypothesis behind these analyses is that there is an increase in photosynthetic activity, or 'greenness', over the growing season. The magnitude of this increase is an indicator of quality of the season.

The NDVI flush for each pixel is compared temporally to give relative ratings of the quality of the season. These ratings are then displayed as images to give pictures of the variation in season quality across the landscape.

The flush this year (so far) can be expressed as a percentage of the flush range (where 0% is equal to the minimum flush and 100% is equal to the maximum flush). This relative, or scaled, percentage is then able to highlight areas that are yet to reach their previous minimum growth, as well as where they have exceeded the previous range. The analysis of past years is the same, but the new extents have been accounted for, so nothing is beyond the range limits.

Long-term products (Trend): The images are then analysed to produce across-season information."

(Extracted from <http://www.deh.gov.au/erin/ndvi/images/seasqual/pdfrl02c.html>)

Example of seasonal quality images

Seasonal quality images for the Gascoyne–Murchison region obtained from ERIN can be seen in Figure 8. These images show considerable variation in seasonal quality (as defined by ERIN) across the region within particular years (e.g. 1995, 1996, 1998, 2001) and between years (e.g. compare 1992 with 1993 and 1994 with 1995). In this sense, these images typify the climatic variability of the rangelands:

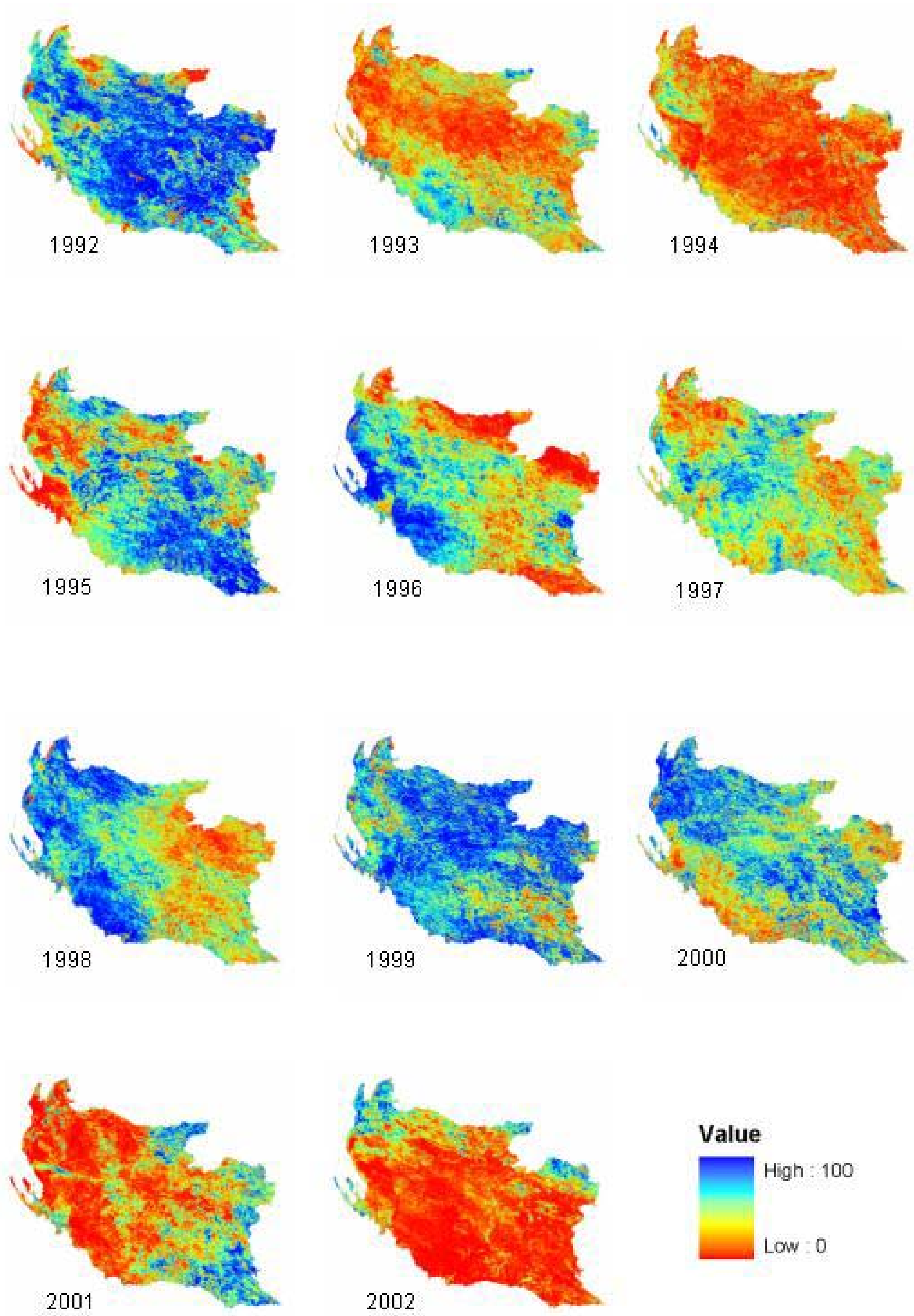

Figure 8 Yearly seasonal quality images of the Gascoyne–Murchison region based on NDVI and derived from NOAA AVHRR imagery

- Regions occasionally experience good conditions for vegetation growth (Gascoyne–Murchison – 1992, 1999).

- At other times, and probably more often, regions receive low rainfall and poor growth results (Gascoyne–Murchison – 1993, 1994, 2001 on western side, 2002).

- The large areas involved can mean that part of a region fares well while another part experiences poor seasonal conditions (Gascoyne–Murchison – 1995, 1996, 2001).

Mean seasonal quality across years

Calculating the mean seasonal quality value for each year (Figure 9) disguises much of the spatial variation in values but does illustrate year-to-year variation. To illustrate the magnitude of this damping across the very large area of the Gascoyne–Murchison (almost 600,000 km^2), we show yearly means for the whole region (Gascoyne–Murchison – dashed black line) and provinces (or sub-IBRAs, coloured solid lines) within bioregions. (The location and extent of sub-IBRAs is shown in Figure 10).

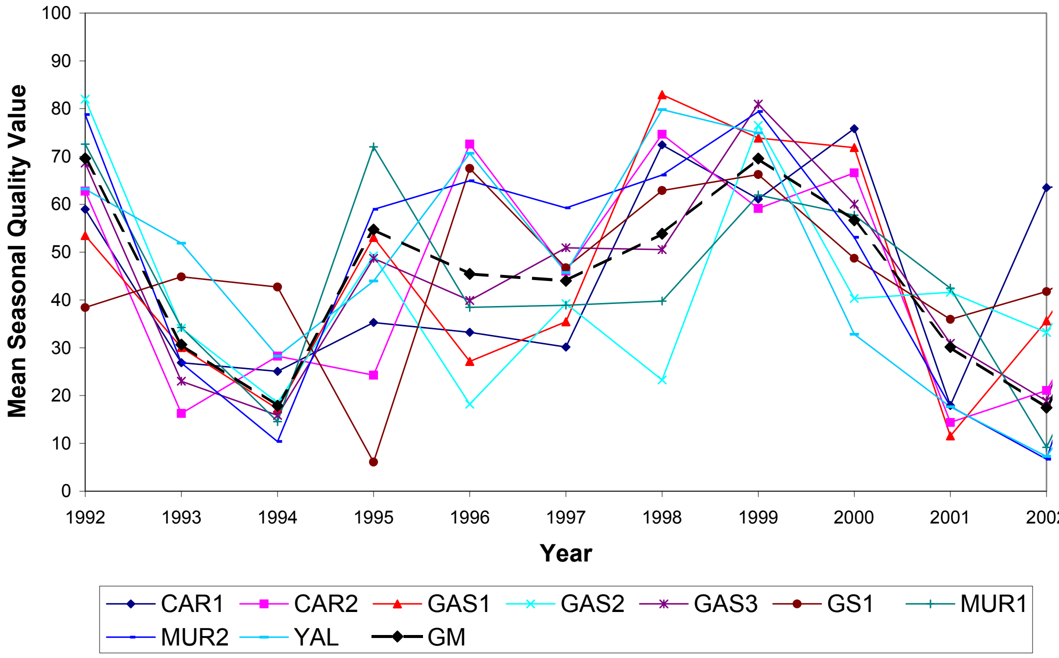

Figure 9 Mean annual seasonal quality values for sub-IBRAs and the entire area of the Gascoyne–Murchison region

The main features apparent from Figure 9 are:

- The considerable year-to-year variation described above. Most sub-IBRAs follow a general pattern, particularly from 1999 to 2003. The Geraldton Sands 1 (Edel) province of bioregion [GS1 (Edel)] sub-IBRA has a markedly different pattern of behaviour between 1992 and 1995.

- 1992 appears to have been one of the better years for vegetation growth (but seasonal quality was poorer for GS1). Seasonal quality then deteriorated to 1994 on all but one sub-IBRA (values among the lowest for all years, along with 2001 and 2002).

- Seasonal conditions improved for most sub-IBRAs in 1995 (but were very poor for GS1 [Edel] and poor for CAR1 and 2 [Cape Range and Wooramel]).

- There was a slight decline in seasonal quality across the entire Gascoyne–Murchison in 1996 and 1997 – but there was considerable variation around this overall mean. CAR2 (Wooramel), YAL (Yalgoo), GS1 (Edel) and MUR2 (Western Murchison) all improved between 1995 and 1996 while other sub-IBRAs deteriorated (only slightly for CAR1 [Cape Range]).

- Seasonal quality across most sub-IBRAs improved in the late 1990s to reach similar values to those recorded in 1992. For GAS2 (Carnegie), MUR1 (Eastern Murchison) and GAS3 (Augustus), this improvement did not come until 1999.

- Seasonal conditions then declined dramatically across most of the Gascoyne–Murchison in 2001 and 2002. This decline occurred a year earlier (2000) in the GAS2 (Carnegie) sub-IBRA. GAS2 values were similar in 2000 and 2001 and then declined a little further in 2002 – but were still better than for most other sub-IBRAs.

- Again GS1 (Edel) has had a different pattern of behaviour. Seasonal quality declined from a peak value in 1999 to a moderate value in 2001 and then improved a little in 2002. GS1 is near the coast and may receive some coastal rainfall. The response could also be due to infrequent cyclonic rainfall.

Figure 10 Bioregions and sub-IBRAs of the Gascoyne–Murchison region

- Seasonal quality improved considerably across most sub-IBRAs between 2002 and 2003 – and a year earlier for CAR1 (Cape Range).

Seasonal quality across regions

Based on the ERIN-produced images of seasonal quality, there was considerable variation in seasonal quality values within years among regions (Figure 11). This is not surprising in that regions are spread across the Australian rangelands and, as such, we are dealing with continental–level climate systems and their attendant variation.

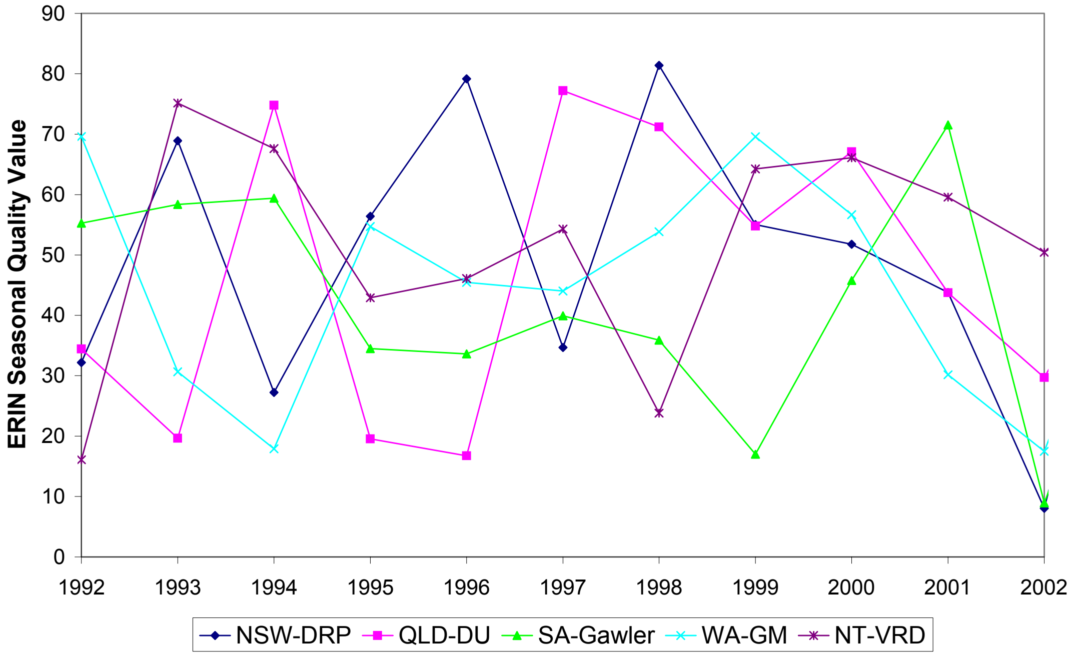

Figure 11 Mean annual seasonal quality values for pilot reporting regions

Remembering:

1. The ERIN seasonal quality index is based on the magnitude of increase in vegetation greenness (i.e. photosynthetic activity) over the growing season – as measured by NDVI,
2. The index is relative (each pixel value is scaled individually), and
3. There is considerable spatial variation in values across the large regions in some years (the mean may be meaningless), the main features from this continental comparison are:

   - In 2002, seasonal quality was poor in all regions except the VRD.
   - In some other years, some regions were experiencing good conditions for vegetation growth, while conditions were ordinary or poor elsewhere (e.g.

compare Desert Uplands in 1996 [poor] with Darling Riverine Plains [good], Gawler in 1999 [poor] with other regions [generally good]).

- Although the Desert Uplands had a poor season in 2002, seasonal conditions appear to have been worse in 1993 and 1995–96. The neatly cyclical response surface for Aussie-GRASS cover calculations (described as part of Question 5 in Section 8) are not matched by the ERIN seasonal quality assessment.

- The VRD has experienced generally favourable conditions for vegetation growth throughout the reporting period (as reported by Karfs and Trueman 2005). Seasonal conditions were poor in 1992 and 1998.

- The Gawler bioregion had reasonable conditions for vegetation growth from 1992 to 1994. Seasonal quality then deteriorated over the next five years (poorest year in 1999) and then improved considerably to 2001, before declining dramatically in 2002.

- There was considerable year-to-year variation in seasonal quality in the Darling Riverine Plains. The highest mean value (best season) was experienced in 1998, followed by progressive decline to the worst season in 2002.

  Note that seasonal quality was averaged across the whole Darling Riverine Plains in NSW whereas most of the reporting for questions answered is based on RAP monitoring sites on the Northern Floodplains of this bioregion. The large latitudinal gradient associated with the Darling 'panhandle' may have introduced excessive variation and accentuated the year-to-year differences shown here.

- The seasonal quality images indicate that the Gascoyne–Murchison experienced poor conditions in 1993 and 1994. Seasonal quality then improved to 1999 and declined to 2002. Averaging across the very large area of this reporting region conceals the within-year spatial variation described above and illustrated in Figure 8.