Report card on sustainable natural resource use in the rangelands: status and trend in the pastoral rangelands of Western Australia

Department of Agriculture and Food, Western Australia
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Report card on sustainable natural resource use in the rangelands
Status and trend in the pastoral rangelands of Western Australia
Supporting your success
Report card on sustainable natural resource use in the rangelands
Status and trend in the pastoral rangelands of Western Australia
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Cover: Cattle grazing on rangeland pasture in the Pilbara

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## Shortened forms

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<thead>
<tr>
<th>Short form</th>
<th>Long form</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARLI</td>
<td>Annual Return of Livestock and Improvements</td>
</tr>
<tr>
<td>CC</td>
<td>carrying capacity</td>
</tr>
<tr>
<td>Commissioner</td>
<td>Commissioner of Soil and Land Conservation</td>
</tr>
<tr>
<td>CU</td>
<td>cattle unit (see Glossary)</td>
</tr>
<tr>
<td>DSE</td>
<td>dry sheep equivalent (see Glossary)</td>
</tr>
<tr>
<td>ha</td>
<td>hectare; 100ha = 1km$^2$</td>
</tr>
<tr>
<td>ha/CU</td>
<td>hectares per cattle unit</td>
</tr>
<tr>
<td>km$^2$</td>
<td>square kilometres; 1km$^2$ = 100ha</td>
</tr>
<tr>
<td>LCD, LCDC</td>
<td>land conservation district, land conservation district committee (see Glossary)</td>
</tr>
<tr>
<td>MODIS</td>
<td>Moderate Resolution Imaging Spectroradiometer</td>
</tr>
<tr>
<td>NAFI</td>
<td>North Australian Fire Information (firenorth.org.au)</td>
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<td>Potential CC</td>
<td>Potential Carrying Capacity (see Glossary)</td>
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<td>Present CC</td>
<td>Present Carrying Capacity (see Glossary)</td>
</tr>
<tr>
<td>RVCI</td>
<td>Rangeland Vegetation Condition Index</td>
</tr>
<tr>
<td>t/ha/y</td>
<td>tonnes per hectare per year</td>
</tr>
<tr>
<td>UCL</td>
<td>unallocated Crown land</td>
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<tr>
<td>WARMS</td>
<td>Western Australian Rangeland Monitoring System (see Glossary)</td>
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Summary

This report card provides a regional overview of the status and trend of the natural resource base of the pastoral rangelands in Western Australia (WA).

The overview information is intended for the use of pastoral lessees, other rangeland and pastoral managers, and industry and government decision-makers with an interest in pastoral areas.

This report is focused on the pastoral lease areas of WA (857 833 square kilometres, based on active leases as at June 2016), which covers 40% of the rangelands (2.2 million square kilometres, or 87% of the state). The rangelands and lease areas cover 20 Australian bioregions with a wide diversity of vegetation types, seasonal conditions and topography. The Kimberley and Pilbara regions comprise the Northern Rangelands and the Gascoyne, Murchison and Goldfields–Nullarbor regions comprise the Southern Rangelands.

The drivers of change in the rangelands — seasonal quality, grazing pressure and fire (particularly in the Northern Rangelands) — interact and their effect is expressed in the condition and trends of natural resources used in pastoralism.

The status and trend of these resources in the pastoral areas are described in the following themes:

- rangeland vegetation condition: from pastoral station assessments
- plant population change: using data from the Western Australian Rangeland Monitoring System (WARMS)
- vegetation cover: from remotely sensed data
- soil erosion: from pastoral station assessments
- soil organic carbon: using modelled data.

The information is presented at the land conservation district (LCD) or regional scale, not at the pastoral lease scale.

The condition and trend for the rangeland's natural resources was mixed (Table 1, Figures 1 and 2). The important findings are:

- In the Northern Rangelands, rangeland vegetation condition at the aggregate LCD scale was 57% good, 29% fair and 14% poor at the last assessment.
- In the Northern Rangelands, WARMS monitoring sites indicate the assessed vegetation condition was stable since the last station inspections (2002–09), except in the Ashburton and De Grey LCDs where condition declined.
- In the Southern Rangelands, rangeland vegetation condition at the aggregate LCD scale was 36% good, 39% fair and 25% poor at the last assessment.
- In the Southern Rangelands, WARMS monitoring sites indicate the assessed vegetation condition was stable since the last station inspections (2002–09).
- There were large variations in condition and trend of the pastoral resource themes, at the paddock, station, LCD and regional scales.
The global demand for food and fibre brings many opportunities and challenges for the agrifood sector. One of these challenges is to achieve productivity growth while ensuring we use our natural resources in a sustainable way.

Opportunities and challenges in the rangelands need to consider the principles of sustainable rangeland management:

- stewardship of natural resources in pastoral rangelands is critical
- managing for longer-term climate variability and trends is important
- current evidence-based resource information is important
- management practice will determine sustainability of resource use
- viable pastoral businesses are needed for sustainable resource management
- innovation for sustainable resource use is important
- pastoral participants need to work together.
Table 1 Resource status and trend summary for the WA pastoral rangelands

<table>
<thead>
<tr>
<th>Theme</th>
<th>Summary</th>
<th>Condition and trend</th>
<th>Confidence</th>
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</thead>
<tbody>
<tr>
<td>Rangeland vegetation condition</td>
<td>Northern Rangelands: Most of the area was in good (57%) to fair (29%) condition and this condition has been stable in recent times in all LCDs, except the Ashburton and De Grey, where it has decreased. There was considerable variation in condition and trend within the region.</td>
<td>Poor:</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fair:</td>
<td>Good:</td>
</tr>
<tr>
<td>Plant population change (desirable perennials)</td>
<td>Northern Rangelands: The average frequency of desirable perennial grasses was good to fair and has increased (3%) in the most recent completed assessment (2012–14), except in the Ashburton (~5%) and North Kimberley (~4%) LCDs. The long-term (21 years) population was stable or increased in all LCDS, except the Ashburton LCD where it decreased.</td>
<td>Poor:</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fair:</td>
<td>Good:</td>
</tr>
<tr>
<td></td>
<td>Southern Rangelands: Most of the area was in fair (39%) to good (36%) condition and this condition has been stable in recent times. There was considerable variation in condition and trend within the region.</td>
<td>Poor:</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fair:</td>
<td>Good:</td>
</tr>
</tbody>
</table>
### Plant population change (all perennials)

#### Northern Rangelands
Perennial grass frequency increased (4%) from 2009–11 to 2012–14. The average perennial grass frequency decreased in the Ashburton LCD.

The long-term (21 years) population change was variable, with increased or stable populations in Kimberley LCDs and stable or decreased populations in Pilbara LCDs.

#### Southern Rangelands
Perennial shrub and tree density decreased (–10%) from 2005–10 to 2010–15. The largest decreases were in the Gascoyne–Wooramel, Meekatharra and Wiluna LCDs, with increases in the Mount Magnet (18%) and Cue (10%) LCDs.

The long-term (18 years) population change decreased in 11 LCDs and increased in 5 of the 19 LCDs. Since 1994, when the WARMS sites were installed, plant density has decreased (–10%) across the Southern Rangelands.

### Vegetation cover

#### Northern Rangelands
In the Kimberley, average vegetation cover between 2006 and 2015 was stable to slightly decreased. Cover in the Halls Creek – East Kimberley LCD decreased significantly and there are some large areas of decreased cover in other LCDs.

In the Pilbara, average cover was stable. However, there were large areas of decreased cover in all LCDs. Cover increased in the East Pilbara LCD.

#### Southern Rangelands
The average vegetation cover was stable between 2006 and 2015. However, there were large areas of decreased cover. Cover increased in the Nullarbor – Eyre Highway, Kalgoorlie and, to a lesser extent, Shark Bay LCDs.
### Soil erosion

#### Northern Rangelands
- Overall, the amount of soil erosion was minor to moderate.
- Soil erosion decreased slightly in recent assessments, particularly in the Halls Creek – East Kimberley and Roebourne – Port Hedland LCDs. There was a slight increase in soil erosion in the Derby – West Kimberley LCD. Other LCDs have been stable.

#### Southern Rangelands
- Overall, the amount of soil erosion was minor to moderate.
- The recent trend for the region was stable. However, soil erosion increased in one-third of the LCDs assessed.

### Soil organic carbon

#### Northern Rangelands
- All LCDs have low (3–15t/ha) soil organic carbon, which is considered normal in this environment. No trend data were available.

#### Southern Rangelands
- Most LCDs have low (3–15t/ha) soil organic carbon, except for the four LCDs that abut the agricultural region that have moderate (15–40t/ha) soil organic carbon. These levels are considered normal. No trend data were available.
To show the variability between LCDs within regions, the trend for four natural resource themes — rangeland vegetation condition, plant population change in desirable perennials, vegetation cover and soil erosion — are summarised for each LCD (Figures 1 and 2).
Figure 1  Summary of trends in natural resources in the Northern Rangelands. The trend in vegetation cover was based on data in 2006–15 and the trends in rangeland vegetation condition, soil erosion and desirable plant populations are based on the WARMS assessments since the last station inspection.
Figure 2 Summary of trends in natural resources in the Southern Rangelands. The trend in vegetation cover was based on data in 2006–15 and the trends in rangeland vegetation condition, soil erosion and desirable plant populations are based on the WARMS assessments since the last station inspection. There are insufficient spatial data for some attributes to confidently determine trends for LCDs 21, 22, 23 and 26.
Section 1 The Western Australian rangelands
Western Australia’s pastoral rangelands at a glance

Pastoral statistics
- Total station area is 857 833km$^2$
  - 436 stations (491 leases)
  - 27 land conservation districts (LCDs)
- Management:
  - 163 individual or family (light blue)
  - 175 company (yellow), of which 7 are owned for conservation purposes (green)
  - 55 indigenous (purple)
  - 41 mining (orange)
  - 2 public sector (grey)

Annual rainfall (mm)
- 100–200
- 200–300
- 300–400
- 400–500
- 500–600
- Over 1000

Percentage of winter rainfall
- 0–10%
- 10–20%
- 20–30%
- 30–40%
- 40–50%
- 50–60%
- 60–70%
- 70–80%
- 80–90%
- 90–100%

Annual rainfall ranges from 180 to 1200mm:
- Kimberley: 350–1200mm
- Pilbara: 220–400mm
- Southern Rangelands: 180–300mm

Potential pastoral production
- 0–7DSE/km$^2$
- 7–14DSE/km$^2$
- 14–20DSE/km$^2$
- 20–30DSE/km$^2$
- 30–40DSE/km$^2$
- 40–50DSE/km$^2$
- >50DSE/km$^2$

* 7DSE = 1CU

Northern Rangelands:
- The Potential Carrying Capacity of tussock grasslands (30–200DSE/km$^2$) is more productive than hummock grasslands (2–30DSE/km$^2$).

Southern Rangelands:
- The Potential CC varies from 5–20DSE/km$^2$ for chenopod shrublands to 3–7DSE/km$^2$ for mulga woodland.

Changes in livestock type
- The type of livestock run has changed over time. In 2014, cattle were run on 88% of stations.

1984
- 763 600 cattle (brown)
- 1 901 600 sheep (yellow)
- 12 800 goats (purple or green)

2014
- 1 402 900 cattle (brown)
- 293 900 sheep (yellow or orange)
- 12 800 goats (purple or green)
1.1 Scope of the report

This report card presents the best information on the condition (or risk to condition) and trend in condition of the natural resources that support pastoralism in the Western Australian (WA) rangelands.

In particular, this report:
• explains how condition, risk and trend was determined
• assesses pastoral resource condition and trend
• highlights factors affecting the sustainable use of this resource
• discusses the management implications of these findings
• provides recommended actions where appropriate.

The report focuses on the sustainable natural resource use of the WA native rangeland for pastoralism (grazing by livestock). Pastoral rangeland activities in WA are on state-managed leasehold land administered by the Department of Lands, under the Land Administration Act 1997.

Pastoral rangelands provide a range of benefits in addition to pastoralism: tourism, ecological services, mining, and cultural and heritage values for Indigenous people. These benefits are not considered in this report.

This report provides information for government, land conservation district committees and the pastoral industry to use in developing strategies and actions to manage change and to ensure a more sustainable use of the pastoral resource.

Information in this report is presented at the land conservation district (LCD) or regional scale; it does not have information at the pastoral lease scale.

Drivers for change in the rangelands

The WA pastoral rangelands have highly variable landscapes, soils, vegetation, rainfall and seasonality. The three primary drivers of change across all WA rangelands are:
• seasonal quality
• grazing pressure
• fire.

Seasonal quality is the amount and distribution of rainfall and its interaction with vegetation to determine grazing values. Climatic variation within and between years is a major concern for management.

Grazing pressure is the demand–supply ratio between forage needs of herbivores and the forage supply in a pasture at a specific time. The aim of management is to match grazing pressure to production and recovery of rangeland vegetation.

Fire is a naturally occurring hazard, especially in the Northern Rangelands, with limited management options.

Natural resource themes

Rangeland status and changes are described in the themes:
• rangeland vegetation condition: from pastoral station assessments
• plant population change at the regional level: from the Western Australian Rangeland Monitoring System (WARMS) data
• vegetation cover: from remotely sensed data
• soil erosion: from pastoral station assessments
• soil organic carbon: from modelling.

The drivers of change interact and their effect manifests in the themes.
1.2 The rangeland regions

Rangeland, sometimes referred to as native pasture, is any extensive area of land that is occupied by native herbaceous or shrubby vegetation which is grazed by livestock, and native and introduced herbivores.

The WA rangelands are highly varied and are contained wholly or partly within 20 IBRA (Interim Biogeographic Regionalisation for Australia) bioregions (environment.gov.au). These rangelands occur in climates ranging from tropical to arid temperate; with topography including coastal plains, rocky ranges and semi-arid desert; and rainfall amount and distribution ranging from summer-dominant with 1200mm annually to winter-dominant and less than 250mm. The combination of climate, topography and soils renders them unsuitable for broadacre farming and so agriculture is typically limited to pastoralism (Harrington et al. 1984).

The WA rangelands cover about 2.2 million square kilometres (87% of WA, which is all but the south-west agricultural region), and pastoral stations for grazing livestock cover 40% (857 833km$^2$) of that, based on active leases as at June 2016 (C Olsen [Landgate] 2016, pers. comm., 4 August). The rest of the rangelands consist of land vested for conservation, Indigenous purposes and unallocated Crown land (UCL).

DAFWA divides the WA pastoral rangelands into two areas: the Northern Rangelands, which contains the Kimberley (206 775km$^2$) and the Pilbara (147 940km$^2$) regions, and the Southern Rangelands, which is south of the Pilbara region and between the south-west agricultural region and the arid interior. It contains the Gascoyne (138 650km$^2$), Murchison (128 620km$^2$) and the Goldfields–Nullarbor (235 850km$^2$) regions (Figure 1.1).

Figure 1.1 Rangeland regions of Western Australia
The rangeland vegetation types range from grasslands to shrublands to woodlands (see Glossary) as well as patches of monsoonal forests in the north. The two distinct types of rangelands used for grazing livestock are:

- grasslands, which are predominantly perennial tussock (bunch) and hummock grasses, with or without some tree cover. They occur mainly in the Northern Rangelands
- shrublands, which are vegetation types characterised by shrubs with a variable mulga (*Acacia aneura*) or eucalypt overstorey. They occur mainly in the Southern Rangelands.

Grasslands and shrublands are both present in the southern Pilbara and Gascoyne.

Perennial vegetation in the Southern Rangelands is adapted to characteristically low and highly variable rainfall, and pasture productivity is low relative to that in the Northern Rangelands. Perennial vegetation in the Southern Rangelands is more susceptible to degradation through overutilisation than that in the Northern Rangelands.

The pastoral industries in the Kimberley and Pilbara are similar in that they consist of enterprises with a high proportion of tropically adapted breeding cattle. Pastoralists in the Kimberley sell most cattle for live export, and pastoralists in the Pilbara sell for live export and domestic markets. Kimberley stations have run only cattle for some time, while a few stations in the south-west of the Pilbara still run sheep.

The Gascoyne, Murchison, Goldfields and Nullarbor were major wool-producing areas as recently as the early 1990s. However, during the following 20 years, the number of sheep, especially Merino sheep, greatly declined. Merinos have been replaced to some extent by meat sheep on stations in the western Gascoyne and Murchison, but the most significant change has been from sheep to cattle across the Southern Rangelands. Rangeland sheep production now comprises less than 3% of the total value of the WA sheep production.

The Southern Rangelands goat population was estimated to be between 150,000 and 250,000, although goats are now rarely sighted in the Goldfields and eastern Murchison. There has been a de facto managed goat industry and an industry based on the sale of unmanaged (feral) goats. Opportunistic harvesting of goats has provided significant and timely income for many leaseholders, even to the extent of some leaseholders imposing a level of management on feral goat flocks rather than simply harvesting.

**Climate**

Climate, particularly the amount, intensity and seasonal distribution of rainfall, is a major determinant of rangeland productivity. Dealing with rainfall variability is a major component of rangeland management.

**Northern Rangelands**

The Kimberley has a tropical monsoon climate with two dominant seasons separated by short transitional periods:

- The wet summer season (November to April) is hot and humid, with seasonal rainfall up to 1200mm in the north (Figure 1.2). Typically, 90% of annual rainfall occurs during this period, when low pressure systems and unstable air dominate.
- The dry winter season (May to October) is influenced by high pressure systems and a predominantly south-easterly airflow from the interior. This rainfall pattern leads to tropical savanna vegetation in the north and arid desert grassland in southern parts.

The Pilbara has a similar summer and winter seasonal pattern to the Kimberley, with generally lower annual rainfall (300–500mm) and more-frequent poor wet seasons. The southern Pilbara occurs roughly on the boundary between the summer-dominant and winter-dominant/seasonally uniform rainfall zones.
Figure 1.2 Rainfall isohyets for the Northern Rangelands and average monthly rainfall for selected locations
Figure 1.3 Rainfall isohyets for the Southern Rangelands and average monthly rainfall for selected locations
Southern Rangelands

The Southern Rangelands have predominantly winter rainfall, with an average annual rainfall generally below 300mm (Figure 1.3). Rainfall is highly variable within and between years, and variation is high compared to similar areas elsewhere in Australia. This arid climate, with frequent dry years interspersed with occasional high rainfall events, makes it difficult to match forage demand (stocking rate) with supply (available forage). Summer rainfall probabilities are low throughout the region, although the proportion of annual rainfall occurring in the summer months has increased over recent decades. Substantial variation in rainfall also occurs in cycles that vary from 2.5 to 30 years or more.

Climate change and the WA rangelands

High seasonal variability in the rangelands masks climate change to some extent.

Climate records indicate a drying trend for much of WA, except for the Kimberley, and modelling suggests a continued warming trend over the coming decades (Indian Ocean Climate Initiative [IOCI] 2012). Rainfall in northern Australia, including the Kimberley, are likely to be heavier, with more rain falling per rain day. As a result, flash floods may become more common. There are likely to be more dry days (time between rains), which may cause water supply problems. In north-western Australia, the wet season is becoming wetter and, since the 1950s, annual rainfall has increased by more than 30mm per decade and exceeding 50mm per decade over parts of the north-west coast (Figure 1.4). This increase in annual rainfall has generally been associated with...
an increase in summer rainfall (Figure 1.5) and a decrease in winter rainfall (Figure 1.6).

In the decade 2005–14, all LCDs in the Southern Rangelands had more years with above-average summer rainfall (6 to 9 years out of 10) than the long-term above-average rainfall in a 10-year period (3 to 4 years out of 10). In this period, the largest increases above the long-term monthly average rainfall were in December (9mm or 76%), January (18mm or 82%) and March (13mm or 50%). In the same period, the average rainfall declined in May (~10mm or ~32%) and June (~12mm or ~36%).

**Legislation, land tenure and pastoral leases**

Land tenure in the rangelands is predominantly pastoral leasehold, with leases issued under the *Land Administration Act 1997*. The statutory authority for managing the pastoral estate rests with the Department of Lands and the Pastoral Lands Board of Western Australia (PLB). DAFWA provides technical assistance to the PLB to support their activities.

The Land Administration Act states that the function of the PLB is to ensure that pastoral leases are managed on an ecologically sustainable basis. Leases are developed and assigned to enable them to be worked as an economically viable and ecologically sustainable pastoral business unit.

In addition, under the *Soil and Land Conservation Act 1945*, the Commissioner of Soil and Land Conservation (the Commissioner) has the duty and powers to prevent activities that could lead to land degradation and, if warranted, the power to instruct lessees to ameliorate or repair degraded land.

A pastoral lease is a title issued by the Minister for Lands for the lease of an area of Crown land for the limited purpose of grazing of livestock (cattle, sheep, goats and horses) and ancillary activities. Under the Land Administration Act and the Soil and Land Conservation Act, pastoral lessees are obliged to manage the vegetation and soil resources on their lease to avoid soil and land degradation and, under the *Biosecurity and Agricultural Management Act 2007*, to control declared plant and animal pests.

A permit from the PLB is required for any non-pastoral use carried out on a pastoral lease. A permit may be granted if the property as a whole continues to be managed for pastoral purposes. Mining leases may be issued concurrent to pastoral leases and mining operations can occur on pastoral land.

In 2016, there were 491 registered pastoral leases in WA, held in 436 pastoral stations: 152 stations in the Northern Rangelands (92 in the Kimberley and 60 in the Pilbara); and 284 stations in the Southern Rangelands. Lease ownership includes large corporations, private companies, family operations, Indigenous organisations, and, particularly in the Pilbara and Goldfields, mining companies (Figures 1.7 and 1.8).

**Land conservation districts**

Information in this report is presented at the LCD scale. Pastoral LCDs, as with all LCDs, are appointed under legislation, constituted under section 22(1) of the *Soil and Land Conservation Act 1945* and comprise pastoral leasehold land, defined conservation areas (which may have formed part of the pastoral estate prior to their declaration as conservation areas) and UCL. Land conservation district committees (LCDCs) are community-based groups focused on sustainable resource management and their role is to promote on-ground involvement in voluntary land management and conservation activities. Many LCDCs also manage externally-funded projects aimed at preventing land degradation and promoting soil and land conservation and reclamation. In WA, the Commissioner resides within DAFWA and provides administrative services for the LCDCs, including a state officer (a nominee of the Commissioner), insurance, information and administrative funds.
Figure 1.7 Land tenure in the Northern Rangelands, as at June 2016
Figure 1.8 Land tenure in the Southern Rangelands, as at June 2016
There are 27 LCDs in the WA rangelands (Figures 1.9 and 1.10). This report relates to the proportion of each LCD that was pastoral land or conservation areas which formed part of the pastoral estate prior to declaration as conservation areas; it does not relate to UCL.

**Legend**
- Pastoral station
- Non-pastoral area
- Land Conservation District boundary
- Area excluded from LCDs (includes UCL and reserves)

**Title**
Figure 1.9 LCDs in the Northern Rangelands
Figure 1.10 LCDs in the Southern Rangelands
In the Northern Rangelands, the Kimberley LCDs are Broome, Derby – West Kimberley, Halls Creek – East Kimberley and North Kimberley; the Pilbara LCDs are Ashburton, De Grey, East Pilbara and Roebourne – Port Hedland (Table 1.1). Pilbara LCDs generally have a reasonably uniform number of stations, but in the Kimberley, the two major catchments of the Ord and the Fitzroy rivers contain most of the pastoral stations.

The Southern Rangelands has 19 LCDs, which have been subdivided based on rainfall distribution. The Gascoyne – Ashburton Headwaters, Upper Gascoyne and Wiluna LCDs are classed as ‘Southern Rangelands (SR) summer’ because they receive a substantial proportion of their annual rainfall in summer. The rest of the LCDs are classed as ‘SR winter’ (Table 1.2).

Table 1.1 LCD statistics in the Northern Rangelands

<table>
<thead>
<tr>
<th>Region</th>
<th>LCD</th>
<th>LCD area (ha)</th>
<th>Number of pastoral stations</th>
<th>Total station area (ha)</th>
<th>Average station area (ha)</th>
<th>Proportion of LCD as pastoral lease (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kimberley</td>
<td>1 North Kimberley†</td>
<td>11 276 364</td>
<td>14</td>
<td>3 772 831</td>
<td>269 488</td>
<td>33</td>
</tr>
<tr>
<td>Kimberley</td>
<td>2 Halls Creek – East Kimberley †</td>
<td>8 753 170</td>
<td>35</td>
<td>8 071 616</td>
<td>230 618</td>
<td>92</td>
</tr>
<tr>
<td>Kimberley</td>
<td>3 Derby – West Kimberley †</td>
<td>7 518 115</td>
<td>32</td>
<td>7 367 869</td>
<td>230 246</td>
<td>98</td>
</tr>
<tr>
<td>Kimberley</td>
<td>4 Broome †</td>
<td>2 582 365</td>
<td>9</td>
<td>1 465 265</td>
<td>162 807</td>
<td>57</td>
</tr>
<tr>
<td>Pilbara</td>
<td>5 De Grey †</td>
<td>5 082 429</td>
<td>15</td>
<td>3 798 009</td>
<td>253 201</td>
<td>75</td>
</tr>
<tr>
<td>Pilbara</td>
<td>6 Roebourne – Port Hedland †</td>
<td>5 177 240</td>
<td>18</td>
<td>2 993 965</td>
<td>166 331</td>
<td>58</td>
</tr>
<tr>
<td>Pilbara</td>
<td>7 East Pilbara †</td>
<td>4 831 201</td>
<td>13</td>
<td>3 168 985</td>
<td>243 768</td>
<td>66</td>
</tr>
<tr>
<td>Pilbara</td>
<td>8 Ashburton †</td>
<td>6 152 959</td>
<td>16</td>
<td>3 733 040</td>
<td>233 315</td>
<td>61</td>
</tr>
</tbody>
</table>

* LCD includes areas of non-pastoral land (UCL and reserves).
† LCD includes Department of Parks and Wildlife reserves.
‡ LCD includes UCL.
Table 1.2 LCD statistics in the Southern Rangelands

<table>
<thead>
<tr>
<th>Rainfall area</th>
<th>LCD</th>
<th>LCD area (ha)</th>
<th>Number of pastoral stations</th>
<th>Total station area (ha)</th>
<th>Average station area (ha)</th>
<th>Proportion of LCD as pastoral lease (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SR summer</td>
<td>9 Gascoyne – Ashburton Headwaters†‡</td>
<td>6 906 425</td>
<td>16</td>
<td>4 982 019</td>
<td>311 376</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td>10 Upper Gascoyne†</td>
<td>4 181 585</td>
<td>18</td>
<td>3 273 876</td>
<td>181 882</td>
<td>78</td>
</tr>
<tr>
<td></td>
<td>11 Wiluna†</td>
<td>33 705 599</td>
<td>18</td>
<td>4 394 778</td>
<td>244 154</td>
<td>13</td>
</tr>
<tr>
<td>SR winter</td>
<td>12 Lyndon†</td>
<td>3 715 081</td>
<td>21</td>
<td>3 302 125</td>
<td>157 244</td>
<td>89</td>
</tr>
<tr>
<td></td>
<td>13 Gascoyne–Wooramel†</td>
<td>1 653 843</td>
<td>16</td>
<td>1 915 542</td>
<td>119 721</td>
<td>116‡</td>
</tr>
<tr>
<td></td>
<td>14 Shark Bay†‡</td>
<td>2 667 947</td>
<td>13</td>
<td>1 491 284</td>
<td>114 714</td>
<td>56</td>
</tr>
<tr>
<td>SR winter</td>
<td>15 Murchison†</td>
<td>4 475 451</td>
<td>24</td>
<td>4 022 350</td>
<td>167 598</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>16 Meekatharra†‡</td>
<td>3 211 619</td>
<td>20</td>
<td>3 648 574</td>
<td>182 429</td>
<td>114‡</td>
</tr>
<tr>
<td>SR winter</td>
<td>17 Cue†‡</td>
<td>1 257 263</td>
<td>8</td>
<td>889 716</td>
<td>111 214</td>
<td>71</td>
</tr>
<tr>
<td></td>
<td>18 Mount Magnet</td>
<td>1 223 568</td>
<td>17</td>
<td>1 651 313</td>
<td>97 136</td>
<td>135‡</td>
</tr>
<tr>
<td>SR winter</td>
<td>19 Sandstone†‡</td>
<td>3 330 243</td>
<td>12</td>
<td>2 409 539</td>
<td>200 795</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td>20 Yalgoo†</td>
<td>3 020 649</td>
<td>19</td>
<td>2 451 420</td>
<td>129 022</td>
<td>81</td>
</tr>
<tr>
<td>SR winter</td>
<td>21 Perenjori†§</td>
<td>1 017 906</td>
<td>2</td>
<td>176 296</td>
<td>88 148</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>22 Binnu†§</td>
<td>1 216 520</td>
<td>3</td>
<td>198 550</td>
<td>66 183</td>
<td>16</td>
</tr>
<tr>
<td>SR winter</td>
<td>23 Mount Marshall†§</td>
<td>782 248</td>
<td>2</td>
<td>274 727</td>
<td>137 364</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>24 North-eastern Goldfields†</td>
<td>3 936 601</td>
<td>29</td>
<td>6 211 091</td>
<td>214 176</td>
<td>158‡</td>
</tr>
<tr>
<td>SR winter</td>
<td>25 Kalgoorlie†</td>
<td>6 092 703</td>
<td>22</td>
<td>3 849 399</td>
<td>174 973</td>
<td>63</td>
</tr>
<tr>
<td></td>
<td>26 Yilgarn†§</td>
<td>3 057 623</td>
<td>4</td>
<td>190 954</td>
<td>47 739</td>
<td>6</td>
</tr>
<tr>
<td>SR winter</td>
<td>27 Nullarbor – Eyre Highway‡</td>
<td>6 247 761</td>
<td>20</td>
<td>6 078 174</td>
<td>303 909</td>
<td>97</td>
</tr>
</tbody>
</table>

* LCD includes UCL and Indigenous land.
† LCD includes Department of Parks and Wildlife reserves.
‡ LCD includes UCL.
§ LCD includes small stations abutting the agricultural zone and UCL.
# For reporting purposes, some stations are aligned with the LCD even though they are not formally incorporated into the LCD and hence the station area exceeds the registered LCD area.
1.3 Rangeland resources and change

The goal of sustainable pastoralism is the continued use of rangeland natural resources for livestock production without causing a loss of land capability. To monitor achievement of this goal, we need to know the starting condition (baseline), changes over time of the natural resources used in pastoralism, and the sustainable carrying capacity for livestock.

Rangeland surveys

Rangeland surveys provide the baseline data for pastoral resource condition and estimates of pastoral value. This baseline data is used to determine rangeland vegetation in ‘good condition’ for different land systems. Rangeland surveys provide information about the amount of vegetation available for grazing on these good condition land systems, and this is used to estimate the Potential Carrying Capacity (Potential CC) for the land systems, LCDs and rangeland regions. See the glossary for explanations of these terms.

Fourteen condition and inventory surveys have been completed and surveys now cover about 87% of the state’s pastoral rangeland. Beard’s vegetation mapping (Beard 1975) is used to provide information for those areas not surveyed (the southern Goldfields and areas east of Wiluna).

Survey reports are available at agric.wa.gov.au/land-use/rangelands-surveys.

Carrying capacity as a measure of sustainable pastoral productivity

Pastoral business viability relies on being able to turn-off a sufficient number of livestock. To determine the number of livestock that could potentially be sustainably carried on a pastoral lease, DAFWA estimates carrying capacity from rangeland vegetation condition (good, fair, poor for each pasture type within a land system) and pastoral values (livestock units per unit area) of the land systems that make up the lease.

Note: The LCD Present Carrying Capacity (Present CC) is calculated from the sum of pastoral station assessments of land systems and their condition. The last on-station assessments were in 2009 or earlier. Based on analysis of WARMS data, seasonal quality and remote sensing data (Normalised Difference Vegetation Index and cover), DAFWA has moderate to high confidence in using these Present CC estimates.

The change from Potential CC to Present CC gives an indication of trend in resource capability for pastoralism.

The Potential CC and the Present CC of all stations in an LCD are summed to provide an estimate of LCD-scale carrying capacity (Tables 1.3 and 1.4). In general, LCDs in the Northern Rangelands are composed of land systems with higher carrying capacities than those in the Southern Rangelands.

Carrying capacities in Tables 1.3 and 1.4 are in cattle units (CU) and dry sheep equivalents (DSE); 1 CU equals 7 DSE.
### Table 1.3  LCD-scale Potential CC and the most recently assessed Present CC in the Northern Rangelands

<table>
<thead>
<tr>
<th>LCD</th>
<th>Potential CC (CU / DSE)</th>
<th>Present CC (CU / DSE)</th>
<th>Period Present CC was determined</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 North Kimberley</td>
<td>105 235/736 645</td>
<td>82 057/574 399</td>
<td>2002–07</td>
</tr>
<tr>
<td>2 Halls Creek – East Kimberley</td>
<td>288 360/2 018 520</td>
<td>199 244/1 394 708</td>
<td>2003–09</td>
</tr>
<tr>
<td>3 Derby – West Kimberley</td>
<td>350 219/2 451 533</td>
<td>237 186/1 660 302</td>
<td>2003–09</td>
</tr>
<tr>
<td>4 Broome</td>
<td>81 578/571 046</td>
<td>65 672/459 704</td>
<td>2005–09</td>
</tr>
<tr>
<td>5 De Grey</td>
<td>68 466/479 260</td>
<td>60 920/426 440</td>
<td>2002–08</td>
</tr>
<tr>
<td>6 Roebourne – Port Hedland</td>
<td>65 566/458 965</td>
<td>51 378/359 646</td>
<td>2002–09</td>
</tr>
<tr>
<td>7 East Pilbara</td>
<td>45 449/318 146</td>
<td>34 155/239 085</td>
<td>2002–08</td>
</tr>
<tr>
<td>8 Ashburton</td>
<td>72 696/508 870</td>
<td>54 605/382 236</td>
<td>2001–08</td>
</tr>
</tbody>
</table>

### Table 1.4  LCD-scale Potential CC and the most recently assessed Present CC in the Southern Rangelands

<table>
<thead>
<tr>
<th>LCD</th>
<th>Potential CC (CU / DSE)</th>
<th>Present CC (CU / DSE)</th>
<th>Period Present CC was determined</th>
</tr>
</thead>
<tbody>
<tr>
<td>9 Gascoyne – Ashburton Headwaters</td>
<td>47 346/331 423</td>
<td>24 880/174 160</td>
<td>2002–09</td>
</tr>
<tr>
<td>10 Upper Gascoyne</td>
<td>32 086/224 605</td>
<td>23 803/166 622</td>
<td>2002–09</td>
</tr>
<tr>
<td>11 Wiluna</td>
<td>35 110/245 769</td>
<td>20 582/144 072</td>
<td>2001–08</td>
</tr>
<tr>
<td>12 Lyndon</td>
<td>62 357/436 497</td>
<td>50 069/350 480</td>
<td>2001–08</td>
</tr>
<tr>
<td>13 Gascoyne–Wooramel</td>
<td>36 917/258 422</td>
<td>24 286/170 000</td>
<td>2003–09</td>
</tr>
<tr>
<td>14 Shark Bay</td>
<td>22 255/155 782</td>
<td>16 801/117 605</td>
<td>2003–08</td>
</tr>
<tr>
<td>15 Murchison</td>
<td>46 677/326 739</td>
<td>33 165/232 155</td>
<td>2003–09</td>
</tr>
<tr>
<td>16 Meekatharra</td>
<td>33 628/235 393</td>
<td>23 580/165 058</td>
<td>2002–09</td>
</tr>
<tr>
<td>17 Cue</td>
<td>9 320/65 240</td>
<td>6 943/48 600</td>
<td>2003–08</td>
</tr>
<tr>
<td>18 Mount Magnet</td>
<td>16 420/114 943</td>
<td>13 061/91 424</td>
<td>2002–08</td>
</tr>
<tr>
<td>19 Sandstone</td>
<td>20 509/143 560</td>
<td>17 405/121 835</td>
<td>2001–08</td>
</tr>
<tr>
<td>20 Yalgoo</td>
<td>24 704/172 926</td>
<td>19 274/134 916</td>
<td>2002–08</td>
</tr>
</tbody>
</table>
### Assessing change

#### The interaction of drivers of change

The most important interaction for pastoral managers is between seasonal quality and grazing pressure. This complex interaction may take many seasons to express changes in some of the themes in this report card.

Fire causes rapid changes to several of the themes and requires specific management for recovery.

#### Interpreting change

The status and trend of themes in this report are based on the continued use of rangeland natural resources for livestock production without causing a loss of land capability.

For example, an increase in unpalatable perennial grasses may be interpreted as a decline in rangeland condition from a pastoral production perspective, whereas the greater soil cover and protection from erosion provided by the additional perennial grasses might be viewed as improving landscape function (see Glossary).

DAFWA uses WARMS to assess plant population change at the regional scale (Watson et al. 2007, Novelly et al. 2008). WARMS comprises a set of fixed sites on representative areas of pastoral land and provides an indication of change at a regional or vegetation type scale, not at the pastoral station scale. WARMS uses permanent ground-based sites on which perennial vegetation (shrubs and grasses of most value to pastoralism) and soil surface characteristics are assessed.

There are 633 grassland sites throughout the Northern Rangelands and on some areas south of the Pilbara, and 989 shrubland sites, mostly in the Southern Rangelands (Figures 1.11 and 1.12). Grassland sites are assessed every three years and shrubland sites are assessed every five years.

Information from these sites is aggregated to indicate changes in plant populations, which is generally expressed as increased, stable or decreased populations of desirable perennial plants.

---

<table>
<thead>
<tr>
<th>LCD</th>
<th>Potential CC (CU / DSE)</th>
<th>Present CC (CU / DSE)</th>
<th>Period Present CC was determined</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>Perenjori 1617/11320</td>
<td>476/3330</td>
<td>2002–04</td>
</tr>
<tr>
<td>22</td>
<td>Binnu 1493/10453</td>
<td>1278/8950</td>
<td>2003</td>
</tr>
<tr>
<td>23</td>
<td>Mount Marshall 2594/18160</td>
<td>1846/12920</td>
<td>2005–06</td>
</tr>
<tr>
<td>24</td>
<td>North-eastern Goldfields 52063/36442</td>
<td>36805/257632</td>
<td>2001–09</td>
</tr>
<tr>
<td>25</td>
<td>Kalgoorlie 35348/247435</td>
<td>25000/175000</td>
<td>2002–09</td>
</tr>
<tr>
<td>26</td>
<td>Yilgarn 3632/25424</td>
<td>2533/17730</td>
<td>2003–07</td>
</tr>
<tr>
<td>27</td>
<td>Nullarbor – Eyre Highway 57807/404650</td>
<td>39781/278465</td>
<td>2005–07</td>
</tr>
</tbody>
</table>
Figure 1.11 Location of WARMS sites in the Northern Rangelands
Figure 1.12 Location of WARMS sites in the Southern Rangelands
Sources of information

Beard, JS 1975, *Vegetation survey of Western Australia*, University of Western Australia Press, Perth.


Payne, AL, Curry, PJ & Spencer, GF 1987, ‘An inventory and condition survey of rangelands in the Carnarvon Basin, Western Australia’, *Technical bulletin 73*, Department of Agriculture and Food, Western Australia, Perth.


Pringle, HJ, Van Vreeswyk, AME & Gilligan, SA 1994, ‘An inventory and condition survey of rangelands in the northern part of the Nullarbor region’, *Technical bulletin 97*, Department of Agriculture and Food, Western Australia, Perth.

Van Vreeswyk, AME, Payne, AL, Leighton, KA & Hennig, P 2004, ‘An inventory and condition survey of the Pilbara region, Western Australia’, *Technical bulletin 92*, Department of Agriculture and Food, Western Australia, Perth.

Waddell, PA, Gardner, AK & Hennig, P 2010, ‘An inventory and condition survey of the Western Australian part of the Nullarbor region’, *Technical bulletin 97*, Department of Agriculture and Food, Western Australia, Perth.

Section 2 Drivers of change
The three primary drivers of change in the rangelands are:

- seasonal quality: essentially the amount and distribution of rainfall and its interaction with vegetation
- grazing pressure: the degree to which the rangeland is grazed by livestock, and native and introduced herbivores
- fire.

Seasonal quality and its variation is determined by climatic conditions. In most of the rangelands, climatic variation within and between years is significant and a major concern for management. Climate interaction with vegetation determines grazing values and erosion risk.

Grazing pressure is the demand–supply ratio between forage needs of herbivores and the forage supply in a pasture at a specific time, and can be managed by varying the number of livestock, and native and introduced herbivores according to the forage available in pastoral vegetation types and land systems. The aim is to match grazing pressure to the sustainable capacity of the rangeland vegetation.

Fire occurs from natural and human causes, especially in the Northern Rangelands, with limited options to manage its extent and severity.

Managers can use knowledge of the interactions between the drivers to develop sustainable pastoral rangeland management. Measurable changes in pastoral condition and trends in response to management are usually over many seasons, and sometimes over decades. Management plans also need to extend over long periods, usually five or more years.

### 2.1 Seasonal quality

Year-to-year variation in rainfall is a major driver of rangeland degradation and recovery. Rainfall is highly variable throughout much of the WA rangelands, both spatially (across the area) and temporally (through time). When combined with the relatively low productivity of much of the rangeland vegetation, this high variability complicates management by causing large variations in available forage. DAFWA scores seasonal quality based on long-term (1900–2015) rainfall and its seasonal distribution (summer and winter; see Appendix A).

The desirable perennial component of rangeland pastures is particularly susceptible — because it is more palatable — to the high grazing pressure that occurs when the stocking rate does not fall as fast as the forage supply in years of poor seasonal quality. This mismatch between grazing pressure and forage supply is more important in the Southern Rangelands, where the between-year variation in rainfall is very high.

**Key message 1:** In the Northern Rangelands, seasonal quality was generally above average or average at the LCD scale in 2009–15.

Favourable seasons, such as those in the Northern Rangelands over the past six years, provided an opportunity to encourage recruitment and establishment of desirable perennials (Table 2.1.1 and Figure 2.1.1).

**Key message 2:** In the Kimberley, seasonal quality was generally above average or average at the LCD scale in 1994–2015.

The extended good conditions have provided good opportunities for recruitment and establishment of desirable perennials.
Table 2.1.1 Seasonal quality in the Northern Rangelands, 2009–15 (2 WARMS assessment periods)

<table>
<thead>
<tr>
<th>LCD</th>
<th>Number of sites</th>
<th>Average long-term (116 years) summer rainfall (mm)</th>
<th>Percentage of sites above average (%)</th>
<th>Percentage of sites average (%)</th>
<th>Percentage of sites below average (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 North Kimberley</td>
<td>46</td>
<td>787</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2 Halls Creek – East Kimberley</td>
<td>113</td>
<td>536</td>
<td>96</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>3 Derby – West Kimberley</td>
<td>175</td>
<td>508</td>
<td>97</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>4 Broome</td>
<td>39</td>
<td>463</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5 De Grey</td>
<td>63</td>
<td>249</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>6 Roebourne – Port Hedland</td>
<td>71</td>
<td>221</td>
<td>80</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>7 East Pilbara</td>
<td>26</td>
<td>195</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8 Ashburton</td>
<td>50</td>
<td>177</td>
<td>50</td>
<td>50</td>
<td>0</td>
</tr>
</tbody>
</table>

Figure 2.1.1 Seasonal quality in the Northern Rangelands (October to September), 2012–13 to 2014–15
Key message 3: In the Southern Rangelands, seasonal quality is highly variable within the region and between years.

Year-to-year variation in seasonal quality resulted in large between-year variation in forage quality and quantity. This variability is typical of the region, making rangeland management and setting the balance between livestock numbers and available forage challenging. Variation across the Southern Rangelands is shown in Table 2.1.2, and between years in Figure 2.1.2.

Table 2.1.2 Seasonal quality in the Southern Rangelands, 2005–15 (2 WARMS assessment periods)

<table>
<thead>
<tr>
<th>LCD</th>
<th>Number of sites</th>
<th>Average long-term (116 years) winter rainfall (mm)</th>
<th>Seasonal quality (2005–15)</th>
<th>Percentage of sites above average (%)</th>
<th>Percentage of sites average (%)</th>
<th>Percentage of sites below average (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9 Gascoyne – Ashburton Headwaters</td>
<td>75</td>
<td>90 (136)*</td>
<td></td>
<td>75</td>
<td>22</td>
<td>3</td>
</tr>
<tr>
<td>10 Upper Gascoyne</td>
<td>57</td>
<td>110 (107)*</td>
<td></td>
<td>26</td>
<td>55</td>
<td>19</td>
</tr>
<tr>
<td>11 Wiluna</td>
<td>77</td>
<td>83 (135)*</td>
<td></td>
<td>50</td>
<td>29</td>
<td>21</td>
</tr>
<tr>
<td>12 Lyndon</td>
<td>47</td>
<td>125</td>
<td></td>
<td>15</td>
<td>57</td>
<td>28</td>
</tr>
<tr>
<td>13 Gascoyne–Wooramel</td>
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<td>137</td>
<td></td>
<td>0</td>
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<td>96</td>
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<td>14 Shark Bay</td>
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<td>56</td>
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<td>109</td>
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<td>46</td>
<td>44</td>
<td>10</td>
</tr>
</tbody>
</table>

* Average summer rainfall is shown in brackets because these LCDs are in a transitional zone from summer to winter rainfall (Appendix A).
Figure 2.1.2 Seasonal quality in the Southern Rangelands (April to March), 2011–15
Annual seasonal quality affects annual biomass and the opportunity to recruit perennials. The seasonal quality affects the number of livestock that can be sustainably grazed.

Key message 4: In the Southern Rangelands, an increase in the proportion of summer rainfall may reduce shrub productivity and increase soil erosion.

In much of the Southern Rangelands, winter rainfall is more important than summer rainfall in determining the dynamics of shrubland vegetation; however, since 2000 there has been an increase in the proportion of annual rainfall in summer (increase of 40mm in average summer rainfall) and a decrease of 22mm in the average winter rainfall. This change in seasonal rainfall may reduce shrub recruitment and survival that is reliant on winter rainfall, and may also increase soil erosion as a result of an increase in intense summer rainfall (see also Section 3.4).

Sources of information

2.2 Grazing pressure

The aim of grazing management is to match forage use to forage supply, without depleting the palatable perennial component of a rangelands pasture. Pastoral managers achieve this balance by manipulating total grazing pressure (through changed stocking rate) so that it does not exceed seasonal available forage. Total grazing pressure is the demand for forage by all herbivores.

An indication of grazing pressure can be inferred from the Annual Return of Livestock and Improvements (ARLI) submitted to the PLB by leaseholders and estimates of seasonal quality. The ARLI does not account for grazing from native and introduced herbivores. Livestock numbers vary greatly between stations, with some stations — such as those used for conservation purposes — being virtually destocked, while a number of stations have been running livestock numbers above the Potential CC. In this report, the individual station ARLIs are aggregated at the LCD and regional scale.

Because there is no direct measure of grazing pressure used in the WA rangelands, this report shows the relationship between livestock number (from ARLI) and seasonal quality, and livestock numbers over time compared to the estimated Potential CC.

The Potential CC of an area is the estimated long-term carrying capacity that assumes the natural vegetation is in good condition, that stations are fully developed (with a sufficient number and distribution of watering points), and that all areas are accessible to livestock. The Potential CC does not account for introduced pastures, such as any intensified agriculture or centre pivots (see Section 1.3).

Table 2.2.1 Total Potential CC and Present CC for the WA rangelands

<table>
<thead>
<tr>
<th>Region</th>
<th>Potential CC (CU)</th>
<th>Present CC (CU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kimberley</td>
<td>825 400</td>
<td>584 160</td>
</tr>
<tr>
<td>Pilbara</td>
<td>252 180</td>
<td>202 630</td>
</tr>
<tr>
<td>Southern Rangelands</td>
<td>541 800</td>
<td>386 500</td>
</tr>
</tbody>
</table>

Cattle in the east Kimberley
Key message 1: Managers can control grazing pressure.

Kimberley cattle numbers (expressed as cattle units) have increased over the last 20 years, in a period when seasonal conditions were generally good (annual rainfall decile 8, 9 or 10), with no consecutive poor seasons (below decile 5) (Figure 2.2.1). In the Pilbara, cattle numbers have increased over the last 20 years, despite variable seasonal conditions (Figure 2.2.2).

Based on the 5-year (2010–14) average livestock numbers, 80% of stations in the De Grey LCD and 43% of stations in the North Kimberley LCD were running above the Potential CC (Figure 2.2.3). In 2014, livestock numbers were above the Potential CC on 30% of Kimberley stations and 44% of Pilbara stations.
Figure 2.2.3 Percentage of stations in each LCD in the Northern Rangelands with average livestock numbers above the Potential CC, 2010–14
In the Southern Rangelands, livestock numbers (expressed as cattle units) have remained relatively stable over the last 30 years (Figure 2.2.4). Some LCDs had increased numbers of livestock — Wiluna (81%), Nullarbor – Eyre Highway (63%) and Upper Gascoyne LCD (23%) — while many LCDs had substantially reduced numbers of livestock, such as Cue (−75%), Mount Magnet (−75%), Murchison (−73%) and Yalgoo (−76%).

Based on the 5-year (2010–14) average livestock numbers, 50% of stations in the Upper Gascoyne LCD were running above the Potential CC, while many stations were running well below the Potential CC (Figure 2.2.5). In 2014, livestock numbers were above the Potential CC on 11% of stations.

**Key message 2: Grazing pressure management needs to respond rapidly to changes in seasonal quality and resource condition.**

Pasture productivity drops substantially in poor seasons (below-average seasonal quality) and often drops faster than the total grazing pressure. This unintentional lag in management response can be a major cause of unsustainable grazing pressure.

**Key message 3: Appropriate grazing pressure management will lead to improved vegetation condition and positive trends.**

Grazing pressure is not evenly distributed in a paddock. Desirable perennials are ‘decreasers’ because they are highly palatable to livestock. Palatable perennials are preferentially grazed, even when there is an excess of other forage, leading to a decreased number of desirable perennials.
Figure 2.2.5 Percentage of stations in each LCD in the Southern Rangelands with average livestock numbers above the Potential CC, 2010–14
2.3 Fire

Fire in the rangelands is an important driver of soil cover, including litter, botanical composition and forage supply for grazing animals. It is a natural part of the ecology and many grassland types in the Northern Rangelands, particularly in the Kimberley, owe their continuance to fire because fire is a major factor in maintaining the open savannas. Increased fire frequency and intensity can damage the rangelands, as can the absence of fire where it was once part of the ecosystem. Controlled fires with a specific objective, such as the removal of woody plants, can be beneficial.

Fire interacts with grazing and weather to have complex effects on rangeland condition and livestock production. Uncontrolled or poorly managed fires (wildfires) can kill pasture and overstorey species, reducing pastoral productivity. When fire removes soil cover, the soil is more susceptible to erosion. More frequent and intense fires have increased soil erosion and decreased water quality through increased sediment content in parts of the Ord River and Fitzroy River catchments.

Fire frequency, intensity, and season affect pastoral vegetation in different ways and there can be a cumulative effect. The interval between fires is an important component of fire regimes (Department of Agriculture and Food, Western Australia 2010).

Data on Kimberley fire occurrence and spatial extent were obtained in January 2016 from the North Australian Fire Information (NAFI) website, firenorth.org.au, which provides information on the timing of fires (Figure 2.3.1), their spatial extent and, by comparison across years, the frequency with which a given area is burnt across northern Australia (Figure 2.3.2). These data are collected and analysed to provide assessments of fires in particular areas.

The NAFI website has been recently updated to include fire data for all the Western Australian rangelands.
Key message 1: Fire is common in the Kimberley and, to a lesser extent, in the Pilbara.

Each year, extensive areas of the Kimberley rangelands are burnt by wildfire and on average, 28% (58 000km$^2$) of pastoral station area is burnt (Figures 2.3.2 and 2.3.3). Fire has a major effect on soil cover, often leaving some areas bare at the start of the wet season, which in turn increases the risk of overland water flow and erosion.

**Figure 2.3.2** The number of years an area in the Kimberley burnt between 2000 and 2014

**Figure 2.3.3** Percentage of pastoral rangeland burnt in the Kimberley LCDs, 2006–15
Key message 2: Fire is less common in the Southern Rangelands.

Large, intense fires can occur following prolonged periods of above-average rainfall that produce high fuel loads. This situation has occurred in recent years in the Nullarbor and Gascoyne.

Sequence of recovery photos in burnt tussock grass pasture in the east Kimberley

Pasture before burning (July)  
Burnt pasture (October)

Pasture 8 months after burning (June)  
Pasture 25 months after burning (November)

Key message 3: Increased frequency and severity of fire increases the risk of soil erosion and reduces water quality.

Fire removes soil cover (standing plant cover and litter) which increases the risk of wind and water erosion, and reduces available forage which may lead to overgrazing. Late dry season fires generally leave the soil unprotected at the start of the wet season when intense thunderstorms occur.

Key message 4: Post-fire management is important for vegetation recovery.

When only a small proportion of a paddock is burned, the green shoots of recovering desirable perennials are very palatable to livestock, leading to heavy grazing pressure on the regrowth — with livestock ignoring the dry standing forage in other parts of the paddock — and the possible localised decline of rangeland vegetation condition.

Sources of information


Department of Agriculture and Food, Western Australia 2010, Fire management guidelines for Kimberley pastoral rangelands, Department of Agriculture and Food, Western Australia, Perth.


Section 3 Natural resource themes
3.1 Rangeland vegetation condition

Key messages

Status and trend

- In the Northern Rangelands, rangeland vegetation condition at the aggregate LCD scale was mostly good or fair, with 57% good, 29% fair and 14% poor (Figure 3.1.1 and Table 3.1.1).
- There was considerable variability between and within LCDs, and between vegetation types on individual stations in the Northern Rangelands.
- In the Northern Rangelands, WARMS monitoring sites indicate a stable trend since the last station inspections (2002–09), except in the Ashburton and De Grey LCDs where the trend was declining.
- In the Southern Rangelands, rangeland vegetation condition at the aggregate LCD scale was mostly fair or good, with 36% good, 39% fair and 25% poor (Figure 3.1.2 and Table 3.1.2).
- There is considerable variability between and within LCDs and stations, and between vegetation types on individual stations in the Southern Rangelands. Many LCDs had less than 30% of the rangeland vegetation in good condition, and vegetation condition in the Upper Gascoyne LCD was poor at more than 50% of traverse points.
- In the Southern Rangelands, WARMS monitoring sites indicate a stable trend since the last station inspections (2002–09).

Management implications

- Vegetation in fair or poor condition needs to be carefully managed to cope with seasonal variation.
- Susceptible land units, particularly in the Southern Rangelands, require rehabilitation and/or improved grazing management to allow regeneration of desirable perennials.
- Optimal placement of watering points and paddock boundary fencing can reduce loss of vegetation condition and improve vegetation use.
Figure 3.1.1 Rangeland Vegetation Condition Index at the most recent assessment in the Northern Rangelands, 2001–09
Figure 3.1.2 Rangeland Vegetation Condition Index at the most recent assessment in the Southern Rangelands, 2001–09
### Table 3.1.1 Status and trend in rangeland vegetation condition at the most recent WARMS assessment in the Northern Rangelands

<table>
<thead>
<tr>
<th>LCD</th>
<th>Number of stations</th>
<th>Number of vegetation condition ratings in LCD</th>
<th>Vegetation condition classes (%)</th>
<th>Rangeland Vegetation Condition Index</th>
<th>Trend</th>
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</thead>
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<td></td>
<td></td>
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<td>1.6</td>
<td>*</td>
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</table>

* Trend was based on the period from the last station inspection to Assessment 8 (2015).
† Trend was based on the condition assessment of the WARMS site between the corresponding year of the last station inspection and Assessment 7 (2012–14).

Note: For WARMS assessment periods, refer to Table 3.2.1.

<table>
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<tr>
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<tr>
<td>Fair</td>
<td>Stable</td>
</tr>
<tr>
<td>Poor</td>
<td>Declined</td>
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41
Table 3.1.2 Status and trend in rangeland vegetation condition at the most recent WARMS assessment in the Southern Rangelands

<table>
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<tr>
<th>LCD</th>
<th>Number of stations</th>
<th>Number of vegetation condition ratings in LCD</th>
<th>Vegetation condition classes (%)</th>
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Table 3.1.2 continued

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<th>Rangeland Vegetation Condition Index</th>
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n/a  No assessment rating was recorded in Assessment 3 (2005–10).

Note: Trend was based on the condition assessment of the WARMS site between the corresponding year of the last station inspection and Assessment 4 (2010–15). For WARMS assessment periods, refer to Table 3.2.1.
Overview

In this report, rangeland vegetation condition relates to livestock grazing (pastoralism) values.

Rangeland vegetation condition (good, fair or poor; see Glossary) is an assessment of the health of the vegetation in relation to a reference or benchmark site — an area perceived to be in a state of good health — within a given set of environmental and managerial factors (Friedel et al. 2000). Rangeland vegetation condition is measured using a defined set of indicators of vegetation for production.

The presence and persistence of palatable perennial grasses and shrubs is the major indicator of rangeland vegetation condition for pastoralism. Palatable (to livestock), productive perennial plants (grasses or shrubs) are essential for sustainable pastoralism. These plants provide drought forage in variable rainfall climates, protect the soil surface, play an important role in nutrient cycling and maintaining soil health (for example soil organic matter), and in some areas, provide fuel for burning to help control woody weeds.

Rangeland vegetation condition declines:

• when desirable plants (generally palatable, perennial species) are replaced by less desirable ones (often, but not necessarily, annual species)
• when there is a loss of vegetation cover leading to an increase in bare ground
• when water flow patterns are altered by soil erosion, thereby reducing water availability for vegetation growth.

Perennial plants provide a degree of production and soil stability for pastoral production systems across variable seasons and years. Annual and short-lived perennial plants provide less soil stability because they drop their leaves and decrease in numbers or disappear in dry conditions.

Stocking rate and livestock productivity can be high on vegetation in poor condition in average or above-average rainfall seasons because the substantial amount of forage produced by annuals and short-lived perennials can mask the underlying impact of prolonged overgrazing on desirable perennials.

However, in below-average rainfall seasons, annuals produce very little forage and perennials are significantly reduced or absent. In these seasons, rangeland in poor condition has more bare ground and less capacity to productively use rainfall, has limited grazing potential and livestock production capacity, and has lost drought resilience.

Rehabilitating and improving rangeland vegetation condition generally requires sequences of above-average rainfall years coupled with low grazing pressure to allow desirable plant populations to recover. In areas where there has been considerable soil loss and substantial vegetation change, irreversible change may have occurred and grazing productivity may have declined permanently.

Assessment method

DAFWA assesses rangeland vegetation condition by comparing the current vegetation to that which would be expected to occur in the natural undisturbed state. Rangeland vegetation condition at the pastoral station scale was assessed using a standard methodology about every six years from 1997 until 2009, and intermittently prior to 1997. These assessments are held in confidential reports. Each station assessment consisted of traverses through the major land systems (see Glossary). At every kilometre along each traverse, rangeland vegetation condition was recorded. The status of the soil surface (cover and erosion) relative to a pristine area of the same pasture type was also recorded.
Example of rangeland condition states for ribbon grass Alluvial Plain pasture in the Kimberley

Good condition: high density and even spacing of perennial ribbon grass, only a small number of undesirable grasses, good soil cover provided by perennial grasses

Fair condition: density of desirable grass is reduced, increased number of undesirable grasses, increased number of bare soil patches

Poor condition: density of desirable grass is sparse, large areas of bare soil

The measures used to report on vegetation condition are:

1. percentages of good, fair and poor vegetation condition (aggregate from points on the traverses on each station)
2. Rangeland Vegetation Condition Index, a weighted figure based on the percentages in point 1.

The Rangeland Vegetation Condition Index (RVCI) derived from these assessments and the trend in RVCI is used to assess the change in rangeland vegetation condition over time.

The RVCI ranges from 1.0 to 3.0, with:

1.0 = good condition
2.0 = fair condition
3.0 = poor condition.

It is calculated as:

RVCI = \( \text{Sum} \left( \left( \frac{\text{percent good vegetation condition}}{100} \times 1 \right) + \left( \frac{\text{percent fair vegetation condition}}{100} \times 2 \right) + \left( \frac{\text{percent poor vegetation condition}}{100} \times 3 \right) \right) \)

For example, in an LCD with 20% of traverse points in good vegetation condition, 50% in fair vegetation condition and 30% in poor vegetation condition, the RVCI is calculated as:

RVCI = \( \left( \frac{0.20 \times 1}{100} \right) + \left( \frac{0.50 \times 2}{100} \right) + \left( \frac{0.30 \times 3}{100} \right) \) = 2.1

If the RVCI is 1.0, the whole LCD is in good rangeland vegetation condition; if the RVCI is 3.0, the whole LCD is in poor rangeland vegetation condition.

Note that LCDs with different proportions of rangeland vegetation condition can have the same RVCI. For example, an LCD with 50% of the vegetation in good condition and 50% in poor condition has
the same RVCI (2.0) as an LCD with 100% in fair condition. Caution is needed when comparing the RVCI of LCDs with different land systems. Figures 3.1.1 and 3.1.2 are based on DAFWA’s most recent assessments (ending in 2009). The RVCI values for each LCD are based on all traverse points for each LCD (regardless of the station they occur on), rather than the average of individual stations within an LCD. Note that the most recent assessment for some stations was from 2001 and 2002 (Tables 1.3 and 1.4).

Status and trend

Northern Rangelands
At the LCD scale, rangeland vegetation in the Northern Rangelands was mostly in good or fair condition. At the aggregate LCD scale, vegetation condition was 57% good, 29% fair and 14% poor (Figure 3.1.1 and Table 3.1.1).

Vegetation in the Broome, De Grey and Roebourne – Port Hedland LCDs was generally in good condition and the vegetation in the rest of the LCDs was in good to fair condition (Table 3.1.1). Spinifex-dominated hummock grasses dominate a large proportion of the Pilbara rangelands (Van Vreeswyk et al. 2004). This grass species composition makes these rangeland types particularly resilient to grazing and is often in good to fair condition.

Considerable variation in vegetation condition exists within LCDs and within individual stations. Vegetation types within land systems vary in resilience to grazing and palatability to livestock, resulting in patch grazing — where continual grazing in certain areas contributes to localised overgrazing — while other areas are lightly grazed or, in some cases, rank and unused. The palatable vegetation types or preferred areas (often in drainage areas or valley floors) generally record a higher percentage of poor condition ratings than less-palatable vegetation types, such as hard spinifex hill pastures. Therefore, between stations within LCDs, there is a wide range of RVCI values. Several stations

have more than 40% of the traverse points in poor condition while, some stations have 80–90% of traverse points in good condition.

In the Kimberley, pasture types dominated by hummock grasses appear more resistant to grazing than tussock (bunch grass) types. In the Ord River Catchment, only 4% of the assessments of hummock pasture types are in poor vegetation condition, compared to 37% of tussock pasture types. Hummock grasses, particularly spinifex (Triodia spp.), have greater resilience to grazing, lower palatability to livestock and are often in locations less attractive to livestock.

Tussock grass-dominated pastures, for instance ribbon grass pasture dominated by the highly palatable grass, Chrysopogon fallax, have limited resistance to heavy and prolonged grazing. Ribbon grass is highly favoured by cattle and native herbivores early in the growing season and so it is particularly susceptible to a decline in rangeland vegetation condition.

Southern Rangelands
At the LCD scale, rangeland vegetation in the Southern Rangelands was mostly in good or fair condition. At the aggregate LCD scale, vegetation condition was 36% good, 39% fair and 25% poor (Figure 3.1.2 and Table 3.1.2).

The LCD RVCI in the Southern Rangelands indicate a more variable rangeland vegetation condition than the Northern Rangelands, with several LCDs having aggregated RVCI values above 2.0 (Table 3.1.2). This variability is, in part, associated with different land uses and lease ownership (Figure 1.8). The Goldfields and Nullarbor have low RVCI values (good condition), with numerous stations having more than 70% of traverse points in good condition. Other areas, particularly in the summer rainfall region, have relatively high RVCI values, indicating a low proportion of traverse points in good condition on many stations. For example, only 2 of the 33 stations in the Gascoyne – Ashburton Headwaters and Upper Gascoyne LCDs recorded more than 50% of traverse points in good condition.
As in the Northern Rangelands, there is considerable variation within LCDs and between land systems and vegetation types within individual stations. While the vegetation in the Goldfields and Nullarbor was generally in good condition, several stations recorded less than 10% of traverse points in good condition. In the Gascoyne River Catchment, when aggregated into land type, the alluvial plains with halophytic shrublands — including the Sable (55% of traverse points in good condition) and Delta (24% in good condition) land systems — recorded the highest percentage of traverse points in good condition.

In contrast, the stony plains with acacia shrublands and halophytic shrublands land type were in the poorest condition, with 68% of traverse points in poor condition (Waddell et al. 2012). This land type includes the Nadarra (73% of traverse points in poor condition), Bryah (71%), Durlacher (70%), Mantle and Yinnietharra (61%) and Kurubuka (53%) land systems. The differences between land systems and their vegetation types are largely a result of differences in the inherent resilience to grazing of the species within the vegetation types, palatability to livestock and the topographic location.

**Discussion and implications**

Rangeland vegetation condition varies widely across the WA pastoral rangelands. While some LCDs, particularly in the Northern Rangelands, have good RVCI values, other areas in the Southern Rangelands are dominated by poorer RVCI values.

Variation in rangeland vegetation condition at the land system scale is exacerbated by the difficulties of managing grazing pressure across pastoral areas that include several land systems. Selective grazing of the more palatable vegetation types in some land systems and seasonal factors are the primary influences on the variability of rangeland vegetation condition.

**Sources of information**


Van Vreeswyk, AME, Payne, AL, Leighton, KA & Hennig, P 2004, ‘An inventory and condition survey of the Pilbara region, Western Australia’, *Technical bulletin 92*, Department of Agriculture Western Australia, Perth.


3.2 Plant population change

Key messages

Status and trend

- In the Kimberley, the frequency (see Glossary) of all perennial grasses and desirable perennial grasses has increased or been stable since monitoring began in 1994, and it was high in all LCDs (Figures 3.2.1 and 3.2.3, Tables 3.2.2 and 3.2.4).
- In the Pilbara, the frequency of all perennial grasses and desirable perennial grasses has been variable. In the Ashburton LCD, the frequency of all perennial grasses and the frequency of desirable perennial grasses have decreased since monitoring began (Figures 3.2.1 and 3.2.3, Tables 3.2.2 and 3.2.4).
- In the Southern Rangelands, the density (see Glossary) of all shrubs and trees and desirable shrubs and trees has been variable since monitoring began in 1994, although density had predominantly decreased (Figures 3.2.2 and 3.2.4, Tables 3.2.3 and 3.2.5).
- In the assessment period 2010–15, the density of all shrubs and trees and the density of desirable shrubs and trees has decreased in 11 of the 15 LCDs where there were sufficient monitoring sites to make an LCD-scale assessment.

Management implications

- Grazing management is maintaining the desirable perennial grasses in the Northern Rangelands.
- Loss of desirable perennial grasses in many parts of the Southern Rangelands has reduced the carrying capacity.
- Loss of desirable perennials in the Southern Rangelands means there is an increasing reliance on annual pasture production which increases the susceptibility to climate variability.
Figure 3.2.1 Percentage of WARMS sites that recorded a change in the frequency of all perennial grasses from Assessment 6 (2009–11) to Assessment 7 (2012–14) in the Northern Rangelands.
Figure 3.2.2 Percentage of WARMS sites that recorded a change in the density of all shrubs and trees from Assessment 3 (2005–10) to Assessment 4 (2010–15) in the Southern Rangelands
Figure 3.2.3 Percentage of WARMS sites that recorded a change in the frequency of desirable perennial grasses from Assessment 6 (2009–11) to Assessment 7 (2012–14) in the Northern Rangelands.
Figure 3.2.4 Percentage of WARMS sites that recorded a change in the density of desirable shrubs and trees from Assessment 3 (2005–10) to Assessment 4 (2010–15) in the Southern Rangelands.
Overview

Rangeland plant population change is calculated from the change in the population of categories of perennial plants at a particular site over time. To detect and understand changes to plant populations caused by different land uses, we need to monitor and assess those rangeland attributes that are affected by the land use. These attributes should define how well the rangeland ecosystems are functioning relative to that expected from pristine or reference areas — areas largely unaffected by land use.

In the early 1990s, DAFWA established the Western Australian Rangeland Monitoring System (WARMS) to assess changes in plant populations. WARMS comprises a set of fixed sites on representative areas of pastoral land and reports at the vegetation type or regional scale; it is not suitable for pastoral station scale assessment (see ‘Assessing change’ in Section 1.3).

WARMS grassland monitoring sites (predominantly in the Northern Rangelands) have been assessed every three years and shrubland sites (predominantly in the Southern Rangelands) have been assessed every five years. The seventh sampling (Assessment 7, 2012–14) of grassland sites was completed in 2014 and the most recent sampling of shrubland sites (Assessment 4, 2010–15) was completed in 2015. DAFWA was carrying out Assessment 8 (2015–17) of the grasslands sites at the time this report was published.

Quantitative data from WARMS sites allows vegetation population and vegetation condition trends to be calculated at the vegetation type or regional scale. DAFWA groups plants in the WARMS sites into three categories: desirable perennial species, which are those species in a pasture type that are perennial, productive and highly palatable to domestic livestock; intermediate species, which are moderately or slightly palatable perennial grasses and shrubs; and undesirable species, which are those that are generally unpalatable (see Glossary).

Rangeland plant populations can be increasing, stable or decreasing. An increasing population occurs when there is a decrease in the area of bare ground or an increase in the density of desirable perennials. An increasing population may also appear as a decrease in noxious and invasive weeds, an increase in litter cover or a general improvement in plant vigour or size. A decreasing population occurs when desirable perennials decrease or undesirable species increase, or both, or when soil cover decreases.

WARMS data can be used to partly filter out the influence of seasonal condition on plant population change, and where fire is not a driver, this leaves grazing pressure (management) as the driver for rangeland vegetation condition change. To achieve reliable estimates of the influence of management on plant population change, we need repeated assessments over a long period.

Assessment method

WARMS uses different methodologies for grassland and shrubland sites, although both are based on quantitative techniques that measure vegetation and soil attributes, are repeatable, and are more reliable than estimations or qualitative rankings (Watson et al. 2007, Novelly et al. 2008).

At grassland sites, the frequency (see Glossary) of all perennial grasses is recorded in 70 x 70 centimetre quadrats and the green crown cover of woody perennials is estimated.

At shrubland sites, the shrub and tree numbers (density) are recorded using a direct census of the position of each plant along three permanent transects; the plant’s maximum green width and height dimensions are also recorded.

At all sites, the landscape function is assessed and standard photographs are taken.

The rangeland plant population change for each LCD aggregates data from all the WARMS assessments in that LCD. Since assessment periods differ between grassland and shrubland sites (Table 3.2.1), the information in this report relates to the most recent assessment, which
is Assessment 8 (2015) for the North Kimberley, Broome and Ashburton LCDs and Assessment 7 (2012–14) for the other Northern Rangeland LCDs. In the Southern Rangelands, it is Assessment 4 (2010–15).

WARMS sites reflect changes that are occurring over a much larger area within a specific vegetation type, but cannot account for all the spatial variation and biophysical processes occurring in the complex rangeland landscape. In essence, pastoral monitoring systems can only report on the soils and vegetation found within the area of the site and their limitations for regional reporting of landscape health have been demonstrated (Pringle et al. 2006).

Care is required in comparing absolute plant density or frequency data between LCDs and between vegetation types, although comparing plant population changes is appropriate. Numbers of desirable perennials in a pristine area vary substantially between vegetation types, as does the capacity of plant numbers to increase.

<table>
<thead>
<tr>
<th>Assessment</th>
<th>Assessment period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grasslands</td>
<td></td>
</tr>
<tr>
<td>A1</td>
<td>1994–96</td>
</tr>
<tr>
<td>A2</td>
<td>1997–99</td>
</tr>
<tr>
<td>A3</td>
<td>2000–02</td>
</tr>
<tr>
<td>A4</td>
<td>2003–05</td>
</tr>
<tr>
<td>A5</td>
<td>2006–08</td>
</tr>
<tr>
<td>A6</td>
<td>2009–11</td>
</tr>
<tr>
<td>A7</td>
<td>2012–14</td>
</tr>
<tr>
<td>A8</td>
<td>2015*</td>
</tr>
<tr>
<td>Shrublands</td>
<td></td>
</tr>
<tr>
<td>A1</td>
<td>1994–99</td>
</tr>
<tr>
<td>A2</td>
<td>1999–2005†</td>
</tr>
<tr>
<td>A3</td>
<td>July 2005 – June 2010</td>
</tr>
<tr>
<td>A4</td>
<td>July 2010 – December 2015</td>
</tr>
</tbody>
</table>

* Sampling in this assessment period was in progress when this report was prepared.
† Not all shrubland sites were installed before the beginning of the second assessment period. Therefore, sites installed in 1994 had their second assessment before other shrubland sites had their first assessment.

Note: In a grassland assessment period (3 years), about one-third of sites are assessed in any year. In a shrubland assessment period (about 5 years), about one-fifth of sites are assessed in any year.
Status and trend

All perennial species (grasses and shrubs)

Northern Rangelands

In all Kimberley LCDs, the frequency of all perennial grasses, not just desirable perennial grasses, generally increased from Assessment 1 (1994–96) to Assessment 7 (2012–14) and into the current assessment period (Assessment 8, 2015), although the increase was more variable in the Broome and North Kimberley LCDs. In Assessment 7 (2012–14), at least half of the WARMS sites had an increase in the perennial grass frequency and the frequency remains close to 100% in all LCDs (Figure 3.2.1 and Table 3.2.2). Perennial grass frequency is currently above that recorded in Assessment 1 (1994–96) in all LCDs except Broome, where initial frequencies were particularly high. Overall, the plant populations are stable.

In the Pilbara LCDs, perennial grass frequency was variable. Frequencies increased from Assessment 6 (2009–11) to Assessment 7 (2012–14) in the De Grey, East Pilbara and Roebourne – Port Hedland LCDs and decreased in the Ashburton LCD (Figure 3.2.1 and Table 3.2.2). These frequencies are all below those recorded in Assessment 2 (1997–99). In the Ashburton LCD, there was a substantial decrease in frequency of nearly 20% (from 90% to 72%) from Assessment 2 (1997–99) to Assessment 8 (2015).

Southern Rangelands

In the Southern Rangelands, the shrub and tree density has generally decreased at the most recent assessment (Figure 3.2.2 and Table 3.2.3). In the Wiluna, Lyndon and Gascoyne–Wooramel LCDs, shrub and tree numbers decreased at more than 70% of WARMS sites in Assessment 4 (2010–15). The general decrease in shrub and tree density in many LCDs indicates an increase in susceptibility to erosion.

Desirable perennial species (grasses and shrubs)

Northern Rangelands

Assessment 7 (2012–14) showed a slight decrease in desirable perennial grass frequency in the Kimberley, particularly in the North Kimberley LCD, even though frequency increased at many WARMS sites (Figure 3.2.3 and Table 3.2.4). Because desirable perennial grass frequency varies among pasture types, this decrease may not indicate a decline in rangeland vegetation condition, but it does represent a negative trajectory. The decrease is not yet substantial and desirable perennial grass frequency remains high in all Kimberley LCDs, with some stations (including in the North Kimberley LCD), recording frequencies of more than 95%. This high frequency indicates the Kimberley rangeland’s capacity as a pastoral resource is being maintained.

The change in desirable perennial grass frequency in the Pilbara was variable. The decrease in desirable perennial grass frequency indicates that the pastoral capacity of the Ashburton LCD has declined. The desirable perennial grass frequency in the De Grey, East Pilbara and Roebourne – Port Hedland LCDs is variable (Figure 3.2.3 and Table 3.2.4).

Southern Rangelands

As with all shrubs and trees, the density of desirable shrubs and trees has generally decreased in the Southern Rangelands. Density decreased by 12% from Assessment 3 (2005–10) to Assessment 4 (2010–15) — some sites recorded a decrease of more than 80% — and density decreased in more than 50% of the WARMS sites in two-thirds of the LCDs (Figure 3.2.4 and Table 3.2.5). Of note is the decrease in density of desirable shrubs and trees from Assessment 3 (2005–10) to Assessment 4 (2010–15) at WARMS sites with above-average seasonal quality (Table 3.2.6).
While some LCDs have insufficient WARMS sites to provide an accurate assessment at the LCD scale, LCDs with a larger number of sites, such as the Gascoyne – Ashburton Headwaters and Wiluna LCDs, also show considerable decreases. There was also variation within LCDs, with an increase in the density of desirable plants at some WARMS sites in an LCD in which decreases occurred at most other sites. This variation reflects the heterogeneity of the landscape, particularly in relation to the resilience of vegetation types to grazing, as well as possible variations in seasonal quality and grazing management across larger LCDs.

There was an increase in perennial grasses, particularly buffel grass (*Cenchrus ciliaris*), in the Southern Rangelands summer rainfall zone. Buffel grass has become naturalised in the WA rangelands and is present in varying densities (from obvious to rare) in many areas. For example, in 2011, of the 96 WARMS sites assessed in the Gascoyne River Catchment, 35 sites (36%) had a perennial grass species present, with buffel grass recorded on 22% of those sites. However, there was little change overall in the presence of perennial grasses from Assessment 3 (2005–10) to Assessment 4 (2010–15), suggesting the increase was localised. These changes may be associated with buffel grass occupying parts of the rangelands previously occupied by perennial shrubs. Additionally, this trend may be encouraged by the increasing proportion of annual rainfall in the hotter summer months, which provides particularly favourable conditions for buffel grass.

**Transition from chenopod pasture to buffel grass pasture in the Southern Rangelands**

In 2002, there were 1600 silver saltbush plants per hectare

In 2008, there were 1000 silver saltbush plants per hectare, with buffel grass frequency of about 10%

In 2015, there were no silver saltbush plants and buffel grass frequency had increased to 56%
Table 3.2.2  Status, change and overall trend in the average frequency of all perennial grasses, and the seasonal quality in the Northern Rangelands, 1994–2015

| LCD |
|------------------|----------------------------------|------------------|------------------|------------------|------------------|
| North Kimberley | Increased | Increased | Stable | Stable | 0 | 25 | 50 | 75 | 100 |
| Halls Creek – East Kimberley* | Stable | Stable | Increased | NA | 0 | 25 | 50 | 75 | 100 |
| Derby – West Kimberley* | Stable | Stable | Increased | NA | 0 | 25 | 50 | 75 | 100 |
| Broome | Increased | Stable | Stable | Stable | 0 | 25 | 50 | 75 | 100 |
| De Grey† | Stable | Decreased | Increased | NA | 0 | 25 | 50 | 75 | 100 |
| Roebourne – Port Hedland‡ | Increased | Stable | Increased | NA | 0 | 25 | 50 | 75 | 100 |
| East Pilbara‡ | Decreased | Decreased | Increased | NA | 0 | 25 | 50 | 75 | 100 |
| Ashburton§ | NA | Stable | Decreased | Stable | 0 | 25 | 50 | 75 | 100 |

* Overall trend was determined from Assessment 1 to Assessment 7 (Assessment 8 is scheduled for 2016 or 2017).
† Overall trend was determined from Assessment 2 to Assessment 7 (Assessment 8 is scheduled for 2016 or 2017).
‡ Overall trend was determined from Assessment 3 to Assessment 7 (Assessment 8 is scheduled for 2017).
§ Overall trend was determined from Assessment 2 to Assessment 8.
NA Data is not available for Assessment 8.

Note: Increased, decreased and stable relate to change between consecutive assessments. The trend symbol relates to overall trend.

Overall trend
- Increased
- Stable
- Decreased

Seasonal quality (percentage of sites in LCD)
- Above average
- Average
- Below average

The proportion of each colour in the bar length represents the percentage for each class.
Table 3.2.3  Status, change and overall trend in the average density of all shrubs and trees and the seasonal quality in the Southern Rangelands, 1994–2015*

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>9  Gascoyne – Ashburton Headwaters</td>
<td>Increased</td>
<td>Decreased</td>
<td>Decreased</td>
<td><img src="#" alt="Increased" /></td>
<td>105 x 75</td>
</tr>
<tr>
<td>10 Upper Gascoyne</td>
<td>Increased</td>
<td>Decreased</td>
<td>Decreased</td>
<td><img src="#" alt="Increased" /></td>
<td>85 x 55</td>
</tr>
<tr>
<td>11 Wiluna</td>
<td>Increased</td>
<td>Stable</td>
<td>Decreased</td>
<td><img src="#" alt="Increased" /></td>
<td>75 x 55</td>
</tr>
<tr>
<td>12 Lyndon</td>
<td>Increased</td>
<td>Decreased</td>
<td>Decreased</td>
<td><img src="#" alt="Increased" /></td>
<td>80 x 50</td>
</tr>
<tr>
<td>13 Gascoyne–Wooramel</td>
<td>Increased</td>
<td>Decreased</td>
<td>Decreased</td>
<td><img src="#" alt="Increased" /></td>
<td>80 x 50</td>
</tr>
<tr>
<td>14 Shark Bay</td>
<td>Stable</td>
<td>Decreased</td>
<td>Stable</td>
<td><img src="#" alt="Increased" /></td>
<td>115 x 85</td>
</tr>
<tr>
<td>15 Murchison</td>
<td>Decreased</td>
<td>Decreased</td>
<td>Decreased</td>
<td><img src="#" alt="Increased" /></td>
<td>85 x 60</td>
</tr>
<tr>
<td>16 Meekatharra</td>
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<td>Decreased</td>
<td>Decreased</td>
<td><img src="#" alt="Increased" /></td>
<td>80 x 60</td>
</tr>
<tr>
<td>17 Cue</td>
<td>Stable</td>
<td>Stable</td>
<td>Increased</td>
<td><img src="#" alt="Increased" /></td>
<td>95 x 65</td>
</tr>
<tr>
<td>18 Mount Magnet</td>
<td>Stable</td>
<td>Increased</td>
<td>Increased</td>
<td><img src="#" alt="Increased" /></td>
<td>70 x 50</td>
</tr>
<tr>
<td>19 Sandstone</td>
<td>Increased</td>
<td>Stable</td>
<td>Stable</td>
<td><img src="#" alt="Increased" /></td>
<td>55 x 45</td>
</tr>
</tbody>
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Table 3.2.3 continued

<table>
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<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>20 Yalgoo</td>
<td>Decreased</td>
<td>Stable</td>
<td>Stable</td>
<td><img src="image" alt="Graph showing density trend" /></td>
<td>65 x 45</td>
</tr>
<tr>
<td>21 Perenjori</td>
<td>Increased</td>
<td>Decreased</td>
<td>Decreased</td>
<td><img src="image" alt="Graph showing density trend" /></td>
<td>70 x 40</td>
</tr>
<tr>
<td>24 North-eastern Goldfields</td>
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<td>Stable</td>
<td>Decreased</td>
<td><img src="image" alt="Graph showing density trend" /></td>
<td>90 x 55</td>
</tr>
<tr>
<td>25 Kalgoorlie</td>
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<td>Decreased</td>
<td><img src="image" alt="Graph showing density trend" /></td>
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<tr>
<td>26 Yilgarn</td>
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<td>Decreased</td>
<td>Stable</td>
<td><img src="image" alt="Graph showing density trend" /></td>
<td>55 x 40</td>
</tr>
<tr>
<td>27 Nullarbor – Eyre Highway</td>
<td>Increased</td>
<td>Decreased</td>
<td>Stable</td>
<td><img src="image" alt="Graph showing density trend" /></td>
<td>65 x 50</td>
</tr>
</tbody>
</table>

* The LCDs of Binnu (LCD 22) and Mount Marshall (LCD 23) had insufficient WARMS sites to represent the LCD.

Note: Increased, decreased and stable relate to change between consecutive assessments. The trend symbol relates to overall trend.

**Overall trend**
- ![Increased](image)
- ![Stable](image)
- ![Decreased](image)

Trend symbol is placed at the average density at the most recent assessment.

**Seasonal quality** (percentage of sites in LCD)
- ![Above average](image)
- ![Average](image)
- ![Below average](image)

The proportion of each colour in the bar length represents the percentage for each class.
Table 3.2.4 Status, change and overall trend in the average frequency of desirable perennial grasses and the seasonal quality in the Northern Rangelands, 1994–2015

<table>
<thead>
<tr>
<th></th>
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<th></th>
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<th></th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>North Kimberley</td>
<td>Stable</td>
<td>Increased</td>
<td>Decreased</td>
<td>Increased</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>Halls Creek – East Kimberley*</td>
<td>Stable</td>
<td>Stable</td>
<td>Stable</td>
<td>Stable</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>Derby – West Kimberley*</td>
<td>Stable</td>
<td>Stable</td>
<td>Increased</td>
<td>NA</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>Broome</td>
<td>Increased</td>
<td>Stable</td>
<td>Stable</td>
<td>Stable</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>De Grey†</td>
<td>Stable</td>
<td>Decreased</td>
<td>Increased</td>
<td>NA</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>Roebourne – Port Hedland‡</td>
<td>Increased</td>
<td>Stable</td>
<td>Increased</td>
<td>NA</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>East Pilbara‡</td>
<td>Decreased</td>
<td>Decreased</td>
<td>Increased</td>
<td>NA</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>Ashburton§</td>
<td>NA</td>
<td>Decreased</td>
<td>Decreased</td>
<td>Stable</td>
<td>0</td>
</tr>
</tbody>
</table>

* Overall trend was determined from Assessment 1 to Assessment 7 (Assessment 8 is scheduled for 2016 or 2017).
† Overall trend was determined from Assessment 2 to Assessment 7 (Assessment 8 is scheduled for 2016 or 2017).
‡ Overall trend was determined from Assessment 3 to Assessment 7 (Assessment 8 is scheduled for 2017).
§ Overall trend was determined from Assessment 2 to Assessment 8.
NA Data is not available for Assessment 8.

Note: Increased, decreased and stable relate to change between consecutive assessments. The trend symbol relates to overall trend.

Overall trend

- Increased
- Stable
- Decreased

Trend symbol is placed at the average frequency at the most recent assessment.

Seasonal quality (percentage of sites in LCD)

- Above average
- Average
- Below average

The proportion of each colour in the bar length represents the percentage for each class.
### Table 3.2.5 Status, change and overall trend in the density of desirable shrubs and trees and the seasonal quality in the Southern Rangelands, 1994–2015

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>Increased</td>
<td>Decreased</td>
<td>Decreased</td>
<td>![Filled Box]</td>
<td>60 x 50</td>
</tr>
<tr>
<td></td>
<td>Gascoyne – Ashburton Headwaters</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Increased</td>
<td>Decreased</td>
<td>Decreased</td>
<td>![Filled Box]</td>
<td>55 x 40</td>
</tr>
<tr>
<td></td>
<td>Upper Gascoyne</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Increased</td>
<td>Stable</td>
<td>Decreased</td>
<td>![Filled Box]</td>
<td>50 x 40</td>
</tr>
<tr>
<td></td>
<td>Wiluna</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Increased</td>
<td>Decreased</td>
<td>Decreased</td>
<td>![Filled Box]</td>
<td>65 x 45</td>
</tr>
<tr>
<td></td>
<td>Lyndon</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Increased</td>
<td>Decreased</td>
<td>Decreased</td>
<td>![Filled Box]</td>
<td>60 x 40</td>
</tr>
<tr>
<td></td>
<td>Gascoyne–Wooramel</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Stable</td>
<td>Decreased</td>
<td>Decreased</td>
<td>![Filled Box]</td>
<td>70 x 55</td>
</tr>
<tr>
<td></td>
<td>Shark Bay</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Stable</td>
<td>Decreased</td>
<td>Decreased</td>
<td>![Filled Box]</td>
<td>50 x 40</td>
</tr>
<tr>
<td></td>
<td>Murchison</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Slightly decreased</td>
<td>Decreased</td>
<td>Decreased</td>
<td>![Filled Box]</td>
<td>50 x 40</td>
</tr>
<tr>
<td></td>
<td>Meekatharra</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Slightly decreased</td>
<td>Stable</td>
<td>Slightly Increased</td>
<td>![Filled Box]</td>
<td>50 x 45</td>
</tr>
<tr>
<td></td>
<td>Cue</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Stable</td>
<td>Increased</td>
<td>Increased</td>
<td>![Filled Box]</td>
<td>40 x 30</td>
</tr>
<tr>
<td></td>
<td>Mount Magnet</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Increased</td>
<td>Stable</td>
<td>Stable</td>
<td>![Filled Box]</td>
<td>35 x 30</td>
</tr>
<tr>
<td></td>
<td>Sandstone</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------------</td>
<td>--------------------------------</td>
<td>--------------------------------</td>
<td>--------------------------------</td>
<td>------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Average plant size (width x height (cm)) at the most recent assessment &amp; seasonal quality, 1994–2015</td>
<td></td>
</tr>
<tr>
<td>20 Yalgoo</td>
<td>Decreased</td>
<td>Stable</td>
<td>Stable</td>
<td>45 x 35</td>
<td></td>
</tr>
<tr>
<td>21 Perenjori</td>
<td>Increased</td>
<td>Decreased</td>
<td>Decreased</td>
<td>55 x 30</td>
<td></td>
</tr>
<tr>
<td>24 North-eastern Goldfields</td>
<td>Increased</td>
<td>Stable</td>
<td>Decreased</td>
<td>50 x 35</td>
<td></td>
</tr>
<tr>
<td>25 Kalgoorlie</td>
<td>Increased</td>
<td>Slightly decreased</td>
<td>Decreased</td>
<td>50 x 35</td>
<td></td>
</tr>
<tr>
<td>26 Yilgarn</td>
<td>Stable</td>
<td>Slightly decreased</td>
<td>Stable</td>
<td>55 x 40</td>
<td></td>
</tr>
<tr>
<td>27 Nullarbor – Eyre Highway</td>
<td>Slightly increased</td>
<td>Decreased</td>
<td>Decreased</td>
<td>50 x 40</td>
<td></td>
</tr>
</tbody>
</table>

* The LCDs of Binnu (LCD 22) and Mount Marshall (LCD 23) had insufficient WARMS sites to represent the LCD.

Note: Increased, decreased and stable relate to change in the particular cycle. The trend symbol relates to overall trend.

**Overall trend**
- 🕩 Increased
- 🗓 Stable
- 🚅 Decreased

Trend symbol is placed at the average density at the most recent assessment.

**Seasonal quality** (percentage of sites in LCD)
- 🔵 Above average
- 🍊 Average
- 🌟 Below average

The proportion of each colour in the bar length represents the percentage for each class.
In 1998, there were 10 700 desirable plants per hectare.

In 2003, there were 4530 desirable plants per hectare.

In 2009, there were 2500 desirable plants per hectare with soil erosion on the right hand side.

Decrease in the desirable shrub saltbush (*Atriplex bunburyana*) and increase in soil erosion in the Southern Rangelands.

### Table 3.2.6 Change in density of desirable shrubs and trees from Assessment 3 (2005–10) to Assessment 4 (2010–15), based on seasonal quality in the Southern Rangelands

<table>
<thead>
<tr>
<th>LCD</th>
<th>Change in density (%)</th>
<th>Change in density (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Above-average seasonal quality</td>
<td>Average seasonal quality</td>
</tr>
<tr>
<td>9</td>
<td>Gascoyne – Ashburton Headwaters</td>
<td>–36</td>
</tr>
<tr>
<td>10</td>
<td>Upper Gascoyne</td>
<td>–22*</td>
</tr>
<tr>
<td>11</td>
<td>Wiluna</td>
<td>–16</td>
</tr>
<tr>
<td>12</td>
<td>Lyndon</td>
<td>na</td>
</tr>
<tr>
<td>13</td>
<td>Gascoyne–Wooramel</td>
<td>na</td>
</tr>
<tr>
<td>14</td>
<td>Shark Bay</td>
<td>na</td>
</tr>
<tr>
<td>15</td>
<td>Murchison</td>
<td>–8*</td>
</tr>
<tr>
<td>16</td>
<td>Meekatharra</td>
<td>–5</td>
</tr>
<tr>
<td>17</td>
<td>Cue</td>
<td>5</td>
</tr>
<tr>
<td>18</td>
<td>Mount Magnet</td>
<td>19</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LCD</th>
<th>Change in density (%)</th>
<th>Change in density (%)</th>
<th>Change in density (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Above-average seasonal quality</td>
<td>Average seasonal quality</td>
<td>Below-average seasonal quality</td>
</tr>
<tr>
<td>19</td>
<td>Sandstone</td>
<td>2</td>
<td>–3</td>
</tr>
<tr>
<td>20</td>
<td>Yalgoo</td>
<td>65</td>
<td>1</td>
</tr>
<tr>
<td>21</td>
<td>Perenjori</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>22</td>
<td>Binnu</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>23</td>
<td>Mount Marshall</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>24</td>
<td>North-eastern Goldfields</td>
<td>na</td>
<td>–7</td>
</tr>
<tr>
<td>25</td>
<td>Kalgoorlie</td>
<td>–10</td>
<td>–5</td>
</tr>
<tr>
<td>26</td>
<td>Vlgarn</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>27</td>
<td>Nullarbor – Eyre Highway</td>
<td>–16</td>
<td>–9</td>
</tr>
</tbody>
</table>

* There were only a few WARMS sites in this category.

na Not applicable: there were no sites in this category.
Discussion and implications

Substantial changes in the number and composition of desirable perennials are being recorded at WARMS sites, particularly in the Southern Rangelands and the Pilbara. These changes imply management may not be appropriate for the prevailing seasonal conditions and continuing this trend will result in a steady decline in the pastoral capacity of the rangelands.

Plant population trend varies between WARMS sites, highlighting the impacts and interactions of management, seasonal conditions and fire. However, the duration and direction of the general trend indicates that the productive capacity of the rangelands in some areas, particularly in the Southern Rangelands, is changing and that these changes and their implications need to be incorporated into management decisions. Managers need to consider the long-term capacity of their rangelands and judge the extent to which livestock numbers carried on the station in previous decades are still able to be supported.

Reversing a decreased plant population is not straightforward. It was previously assumed that removing the driver of change would reverse the change and the previously present desirable perennial species would return to the rangeland. This simple reversal does not always happen. In some areas, the rangeland has ecologically changed and removing the driver (for example, grazing pressure) may have no effect on reversal or may permit a whole new suite of species to establish, rather than a return to previous conditions. These changes are called ‘transitions’ and they can permanently alter the rangeland and, consequently, a considerable and commonly negative change in rangeland productivity (Westoby et al. 1989). An example is the increase in black speargrass (*Heteropogon contortus*) dominance in the east Kimberley rangeland (Fletcher 2011).

Despite perennial grasses replacing desirable shrubs and trees in some areas, primary production in arid and semi-arid rangelands is fundamentally determined by rainfall, soils and topography, not by species composition (Fischer & Turner 1978, Friedel 1981). Changes in

Increase in the undesirable shrub *Eremophila* spp. in chenopod pasture in the southern Goldfields and Nullarbor

In 1988, there were 6500 saltbush plants per hectare and 80 *Eremophila* spp. plants per hectare

In 2002, saltbush numbers have decreased to 5180 plants per hectare and *Eremophila* spp. numbers have increased to 1600 plants per hectare

In 2012, saltbush numbers have decreased to 3370 plants per hectare and *Eremophila* spp. numbers are stable at 1500 plants per hectare
In 1998, black speargrass frequency was 49%

In 2004, black speargrass frequency was 78%

In 2013, black speargrass frequency was 100%

species composition do not significantly increase biomass production, unless the change is one from a degraded to non-degraded state. Consequently, changes in the species composition from shrub dominance to a mixed community containing a large component of grass — as is occurring at some WARMS sites in the Gascoyne Catchment, for example — does not necessarily imply an increase in carrying capacity. The invasion of degraded rangeland by buffel grass and other grasses or shrubs does not automatically confer on these areas a carrying capacity greater than that which existed under the pristine vegetation, although it may greatly increase the carrying capacity of the degraded rangeland.

Sources of information


Pringle, HJR, Watson, IW & Tinley, KL 2006, ‘Landscape improvement or on-going degradation – reconciling apparent contradictions from the arid rangelands of Western Australia’, *Landscape Ecology*, vol. 21, pp. 1267–79.


3.3 Vegetation cover

Key messages

Status and trend

- Estimated average vegetation cover is naturally higher in the grasslands in the Kimberley (9–44%) and Pilbara (9–30%) than in the shrublands in the Southern Rangelands (2–24%).
- From 2006 to 2015, vegetation cover was stable in most LCDs (Figures 3.3.1, 3.3.2 and 3.3.3). The Nullarbor – Eyre Highway LCD has the largest increasing vegetation cover trend, largely because of the perennial grass response to the exceptional 2011 season and the significant increase in vegetation cover in four vegetation functional groups.
- In the Northern Rangelands, while stable at the LCD scale from 2006 to 2015, vegetation cover decreased in at least one vegetation functional group in each of the Halls Creek – East Kimberley, Derby – West Kimberley, Ashburton and Roebourne – Port Hedland LCDs.
- In the Southern Rangelands, vegetation cover decreased in three vegetation functional groups in the Gascoyne–Wooramel LCD, two functional groups in the Meekatharra LCD, and one functional group in each of the Lyndon and Cue LCDs.
- In 2015, average vegetation cover in the vegetation functional groups in the Halls Creek – East Kimberley LCD were at the low end of their respective vegetation cover ranges. Other Kimberley LCDs had vegetation cover in the mid-range. In the Pilbara, the average vegetation cover varied across LCDs but was generally in the middle to high vegetation cover range. Average vegetation cover in the Southern Rangeland LCDs varied, but generally at the middle to lower end of the range.

Management implications

- Grazing pressure (a driver of vegetation cover) affects different vegetation functional groups in different ways, even in a run of good years. To retain adequate vegetation cover in all functional groups, grazing pressure needs to be managed for the most susceptible vegetation functional group within the paddock.
- Susceptible vegetation functional groups may need innovative management to retain their production and environmental values.
- Preserving and recovering perennials in the pastoral rangelands requires long-term management of grazing pressure and fire.
Figure 3.3.1 Vegetation cover trend in the Kimberley, 2006–15: 
a) uncorrected trend, which shows the gross changes in vegetation cover across the landscape; b) corrected trend, which better accounts for trend related to seasonality, management or fire; c) uncorrected trend (gross change in vegetation cover) in relation to vegetation cover in 2015.
Figure 3.3.2 Vegetation cover trend in the Pilbara, 2006–15: a) uncorrected trend, which shows the gross changes in vegetation cover across the landscape; b) corrected trend, which better accounts for trend related to seasonality, management or fire; c) uncorrected trend (gross change in vegetation cover) in relation to vegetation cover in 2015.
Figure 3.3.3 Vegetation cover trend in the Southern Rangelands, 2006–15: a) uncorrected trend, which shows the gross changes in vegetation cover across the landscape; b) corrected trend, which better accounts for trend related to seasonality, management or fire; c) uncorrected trend (gross change in vegetation cover) in relation to vegetation cover in 2015.
Overview

Maintaining adequate groundcover protects the soil by intercepting raindrops and impeding run-off, thereby retaining more water and soil nutrients for plant growth and reducing siltation. Plant material, alive or dead, is the most common and important form of groundcover and perennial plants are the most efficient means of providing year-round groundcover. As groundcover decreases, patches of bare ground begin to interconnect, allowing run-off to more freely flow and increase its capacity to erode soil. Decreased vegetation cover also means less of the rain drops’ energy is absorbed, increasing soil particle dislodgement. Wind erosion losses also increase as vegetation cover decreases.

Historically, the WA rangelands had a higher proportion of perennial grasses and shrubs. Perennial plants are valuable for soil stabilisation because they maintain year-round groundcover, have extensive root systems and are quite productive for animal production. A decrease in perennial plants is often followed by an increased abundance of annual or short-lived perennial plants in the space previously occupied by the perennial plant. While these plants often produce considerable seed and have effective dispersal mechanisms, they do not maintain year-round groundcover.

A change in vegetation cover may be the result of changes in plant numbers (either in the ground or tree layer), changes in crown cover (upper, middle or lower storey), or changes in foliage density. Climate, management or fire all influence vegetation cover. Fire is more frequent in the Kimberley and Pilbara grasslands. Fire in the Southern Rangelands in vegetation types without spinifex is seasonally dependent on fuel load.

Interpreting cover change

Vegetation cover levels change throughout the year as annual plants germinate, develop and die. To reduce the influence of annuals on vegetation cover estimates, vegetation cover trend in this report is based on early dry season data, although some annuals may persist into the dry season in a favourable year.

Vegetation cover assessed from remotely sensed data is indicative, not absolute. Although vegetation cover may act as a surrogate for landscape function, rangeland vegetation condition or potentially available forage, there are limitations and assumptions in using remotely sensed data for any of these parameters:

- Vegetation cover does not discriminate between species; therefore, it cannot assess rangeland vegetation condition or livestock carrying capacity.
- Vegetation cover does not distinguish between the overstorey (trees and their associated canopies) and middle and lower storey cover (the herbaceous layer of grasses and/or shrubs). For example, mulga or eucalypt on chenopods in the Southern Rangelands, and the genera Corymbia or Eucalyptus in Kimberley or Pilbara grasslands, can significantly mask what is occurring with grasses and shrubs at ground level, with the assessed vegetation cover determined more by the tree cover than the groundcover.
- Vegetation cover does not distinguish between vegetation cover change detected by change in plant numbers and vegetation cover change detected by change in crown dimension or foliage density (that is, plant size or ‘leafiness’).
- Vegetation cover change can be assessed but it does not equate to causality (what caused the assessed change), such as seasonal drivers like rainfall, management factors such as stocking intensity, or the impact of fire. However, the vegetation cover trend relative to the respective vegetation functional group map highlights pixels changing more than that respective
vegetation functional group (see Glossary) as a whole, and is likely to indicate management effects or fire and not season (Figures 3.3.1b, 3.3.2b and 3.3.3b).

**Assessment method**

The vegetation cover trend analysis and average vegetation cover calculations are based on the fractional cover generated by CSIRO (Guerschman et al. 2009) and sourced from data.wron.csiro.au/remotesensing/MODIS/products/Guerschman_etal_RSE2009/.

Fractional cover for each pixel — an area of about 500 x 500m — refers to the cover estimate provided by three components: photosynthetic vegetation (essentially green, growing plants), nonphotosynthetic vegetation (dead plants, sticks, logs) and bare soil. The cover analysis was derived from the photosynthetic vegetation component of the fractional cover dataset. This component best relates to field (WARMS and traverse inventory sites) and expert knowledge on cover levels of perennial vegetation, although it does not incorporate dead material or stones which may offer some soil cover.

In the Northern Rangelands, July (day 185) imagery is used to minimise the influence of fire, based on analysis of the NAFI data (Section 2.3). Kimberley fire data from 2006 to 2015 shows the incidence and extent of fire increases after July, which is also considered to be the earliest month when the influence of annual plants on vegetation cover is reduced.

From the 2006 to 2015 sequence, the years suitable for vegetation cover trend analysis were determined by successive visual assessment for fire scars, evaluation of monthly NAFI fire scar mapping and assessing the seasonal response through time traces of MODIS NDVI (Moderate Resolution Imaging Spectroradiometer Normalised Difference Vegetation Index). Consequently, several years were dismissed, resulting in the Kimberley analysis being based on 2006, 2009, 2012, 2013, 2014 and 2015 data. The same selection approach in the Pilbara determined that 2006, 2008, 2011, 2012, 2013, 2014 and 2015 were best suited for analysis.

In the Southern Rangelands, October imagery (day 289) is considered most suitable for perennial cover (when the influence of annual plants is reduced). As fire in the Southern Rangelands is far less frequent than in the Northern Rangelands, all years — 2006 to 2015 — were analysed. While seasonal conditions vary across the Southern Rangelands, this variation did not preclude any years. Large fires in the Gascoyne (732 750ha), northern Nullarbor (320 700ha) and Meekatharra (87 500ha) were masked from the analysis. No other fire masking was undertaken.

Using land system descriptions and expert knowledge, the 554 land systems in the rangelands were aggregated into larger, vegetation functional groups for stratification and analysis. This aggregation resulted in 10 vegetation functional groups in the Kimberley, 14 in the Pilbara and 36 in the Southern Rangelands (Robinson et al. 2012).

The vegetation cover trend is the change — defined by the slope of the trend line (the time series of actual vegetation cover) — over time. It is calculated by linear regression for each vegetation functional group within the respective region. Two summaries are generated: the uncorrected vegetation cover trend and corrected vegetation cover trend (Figures 3.3.1, 3.3.2 and 3.3.3). The uncorrected vegetation cover trend shows the actual slope for each pixel relative to zero slope (that is, no trend) where the trend classes are defined by zero plus or minus one standard deviation (Figure 3.3.4a). This uncorrected vegetation cover trend is suitable for state of the environment reporting (Wallace & Thomas 1998) and shows the gross changes in vegetation cover across the landscape.

The corrected vegetation cover trend identifies those areas where cover trend differs from the mean cover trend for the respective vegetation functional group. Trend classes are calculated as the mean slope for the respective vegetation functional group plus or minus one standard deviation (Figure 3.3.4b). It shows the areas in which cover has substantially (greater than one standard deviation) increased or decreased relative to the mean slope for the respective vegetation
functional group. The corrected vegetation cover trend reduces any trend related to seasonality and more effectively shows trend related to management or fire. It is more relevant to land managers and administrators.

If the mean slope for the vegetation functional group is around zero, the uncorrected and corrected vegetation cover trends will be similar.

**Status and trend**

**Northern Rangelands**

In the Kimberley, average vegetation cover trend was generally stable or slightly decreased from 2006 to 2015 (Figure 3.3.5). The decrease in vegetation cover in all Kimberley LCDs was within one standard deviation, suggesting that the trend in average vegetation cover over this period was essentially stable.

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**Figure 3.3.4** An example of uncorrected and corrected vegetation cover trend for a vegetation functional group: a) the uncorrected vegetation cover trend, plus or minus one standard deviation (32) from zero slope (no trend); b) the corrected vegetation cover trend, plus or minus one standard deviation (32) from the mean slope (−35)
There are large contiguous areas within each LCD where vegetation cover has substantially decreased (Figure 3.3.1b). The extent and frequency of fire in the North Kimberley LCD (Section 2.3) may account for some of the decrease in cover in this area. The areas shown in yellow in Figure 3.3.1c — predominantly in the Derby – West Kimberley and North Kimberley LCDs — present a higher risk of declining natural resources because these areas show a decreased trend in vegetation cover and in 2015, they are estimated to have only moderate vegetation cover.

Throughout the Kimberley, no vegetation functional group increased in vegetation cover from 2006 to 2015 (Table 3.3.1). Average vegetation cover for three vegetation functional groups decreased in the Halls Creek – East Kimberley and Derby – West Kimberley LCDs. In 2015, most vegetation functional groups in the Kimberley were at the lower end of their respective vegetation cover ranges (Table 3.3.2).

The vegetation functional groups in the Kimberley appear to have a relatively narrow cover range suggesting lesser interseason variability and a more defined start to the dry season than in the Pilbara (Tables 3.3.2 and 3.3.4).

Table 3.3.1 Vegetation cover trend in the vegetation functional groups in the Kimberley, 2006–15

<table>
<thead>
<tr>
<th>LCD</th>
<th>Number of vegetation functional groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Increased cover trend</td>
</tr>
<tr>
<td>1 North Kimberley</td>
<td>0</td>
</tr>
<tr>
<td>2 Halls Creek – East Kimberley</td>
<td>0</td>
</tr>
<tr>
<td>3 Derby – West Kimberley</td>
<td>0</td>
</tr>
<tr>
<td>4 Broome</td>
<td>0</td>
</tr>
</tbody>
</table>
Table 3.3.2  Average percentage vegetation cover and trend in dominant vegetation functional groups of moderate or higher Potential CC in the Kimberley, 2006–15

<table>
<thead>
<tr>
<th>LCD</th>
<th>Tussock grass on cracking clays</th>
<th>Tussock grass on undulating plains</th>
<th>Soft spinifex on undulating plains</th>
<th>Pindan (soft spinifex)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cover range</td>
<td>12 22 32%</td>
<td>14 25 36%</td>
<td>14 23 33%</td>
</tr>
<tr>
<td>1</td>
<td>North Kimberley</td>
<td>•</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>2</td>
<td>Halls Creek – East Kimberley</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>3</td>
<td>Derby – West Kimberley</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>4</td>
<td>Broome</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
</tbody>
</table>

na  Not applicable: vegetation group does not occur in LCD.

**Range of average percentage vegetation cover**

**Range of average percentage vegetation cover for respective LCD (2006–15)**

**Recent trend**

- ▲  Increased
- □  Stable
- □  Decreased

Trend symbol is placed at the average percentage vegetation cover in 2015.
In the Pilbara, average vegetation cover trend was generally stable from 2006 to 2015, despite the decreased cover, but not significant within one standard deviation, in all LCDs, except for the East Pilbara (Figure 3.3.6). Figure 3.3.2b shows a large area of decreased vegetation cover in the Ashburton and Roebourne – Port Hedland LCDs and localised patterns of decreased vegetation cover in other LCDs. No fire masking was used in this analysis but it is likely to account for some of the decrease in cover. Areas shown in yellow in Figure 3.3.2c present a higher risk of declining natural resources because these areas show a decreased vegetation cover. In 2015, they were estimated to have only moderate vegetation cover.

Increase in vegetation cover as a result of the increase in the woody weed bardi bush (Acacia victoriae) in the east Pilbara

In 2005, the perennial grass frequency was 37% and the woody weed cover was 5%  
In 2014, the perennial grass frequency was 44% and the woody weed cover was 17%
In dominant vegetation functional groups where vegetation cover decreased — Roebourne – Port Hedland mulga hardpan, Roebourne – Port Hedland soft spinifex, Ashburton tussock and Ashburton soft spinifex — the average vegetation cover in 2015 was in the middle to upper average vegetation cover range for the respective functional group in that LCD (Table 3.3.4). Although stable, functional groups in the De Grey LCD are at the lower end of the respective cover ranges in 2015.

The wide range of vegetation cover within a vegetation functional group between 2006 and 2015 (Table 3.3.4) may have been caused by the variable seasons. Variability in the date the wet season ended — particularly on the coast where late rainfall may allow annual vegetation to persist and soil moisture to increase — may have influenced the estimated vegetation cover.

Table 3.3.3 Vegetation cover trend in the vegetation functional groups in the Pilbara, 2006–15

<table>
<thead>
<tr>
<th>LCD</th>
<th>Number of vegetation functional groups</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Increased cover trend</td>
<td>Stable cover trend</td>
<td>Decreased cover trend</td>
<td>Total</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 De Grey</td>
<td>0</td>
<td>9</td>
<td>0</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 Roebourne – Port Hedland</td>
<td>0</td>
<td>4</td>
<td>4</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 East Pilbara</td>
<td>2</td>
<td>11</td>
<td>0</td>
<td>13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 Ashburton</td>
<td>0</td>
<td>8</td>
<td>2</td>
<td>10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 3.3.6 Trend lines for the average vegetation cover in the Pilbara, based on data from 2006, 2008, 2011, 2012, 2013, 2014 and 2015
Table 3.3.4 Average percentage vegetation cover and trend in dominant vegetation functional groups of moderate or higher Potential CC in the Pilbara, 2006–15

<table>
<thead>
<tr>
<th>LCD</th>
<th>Tussock grass on cracking clay</th>
<th>Tussock grass or grassy woodlands on river plains</th>
<th>Soft spinifex</th>
<th>Mulga wash plains on hardpan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cover range</td>
<td>9 18 27%</td>
<td>14 21 28%</td>
<td>10 16 23%</td>
<td>11 20 29%</td>
</tr>
<tr>
<td>5 De Grey</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 Roebourne – Port Hedland</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 East Pilbara</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 Ashburton</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| na Not applicable: vegetation group does not occur in LCD. |

![Range of average percentage vegetation cover and trend in dominant vegetation functional groups of moderate or higher Potential CC in the Pilbara, 2006–15](image_url)
Southern Rangelands

In the Southern Rangelands overall, the trend in vegetation cover from 2006 to 2015 was generally stable, with a slightly increased trend (within one standard deviation). In the Kalgoorlie and Nullarbor – Eyre Highway LCDs, the vegetation cover trend significantly increased (greater than one standard deviation). The increase in vegetation cover in other LCDs, such as Lyndon and Shark Bay, was within one standard deviation. No LCD had a significant decrease in cover from 2006 to 2015 (Figures 3.3.7, 3.3.8 and 3.3.9).

A number of LCDs showed large contiguous areas of increased vegetation cover (Figure 3.3.3a). There are some areas in the central region that showed large areas of decreasing cover. The corrected vegetation cover trend (Figure 3.3.3b) highlights a number of discrete areas where the decrease in vegetation cover was substantially higher than the trend for the respective vegetation group. Areas shown in yellow in Figure 3.3.3c present a higher risk of declining natural resources because these areas show a decreased trend in vegetation cover and in 2015, they are estimated to have low vegetation cover.
Vegetation functional groups which showed significant decreases (Table 3.3.5) were:

- 3 in the Gascoyne–Wooramel LCD
- 2 in the Meekatharra LCD
- 1 each in the Cue and Lyndon LCDs

Vegetation functional groups which showed significant increases (Table 3.3.5) were:

- 13 in the Kalgoorlie LCD
- 8 in the Lyndon LCD

- 4 in the Nullarbor – Eyre Highway LCD. The increase in vegetation cover largely resulted from the response of a perennial grass (*Austrostipa* spp.) to the exceptional 2011 season. Some perennial shrub recruitment has been noted in areas of increased cover in the Nullarbor – Eyre Highway LCD.

**Table 3.3.5** Vegetation cover trend in vegetation functional groups in the Southern Rangelands, 2006–15

<table>
<thead>
<tr>
<th>LCD</th>
<th>Increased cover trend</th>
<th>Stable cover trend</th>
<th>Decreased cover trend</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>9 Gascoyne – Ashburton Headwaters</td>
<td>0</td>
<td>14</td>
<td>0</td>
<td>14</td>
</tr>
<tr>
<td>10 Upper Gascoyne</td>
<td>0</td>
<td>15</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td>11 Wiluna</td>
<td>0</td>
<td>13</td>
<td>0</td>
<td>13</td>
</tr>
<tr>
<td>12 Lyndon</td>
<td>8</td>
<td>10</td>
<td>1</td>
<td>19</td>
</tr>
<tr>
<td>13 Gascoyne–Wooramel</td>
<td>0</td>
<td>8</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>14 Shark Bay</td>
<td>2</td>
<td>4</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>15 Murchison</td>
<td>0</td>
<td>15</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td>16 Meekatharra</td>
<td>0</td>
<td>15</td>
<td>2</td>
<td>17</td>
</tr>
<tr>
<td>17 Cue</td>
<td>0</td>
<td>11</td>
<td>1</td>
<td>12</td>
</tr>
<tr>
<td>18 Mount Magnet</td>
<td>1</td>
<td>10</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td>19 Sandstone</td>
<td>0</td>
<td>13</td>
<td>0</td>
<td>13</td>
</tr>
<tr>
<td>20 Yalgoo</td>
<td>0</td>
<td>12</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td>21 Mount Marshall</td>
<td>0</td>
<td>7</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>22 Binnu</td>
<td>1</td>
<td>5</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>23 Perenjori</td>
<td>0</td>
<td>10</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>24 North-eastern Goldfields</td>
<td>0</td>
<td>10</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>25 Kalgoorlie</td>
<td>13</td>
<td>1</td>
<td>0</td>
<td>14</td>
</tr>
<tr>
<td>26 Yilgarn</td>
<td>0</td>
<td>10</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>27 Nullarbor – Eyre Highway</td>
<td>4</td>
<td>4</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>LCD</td>
<td>Mulga wash plains on hardpan</td>
<td>Stony plains with acacia shrublands and halophytic shrublands</td>
<td>Breakaways with stony plains with acacia or eucalypt woodlands and halophytic shrublands</td>
<td>Tussock grass or grassy woodlands on river plains</td>
</tr>
<tr>
<td>------------------------------</td>
<td>------------------------------</td>
<td>-----------------------------------------------------------------</td>
<td>-----------------------------------------------------------------</td>
<td>---------------------------------------------------</td>
</tr>
<tr>
<td>Cover range</td>
<td>2 12 22%</td>
<td>2 12 21%</td>
<td>2 13 24%</td>
<td>5 10 15%</td>
</tr>
<tr>
<td>9 Gascoyne – Ashburton Headwaters</td>
<td>[Image]</td>
<td>[Image]</td>
<td>[Image]</td>
<td>[Image]</td>
</tr>
<tr>
<td>10 Upper Gascoyne</td>
<td>[Image]</td>
<td>[Image]</td>
<td>[Image]</td>
<td>[Image]</td>
</tr>
<tr>
<td>11 Wiluna</td>
<td>[Image]</td>
<td>[Image]</td>
<td>[Image]</td>
<td>na</td>
</tr>
</tbody>
</table>

**Table 3.3.6** Average percentage vegetation cover and trend in dominant vegetation functional groups of moderate or higher Potential CC in the Southern Rangelands summer rainfall LCDs, 2006–15

- **Range of average percentage vegetation cover**
- **Recent trend**
  - ▲ Increased
  - □ Stable
  - ✓ Decreased

Trend symbol is placed at the average percentage vegetation cover in 2015.

*na Not applicable: vegetation group does not occur in LCD.*
### Table 3.3.7
Average percentage vegetation cover and trend in dominant vegetation functional groups of moderate or higher Potential CC in the Southern Rangelands winter rainfall coastal LCDs, 2006–15

<table>
<thead>
<tr>
<th>LCD</th>
<th>Mulga wash plains on hardpan</th>
<th>Sandplains and occasional dunes with grassy acacia shrublands</th>
<th>Salt lakes fringing alluvial plains and alluvial plains with halophytes</th>
<th>Soft spinifex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cover range</td>
<td>_range</td>
<td>2</td>
<td>12</td>
<td>22%</td>
</tr>
<tr>
<td>12 Lyndon</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13 Gascoyne – Wooramel</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14 Shark Bay</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| na | Not applicable: vegetation group does not occur in LCD. |

**Range of average percentage vegetation cover**

**Recent trend**
- **Increased**
- **Stable**
- **Decreased**

Trend symbol is placed at the average percentage vegetation cover in 2015.
Table 3.3.8  Average percentage vegetation cover and trend in dominant vegetation functional groups of moderate or higher Potential CC in the Southern Rangelands winter rainfall central LCDs, 2006–15

<table>
<thead>
<tr>
<th>LCD</th>
<th>Mulga wash plains on hardpan</th>
<th>Sandplains and occasional dunes with grassy acacia shrublands</th>
<th>Breakaways with stony plains with acacia or eucalypt woodlands and halophytic shrublands</th>
<th>Salt lakes fringing alluvial plains and alluvial plains with halophytes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cover range</td>
<td>2 12 22%</td>
<td>4 14 24%</td>
<td>2 13 24%</td>
<td>2 9 16%</td>
</tr>
<tr>
<td>15 Murchison</td>
<td>![Image]</td>
<td>![Image]</td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
<tr>
<td>16 Meekatharra</td>
<td>![Image]</td>
<td>![Image]</td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
<tr>
<td>17 Cue</td>
<td>![Image]</td>
<td>![Image]</td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
<tr>
<td>18 Mount Magnet</td>
<td>![Image]</td>
<td>![Image]</td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
<tr>
<td>LCD</td>
<td>Mulga wash plains on hardpan</td>
<td>Sandplains and occasional dunes with grassy acacia shrublands</td>
<td>Breakaways with stony plains with acacia or eucalypt woodlands and halophytic shrublands</td>
<td>Salt lakes fringing alluvial plains and alluvial plains with halophytes</td>
</tr>
<tr>
<td>------</td>
<td>-------------------------------</td>
<td>-------------------------------------------------------------</td>
<td>-----------------------------------------------------------------</td>
<td>------------------------------------------------------------------</td>
</tr>
<tr>
<td>19</td>
<td>Sandstone</td>
<td><img src="chart1.png" alt="chart" /></td>
<td>![chart2.png]</td>
<td>![chart3.png]</td>
</tr>
<tr>
<td>20</td>
<td>Yalgoo</td>
<td>![chart1.png]</td>
<td>![chart2.png]</td>
<td>![chart3.png]</td>
</tr>
<tr>
<td>21</td>
<td>Perenjori</td>
<td>![chart1.png]</td>
<td>![chart2.png]</td>
<td>![chart3.png]</td>
</tr>
</tbody>
</table>

**Table 3.3.8 continued**

<table>
<thead>
<tr>
<th>LCD</th>
<th>Mulga wash plains on hardpan</th>
<th>Sandplains and occasional dunes with grassy acacia shrublands</th>
<th>Breakaways with stony plains with acacia or eucalypt woodlands and halophytic shrublands</th>
<th>Salt lakes fringing alluvial plains and alluvial plains with halophytes</th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td>Sandstone</td>
<td><img src="chart1.png" alt="chart" /></td>
<td>![chart2.png]</td>
<td>![chart3.png]</td>
</tr>
<tr>
<td>20</td>
<td>Yalgoo</td>
<td>![chart1.png]</td>
<td>![chart2.png]</td>
<td>![chart3.png]</td>
</tr>
<tr>
<td>21</td>
<td>Perenjori</td>
<td>![chart1.png]</td>
<td>![chart2.png]</td>
<td>![chart3.png]</td>
</tr>
</tbody>
</table>

**Recent trend**
- ▶️ Increased
- □ Stable
- 🅿️ Decreased

Trend symbol is placed at the average percentage vegetation cover in 2015.
### Table 3.3.9
Average percentage vegetation cover and trend in dominant vegetation functional groups of moderate or higher Potential CC in the Goldfields–Nullarbor, 2006–15

<table>
<thead>
<tr>
<th>LCD</th>
<th>Mulga wash plains on hardpan</th>
<th>Breakaways and stony plains with acacia or eucalypt woodlands and halophytic shrublands</th>
<th>Salt lakes fringing alluvial plains and alluvial plains with halophytes</th>
<th>Open Nullarbor with bluebush and/or saltbush and speargrass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cover range</td>
<td>2</td>
<td>12</td>
<td>22%</td>
<td>2</td>
</tr>
<tr>
<td>Recent trend</td>
<td>![Increased]</td>
<td></td>
<td></td>
<td>![Increased]</td>
</tr>
<tr>
<td>Range of average percentage vegetation cover for respective LCD (2006–15)</td>
<td>![Range of average percentage vegetation cover]</td>
<td></td>
<td></td>
<td>![Range of average percentage vegetation cover]</td>
</tr>
</tbody>
</table>

- **24 North-eastern Goldfields**: Not applicable: vegetation group does not occur in LCD.
- **25 Kalgoorlie**: Not applicable: vegetation group does not occur in LCD.
- **27 Nullarbor – Eyre Highway**: Not applicable: vegetation group does not occur in LCD.

**Recent trend**
- ![Increased] Increased
- ![Stable] Stable
- ![Decreased] Decreased

Trend symbol is placed at the average percentage vegetation cover in 2015.
Discussion and implications

In addition to providing forage, the perennial vegetation cover (and by association root material) is important for soil surface protection (from wind and water erosion), retaining and regulating water flow across the landscape and nutrient cycling. Vegetation mounds, tussocks or clumps have higher water infiltration rates (up to 10 times) and higher nutrient levels than the unvegetated landscape. Decreased vegetation cover can be associated with reduced soil protection (increased erosion risk) and fewer areas for high water infiltration and soil accumulation.

Because the vegetation cover of the WA rangeland varies with vegetation type, soil characteristics and climatic conditions, direct numerical comparisons of vegetation cover levels for the same vegetation functional group in different climatic zones should be considered with caution.

While the vegetation cover trend was stable in most vegetation types in most LCDs, regional maps show large areas of decreased vegetation cover within some LCDs which may indicate reduced available perennial forage and increased likelihood of soil erosion.

Because remotely sensed vegetation cover cannot identify individual species, it is not possible to determine if the areas that show an increased vegetation cover trend have increased vegetation typical of that vegetation functional group or increased in unpalatable vegetation. While stable or increased vegetation cover may be beneficial for soil retention, vegetation composition may be changing with negative consequences for forage production.

Sources of information


Wallace, JF & Thomas, PWE 1988, Rangeland Monitoring in Northern Western Australia Using Sequences of Landsat Imagery, Report for the Pastoral Lands Board Western Australia, CSIRO Mathematical and Information Services and Western Australian Department of Agriculture, Perth.
High vegetation cover levels of speargrass (*Austrostipa* spp.) in response to the exceptional 2011 season, May 2012

Area of speargrass (*Austrostipa* spp.) in an average year, November 2007

Area of speargrass (*Austrostipa* spp.) burnt by wildfire, July 2012

Recruitment of Western myall (*Acacia papyrocarpa*), December 2012

Recruitment of bluebush (*Maireana sedifolia*), June 2013
3.4 Soil erosion

Key messages

Status and trend

- Some degree of soil erosion occurs throughout the entire rangelands, most notably in the Gascoyne and Murchison, and to a lesser extent in the Kimberley, Pilbara and Goldfields (Figures 3.4.1 and 3.4.2).
- The Upper Gascoyne LCD has the highest level of recorded erosion, with 6% of the LCD with moderate to severe erosion (Table 3.4.1).
- Recent climatic and vegetation cover trends indicate that the likelihood of soil erosion by water has slightly increased in parts of the rangelands.

Management implications

- The nature of episodic heavy rainfall and removal of vegetation cover by fire or grazing in the rangelands means that total prevention of soil erosion (especially by water) is not possible.
- Affected and at-risk areas require maintenance or improved groundcover to minimise run-off and erosion and maintain landscape function.
- Affected and at-risk areas may require infrastructure, especially roads, to be constructed or altered in a way that manages water flows to reduce the risk of water erosion.
- For areas that are actively eroding, physical intervention, such as earthworks, may be required.
Figure 3.4.1 LCD soil erosion summary ratings in the Northern Rangelands
Figure 3.4.2 LCD soil erosion summary ratings in the Southern Rangelands
### Table 3.4.1 Summary assessment of soil erosion from traverse data for 2001–09

<table>
<thead>
<tr>
<th>LCD</th>
<th>Percentage of traverse sites in soil erosion categories (%)</th>
<th>LCD summary rating</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>None</td>
<td>Minor</td>
</tr>
<tr>
<td>1</td>
<td>94</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>87</td>
<td>9</td>
</tr>
<tr>
<td>3</td>
<td>88</td>
<td>9</td>
</tr>
<tr>
<td>4</td>
<td>99</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>97</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>90</td>
<td>6</td>
</tr>
<tr>
<td>7</td>
<td>94</td>
<td>3</td>
</tr>
<tr>
<td>8</td>
<td>89</td>
<td>7</td>
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<td>9</td>
<td>93</td>
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<td>10</td>
<td>86</td>
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<td>12</td>
<td>87</td>
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<td>13</td>
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<td>17</td>
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<td>18</td>
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<td>19</td>
<td>95</td>
<td>2</td>
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<td>20</td>
<td>93</td>
<td>4</td>
</tr>
<tr>
<td>21</td>
<td>93</td>
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</tr>
<tr>
<td>22</td>
<td>93</td>
<td>5</td>
</tr>
<tr>
<td>23</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>94</td>
<td>3</td>
</tr>
<tr>
<td>25</td>
<td>95</td>
<td>3</td>
</tr>
<tr>
<td>26</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>100</td>
<td>&lt;1</td>
</tr>
</tbody>
</table>

### Criteria for traverse assessment rating of soil erosion

<table>
<thead>
<tr>
<th>Rating</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good</td>
<td>&lt;2% of traverse sites with moderate to severe erosion (see Table 3.4.2)</td>
</tr>
<tr>
<td>Fair</td>
<td>2–3% of traverse sites with moderate to severe erosion</td>
</tr>
<tr>
<td>Poor</td>
<td>&gt;3 to 5% of traverse sites with moderate to severe erosion</td>
</tr>
<tr>
<td>Very poor</td>
<td>&gt;5% of traverse sites with moderate to severe erosion</td>
</tr>
<tr>
<td>n/a</td>
<td>Not assessed because there was insufficient traverse data</td>
</tr>
</tbody>
</table>
Overview

Soil erosion is the removal of soil from the earth’s surface by wind or water.

In principle, loss of soil by erosion should be no more than the rate that soil is created, should not exceed natural or geological erosion rates and should not lead to any decrease in soil function. Estimated soil formation in WA ranges from 1mm/1000 years to 1mm/100 years, which equates to between 1.4 tonnes per hectare per year (t/ha/y) and 14t/ha/y, respectively (McFarlane et al. 2000, State of the Environment 2011 Committee 2011). In the semi-arid areas of WA, comprising much of the rangelands, soil formation rates are likely to be at the lower levels.

Soil erosion loss of about 0.5t/ha/y is regarded as natural, but in WA, soil loss at almost any rate is unlikely to be sustainable (George 2001).

Loss and redistribution of topsoil through wind and water erosion of soil can cause permanent loss of soil productive capacity. Eroded sites also alter water flows and ability of the site to absorb and store soil moisture for plant growth.

Wind erosion

Wind erosion is the process by which soil particles are detached and transported from the land surface by the action of wind. Transport occurs by suspension, saltation or creep (Figure 3.4.3).

Wind erosion is a natural process that has assisted in shaping Australian landscapes. However, inadequate or inappropriate management accelerates degradation by wind erosion. This damage to the soil resource has on-site and off-site impacts.

Livestock concentration at a water point, particularly during dry periods, leads to loss of protective perennial vegetation cover and disturbance of the topsoil and an increased likelihood of wind erosion.

Figure 3.4.3 Mechanisms of wind erosion
Water erosion

Water erosion occurs when raindrops impact the soil surface and displace soil particles or when water flowing over the land surface mobilises soil particles. Water erosion occurs at low rates naturally; however, inadequate or inappropriate management accelerates degradation by water erosion.

Water erosion and sedimentation can be insidious and are often episodic, and are largely irreversible. The time required to form new soil is so long that soil should be considered a finite resource.

Water erosion is a two-stage process:

- Stage 1 occurs with raindrop impact and broad overland sheet flow on slopes, before flow becomes concentrated into channels and streams.
- Stage 2 occurs within the channelised flow of gullies, streams and rivers.

Distinguishing between the two stages is important because the processes in action, the effect on the landscape and the methods used to identify, monitor or model the rate and extent of erosion, are different in each stage.

Stage 1 is commonly called hillside erosion or ‘sheetwash and rill’ erosion. This erosion reduces pastoral productivity by:

- mobilising or removing nutrients
- leaving potentially hostile subsoils closer to the surface, thus reducing effective rooting depth
- silting-up dams, waterways and lowlands, which can exacerbate flooding and waterlogging.

Hillside erosion contributes only a small fraction of the total sediment delivery to its final resting point in a catchment, and it also contributes a relatively minor direct cost to pastoralism. The annual direct cost of water erosion in the rangelands is unknown.

Accelerated hillside erosion occurs when raindrops impact and run-off increases because of one or more of the following factors:

- low levels of groundcover, especially at critical times, such as during intense summer storms
- detached surface soil caused by livestock disturbance
- poorly constructed or sited engineering works, including surface water earthworks, dams and dam overflows, road and rail culverts.

These factors increase the erosivity of water flowing through catchment drainages, resulting in erosion rates being orders of magnitude higher than in undisturbed areas.
Stage 2 is channelised flow which occurs when overland flow concentrates in gullies and streams, scouring the heads, beds and banks of gullies and channels. The on-site impact of this erosion is reduced vehicle and livestock movement in areas affected by gullying, and the cost of fixing or living with the gullies and loss in production.

Off-site impacts of channelised erosion on the environment are far greater. Erosion and associated sedimentation alters or destroys habitat for riverine and estuarine flora and fauna. Eutrophication of rivers, lakes and estuaries, caused partly by the mobilisation of soil fines and attached nutrients, also reduce habitat values. Both processes result in a decrease in economic and social value of fisheries and tourism.

Voluminous, fast-flowing water in gullies, streams and rivers has repeatedly disrupted communities and the broader WA society by destroying bridges, roads and other infrastructure for utilities, removing valuable soil from productive land and burying infrastructure under sediments.

### Assessment method

Two assessment methods are used for this theme.

**Method 1: Traverse assessment of soil erosion**

From 2001 to 2009, pastoral stations were inspected by ground-based traversing, where rangeland condition was recorded to documented standards at regular intervals along station tracks. At each kilometre along preselected traverse routes, the type and extent of accelerated erosion was assessed in an area defined by a circle of 50m radius centred on each traverse point. Criteria for assessment of accelerated erosion extent are shown in Table 3.4.2 (Van Vreeswyk et al. 2004).

<table>
<thead>
<tr>
<th>Severity rating</th>
<th>Estimated area affected by erosion</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>No accelerated erosion present</td>
</tr>
<tr>
<td>Slight</td>
<td>&lt;10% of site affected</td>
</tr>
<tr>
<td>Minor</td>
<td>10–25% of site affected</td>
</tr>
<tr>
<td>Moderate</td>
<td>25–50% of site affected</td>
</tr>
<tr>
<td>Severe</td>
<td>50–75% of site affected</td>
</tr>
<tr>
<td>Extreme</td>
<td>75–100% of site affected</td>
</tr>
</tbody>
</table>

For this report, the slight and minor ratings are grouped together as minor.

The traverse assessments of soil erosion included water and wind erosion. This information, within the sampling limitations imposed by the traverse routes being restricted to existing track networks, provides a quantifiable snapshot of conditions. In the Nullarbor – Eyre Highway LCD, all stations were assessed in 2006 as part of the western Nullarbor survey (Waddell et al. 2010). All other LCDs had fewer than half of the stations within the LCD assessed in any given year. Mount Marshall, Perenjori and Yilgarn LCDs had insufficient traverse points to provide a reliable estimate of erosion and so are not assessed.

**Method 2: Modelling status and trends in erosion hazard**

Water erosion is the major cause of soil erosion in the rangelands. A GIS-based model was used to assess the hazard (the source of risk) of water erosion, using the datasets that account for primary erosion-causing factors, as identified in the Revised Universal Soil Loss Equation (RUSLE; United States Department of Agriculture 1997).

This assessment provides relative erosion hazards and indicates where changes in location of erosion hazard are likely to occur because of climate change. It does not quantify the current erosion rate or the extent or severity of past water erosion events, because the small amount of reliable data limits the model’s applicability for channelised flow in WA conditions (Marillier et al. 2008).
Factors contributing to hillside erosion and accounted for in RUSLE (see information box and Figure 3.4.4) are:

1. intrinsic susceptibility of the land, comprising:
   a. slope length
   b. slope steepness (gradient)
   c. soil erodibility
2. rainfall erosivity
3. cover, comprising:
   a. land cover (usually by vegetation)
   b. land management practices.

The Revised Universal Soil Loss Equation (RUSLE)

RUSLE is an empirical model that uses experimental erosion data from a series of sites and compares the erosion rate of these to a ‘standard plot’. The result is presented as an average annual soil loss value, based on steady-state conditions of overland flow on hillsides. The RUSLE is unable to present reliable results for extreme events and requires extensive data to deliver a reliable absolute result. The RUSLE does not account for erosion caused by channelised water.

Susceptibility: the intrinsic susceptibility of the land

Susceptibility is derived from a combination of slope length, slope steepness (gradient) and the inherent erodibility of the soil. The relative index of susceptibility to soil erosion by water is determined using these factors in an equation described by Mitasova et al. (1996), based on foundational work by Wischmeier and Smith (1978).

The slope length and slope steepness factors are derived from the one second (30m grid), Shuttle Radar Topography Mission (SRTM) hydrological digital elevation model (DEM-H, version 1.0a) (Geoscience Australia 2011), which was resampled to a 186m grid to reduce the dataset to a manageable size.

The inherent soil erodibility factor is based on the soil characteristics from DAFWA’s map unit database associated with DAFWA’s soil-landscape mapping (Tille 2006, van Gool et al. 2005).

Figure 3.4.4 The factors used to determine water erosion hazard
Rainfall erosivity

Most erosion is episodic and in this assessment it is assumed that rainfall has the most erosive impact when vegetation cover is likely to be least. Relative assessments of erosion hazard can be determined by considering the trend over time for the occurrence of potentially erosive rainfall events. This assessment does not link individual rainfall events with the cover at the time of the event, but looks at the trend in the number of erosive rainfall events per year, assuming that the distribution of events follows an established seasonal pattern.

A potentially erosive rainfall event which is likely to cause soil erosion is defined for this assessment as more than 50mm of rain in a 24-hour period. The number of potentially erosive rainfall events per year, over two time periods, was compared. The World Meteorological Organization (1989) regards the period 1961–90 as the current ‘normal’ baseline average period; the latest period available for this assessment was the 14-year interval from 2000 to 2013.

There was a slightly increased trend from 1961–90 to 2000–13 in the number of potentially erosive (more than 50mm) daily rainfall events throughout most of the rangelands. The trend was most notable in the northern Kimberley region and central to southern rangelands (Figures 3.4.5 and 3.4.6).

Cover: the protective cover on land

The protective cover on land is made up of three components: living and dead vegetation cover and gravel/stone. Estimates of photosynthetic (living) vegetation cover are derived from MODIS remotely sensed data for four, 3-month periods — summer (December–February), autumn (March–May), winter (June–August) and spring (September–November) — averaged over the 10-year period 2004–13 (Figure 3.4.7 and Section 3.3). The dead vegetative component, especially senescing annual growth, is linked to and generally lags behind, the peaks in the living vegetative component. Gravel/stone cover is essentially static and is not used as an input to estimate trend.
The living vegetative component of cover over the WA rangelands varies geographically and seasonally. In northern WA, cover is highest at the end of the summer wet season, whereas in southern WA, with a predominantly winter rainfall, cover is highest during winter/early spring. In the central parts of the rangelands, where seasonality of rainfall is not well defined, cover does not have a marked seasonal cycle. In these areas, vegetation cover changes usually occur in response to exceptional rainfall associated with cyclones.

It should be noted that in some areas, such as in the Goldfields–Nullarbor, trees and large shrubs may provide relatively high vegetation cover while there may still be inadequate groundcover to protect the soil from eroding.
Figure 3.4.7 Average vegetation cover for summer (December–February), autumn (March–May), winter (June–August) and spring (September–November), 2004–13
Status and trend

Soil erosion
Some degree of soil erosion occurs throughout the entire rangelands, most notably in the Gascoyne and Murchison, and to a lesser extent in the Pilbara, Kimberley and Goldfields. Most erosion is caused by water, except in the Nullarbor – Eyre Highway LCD where wind erosion is the dominant erosional form, although at very low levels.

The traverse assessments indicated that about half of the LCDs had rangelands with a poor to very poor soil erosion summary rating (Figures 3.4.1, 3.4.2 and Table 3.4.1). The Upper Gascoyne LCD had the highest level of recorded erosion, with 6% of the area with moderate to severe erosion. Conversely, the Broome and Nullarbor – Eyre Highway LCDs had less than 1% of traverse sites with moderate to severe erosion and therefore had a good soil erosion summary rating.

The ratings are a qualitative assessment based on expert opinion. This opinion is guided by the criteria used in the Australia state of the environment 2011 (State of the Environment 2011 Committee 2011), Reading the rangeland (Burnside et al. 1995) and the Report card on sustainable resource use in agriculture (Department of Agriculture and Food, Western Australia 2013).

Erosion hazard
There was a small increase in the likelihood of potentially erosive rainfall events throughout most of the rangelands (Figures 3.4.8 and 3.4.9). The most significant increases were in the central to southern rangelands in response to more potentially erosive rainfall events in 2000–13.

Figure 3.4.8 Modelled erosion hazard for erosive rainfall events in 1961–90
Ground-based traverse assessments showed that soil erosion in the rangelands, mostly caused by water, was widespread, particularly in the Gascoyne and Murchison. Based on traverse assessments in 2001–09 and the criteria for interpreting these assessments (Table 3.4.1), soil erosion in half of the rangeland LCDs was poor to very poor.

Grazing pressure is an important driver of vegetation cover and can be managed to retain adequate vegetation cover to protect the soil. The evidence indicates historical grazing pressure was too high in many areas, resulting in loss of vegetation cover leading to soil erosion.

Modelling based on soil-landscape parameters, vegetation cover and climate indicated that the likelihood of soil erosion by water was slightly increasing across most of the rangelands. Decreased vegetation cover in parts of the rangeland is likely to increase erosion hazard (Section 3.3).

The likelihood of water erosion occurring can be reduced by diverting, channelling or avoiding blocks to water flows through strategic siting and construction of infrastructure, particularly roads.

The opportunity costs of ongoing erosion are unknown, but are likely to be significant because there is nearly 2.5 million hectares in the moderate to severe soil erosion categories. Costs to the pastoral industry are cumulative because of the largely irreversible nature of soil erosion, but the cost may not be realised until a threshold is reached. For example, there will be little reduction in profitability or increase in costs until the bulk of the topsoil has been removed and vegetation growth is significantly reduced.

Managers may be able to rehabilitate some degraded areas with targeted intervention (Payne et al. 2004, Bastin et al. 2001). However, not all rehabilitation will be cost-effective and recovery can be very slow, especially in highly degraded sites in areas with variable seasons (Sparrow et al. 2003). In areas that are actively eroding, intervention to manage water flow may be needed to stabilise the system and begin...
a recovery process (G Bastin [CSIRO] 2014, pers. comm., 9 May). Spectacular recovery has been achieved in the Ord Regeneration Area through targeted, well-funded and sustained intervention (Payne et al. 2004).

Recovery in Kimberley grassland over a 40-year period, following regeneration, removal of grazing pressure and 10 years of above-average seasons

Preventing soil erosion in the rangelands is likely to be more profitable in the long term and it also meets the requirements of pastoral lease agreements.

Lack of regeneration in the Southern Rangelands over a 27-year period, following regeneration, no control of grazing pressure and variable seasons
Sources of information

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3.5 Soil organic carbon

Key messages

Status and trend

- Soil organic carbon (SOC) levels in the WA rangelands are low by global standards, even in higher rainfall areas (Figures 3.5.1 and 3.5.2).
- Rainfall has very little influence on SOC where average annual maximum temperature is above 24°C. All of the WA rangelands fit in this category.
- Predicted increases in temperature across the rangelands are likely to decrease potential SOC levels.
- Predicted increases in rainfall are unlikely to significantly increase SOC potential levels.

Management implications

- SOC loss could be minimised by reducing the impact of wind and water erosion, fire damage and loss of vegetation.
- SOC levels could be increased by increasing plant biomass and groundcover, especially on potentially productive degraded land.
Figure 3.5.1 Average soil organic carbon stocks in the Northern Rangelands
Figure 3.5.2 Average soil organic carbon stocks in the Southern Rangelands
Overview

Soil organic carbon (SOC) is derived from organic matter which ranges from living organisms to decaying plant material to charcoal. Organic matter has beneficial physical, chemical and biological influences on soil condition and plant growth and, in some soils, can be the major source of plant available nutrients. The inorganic carbon present in soil minerals (for example, calcium carbonate) is not considered here.

In this assessment, the values of SOC are represented in two ways: SOC at a given point (for example, a soil sample or soil profile) expressed as a percentage, and SOC for a given area expressed as a stock (tonnes/hectare [t/ha]).

The SOC stocks in the rangeland soils of WA are typically below 15t/ha in the top 30cm of the soil profile, which is low by global standards (Hiederer & Köchy 2011).

SOC levels depend on the balance between organic matter inputs (biomass production) and organic matter losses (soil microflora and microfauna conversion rate and erosion). That is, SOC in any one environment depends on climatic, biological and soil physical and chemical factors.

Attainable SOC levels are largely determined by rainfall and temperature (see ‘Climate’ in Section 1.2) and soil clay content. As a general rule, SOC is positively correlated with rainfall and soil clay content, and negatively correlated with temperature. Actual SOC levels are also influenced by other factors: plant biomass, management, and site characteristics, such as landscape position and microclimate (Hoyle 2013).

Increasing SOC levels is widely regarded as beneficial to soil function and fertility and has been associated with increased pastoral productivity. Although there is no ‘desirable’ SOC level for any soil–location–management situation, in general, the loss of SOC adversely affects nutrient supply, soil water storage and carbon storage. Gains in SOC generally have the reverse effects.

Increasing SOC requires increased plant growth, increased organic matter inputs or reduced decomposition, or a combination of these. Biomass removal, burning and erosion cause soil organic matter loss and are considered within the influence of management. Microbial decomposition is related to the temperature and water status of the soil, as well as the availability of substrates.

Where organic matter inputs outweigh organic matter losses, SOC levels should slowly increase (Hoyle 2013).

With soil being a major world carbon sink, increasing the amount of organic carbon in rangeland soils is seen as one way of decreasing atmospheric carbon dioxide concentrations and mitigating climate change.

Consequently, there is great interest in quantifying the ability of various soil types and land management practices to increase net organic carbon inputs to the soil, and carbon sequestration in the medium and long term.

Assessment method

The spatial unit for reporting SOC in the rangelands is the LCD. To compare, data are also presented for the south-west agricultural region and, to provide a similar resolution of spatial unit, DAFWA agricultural districts are used. The number of geo-located sites with SOC data is very limited in WA, with the lowest density of sites in the rangelands (Figure 3.5.3).

With the relatively sparse availability of measured SOC data in the rangelands, this assessment relies on modelling. Comparing the SOC estimates gained from using the purely modelled approach of the National Land and Water Resources Audit (NLWRA; Raupach et al. 2001) with available SOC site data shows a modest correlation, which gives some confidence to the modelled SOC levels across the state (Figure 3.5.4). This figure also demonstrates the general observation that SOC levels tend to be low when temperatures are high.
Figure 3.5.3 Location of sites that have laboratory analysis of SOC levels (%) in the top 10cm of the soil profile (site data sources: DAFWA, CSIRO and Geoscience Australia, various dates)

Figure 3.5.4 Measured SOC levels (%) for available sites plotted against modelled (Raupach et al. 2001) SOC stocks (t/ha). A linear relationship is plotted in a solid red line. The circles represent the intersection of sites with measured SOC levels for the top 10cm of the soil profile with modelled SOC stocks for the top 30cm. The circle sizes are adjusted for the average annual maximum temperature at the site — the larger the circle, the higher the temperature, ranging from 19.1°C average annual maximum temperature for the smallest circle to 34.7°C for the largest circle.
Status and trend

SOC stocks

During the NLWRA, estimates of SOC stocks in the top 30cm of the soil profile for 1997–2008 were modelled (Figure 3.5.5; Raupach et al. 2001). The modelled levels have been averaged (modal level) for each LCD and in most areas, the modelled SOC stocks in the rangelands are low (Figure 3.5.6).

More recent modelling of carbon data by Viscarra-Rossel et al. (2014) has created a new baseline map of SOC stocks across Australia. In general, this map echoes the results of the NLWRA and demonstrates that carbon levels throughout the WA rangelands are generally low and driven by rainfall and temperature. This section is based on the NLWRA estimates, but similar conclusions would have been reached if the more recently published baseline map had been used.

Since 2013, Rangelands NRM (WA) has undertaken intensive field sampling and measurement aimed at increasing knowledge of the distribution of SOC stocks in a limited number (about 5%) of land systems in the WA rangelands.

The results show that SOC stocks vary considerably between land systems, depending on the climate, soil and vegetation type and condition in each land system (Russell & Williams in prep.). The results to date show the highest SOC stocks (25–35t/ha) are in the coastal and tidal flats in the Kimberley (Alchin et al. 2010) and the lowest stocks (6t/ha) are on the mulga hardpan wash plains in the Murchison (Russell & Williams in prep.). These results are consistent with the generalised results at the LCD scale used in this report, acknowledging that within any LCD there will be a range of SOC stocks based on a range of environmental factors.

Effect of temperature on SOC levels

An analysis of average SOC levels for each spatial unit shows that above about 24°C average maximum temperature, rainfall has very little influence on SOC levels (Figure 3.5.7). All of the rangeland LCDs fit in

Figure 3.5.5 Modelled SOC stocks (t/ha) for the top 30cm of the soil profile (source: Raupach et al. 2001). The naming of categories from very low to very high is within the WA range of levels, not global ranges.
Figure 3.5.6 Modelled SOC stocks (t/ha) for the top 30cm of the soil profile by modal level within each LCD (adapted from Raupach et al. 2001).

Figure 3.5.7 Average SOC levels (%) in 0–10cm of the soil profile plotted against average annual maximum temperature for each spatial unit. The solid circles represent averages within each of the rangeland LCDs and the unfilled circles represent averages within the south-west agricultural region. The circle sizes are scaled by rainfall — the larger the circle, the higher the rainfall, ranging from 204mm average annual rainfall for the smallest circle to 1054mm for the largest circle.
this category (Figure 3.5.8). In contrast, rainfall is a major influence on SOC levels in areas with an average annual maximum temperature below 24°C, such as in the south-west agricultural region. Generally, in these cooler areas, the higher the rainfall, the higher the SOC levels. This generally negative correlation between SOC levels and temperature is well documented (Kirschbaum 1995) and because of this temperature influence, current evidence indicates SOC levels are unlikely to significantly increase with increased rainfall in rangeland areas.

The evidence from Figure 3.5.7 also indicates that SOC levels greater than 1.5–2% is unlikely anywhere in the rangelands, irrespective of management.

**Effect of predicted climate trends on SOC levels**

Mean temperatures have been rising throughout most of WA over the last 40–50 years (Figure 3.5.9). Climate forecasts indicate that these trends are likely to continue and although the actual degree of temperature rise is uncertain, most models predict significant increases over the next 60 years.

Figure 3.5.10 shows predicted temperature changes from 2014 to 2070 under three greenhouse gas emissions scenarios. Even under the most optimistic scenario (low emissions and 10th decile of results), temperatures are predicted to rise by 0.6–1.5°C, and under more realistic predictions — medium emissions, 50th percentile (average) results — rises of 2–3°C are predicted across most of the rangelands.
Figure 3.5.10 Predicted annual temperature changes for WA from 2014 to 2070 under low, medium and high emissions scenarios (source: Climate Change in Australia 2014)

Figure 3.5.11 Predicted annual rainfall changes from 2014 to 2070 under low, medium and high emissions scenarios (source: Climate Change in Australia 2014)
This predicted temperature rise is likely to result in a decline in SOC levels.

Under the low emissions scenarios, SOC levels are likely to increase slightly in tropical regions, such as the Kimberley, but stay static or decline elsewhere. However, under high emissions scenarios, which lead to large temperature increases, SOC levels will universally decline (Grace et al. 2006).

Predictions for rainfall change show greater variability. Under all emissions scenarios, the 50th percentile (average) results predict rainfall to decline over most of the rangelands, except in the northern Kimberley where a neutral trend is expected (Figure 3.5.11). The predicted rainfall declines in most areas of the rangelands combined with predicted temperature rises across all areas will put strong downward pressure on existing SOC levels.

**SOC sequestration rates**

SOC sequestration rates have not been comprehensively studied in the WA rangelands. Two WA studies that have measured or modelled SOC sequestration rates in the Pilbara pastoral grasslands provided SOC sequestrations rates ranging from 0.02t/ha/y on Yalleen Station in the Roebourne – Port Hedland LCD (Alchin 2012) to 0.07t/ha/y on Cheela Plains Station in the Ashburton LCD (Wiley et al. 2007). These values are similar or slightly lower than rates determined for the North American Great Plains (Dermer & Schuman 2007).

**Management implications**

Land management plays an important role in maximising the SOC levels within the primary constraints of rainfall, temperature and soil clay content. Improving land management and biomass production, and rehabilitating degraded sites could increase SOC levels twofold or threefold (Russell & Williams in prep.) and potentially return them to predegradation levels. Rehabilitating large areas of degraded sites could lead to large increases in SOC levels.

Most of the SOC is stored in the top 30cm of the soil profile (Griffin et al. 2013) and if this layer is lost through erosion (wind or water), it may take many decades or more to rebuild this layer and replace the lost carbon stores.

Rehabilitating degraded land can be accelerated through intervention (Payne et al. 2004, Bastin et al. 2001); however, intervention is very expensive and recovery can be very slow and uneconomical for highly degraded sites in areas with variable seasons (Sparrow et al. 2003). In areas that are actively eroding, intervention may be the only way to stabilise the system and begin a recovery process (G Bastin [CSIRO] 2014, pers. comm., 9 May). Therefore, it is critical that soil condition is maintained or improved and management practices that adversely affect soil condition are avoided.

Although intrinsic or natural SOC sequestration rates for most rangeland ecosystems are very low compared to improved agricultural cropland and pasture soils, the multiplier-effect of very extensive rangeland areas means that the rangelands account for significant stocks of SOC. There exists some potential to increase SOC content over areas of degraded rangeland soils; however, the potential is variable. Based on limited data, the highest potential for additional sequestered carbon (also known as incremental carbon) in the shorter term (one to two decades) probably exists in the degraded parts of the most fertile grassland soils, that is, the clay- or silt-rich alluvial plain soils, particularly the self-mulching, cracking-clay types of the Northern Rangelands.
Sources of information


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Section 4 Conclusion
4.1 Principles of rangeland management

The global demand for food and fibre brings many opportunities and challenges for the agrifood sector. One of these challenges is to achieve productivity growth while ensuring we use our natural resources in a sustainable way.

Opportunities and challenges in the rangelands need to consider the principles of sustainable rangeland management:

**Stewardship of natural resources in pastoral rangelands is critical**

The economic and environmental sustainability of the rangelands requires that we meet the needs of the present without compromising the ability of future generations to meet their needs. Sustainable natural resource use in pastoral areas means maintaining — and where possible improving — the productive capability of the land which underpins pastoralism while mitigating off-site impact.

Therefore, stewardship of natural resources in the pastoral rangelands is essential. Those who directly manage the land need to have access to the information, resources and support to carry out this critical role.

**Managing for longer-term climate variability and trends is important**

Management for the long term in a highly variable climate is essential for sustainability in the pastoral areas.

Climate varies across the rangelands from a reliable tropical monsoon in the north Kimberley to the erratic desert climate of the arid interior. Rainfall variability is a defining characteristic of much of the non-Kimberley pastoral rangelands, as is increasing aridity in the inland Southern Rangelands. Highly variable rainfall causes wide fluctuations in the quantity and quality of forage for livestock and can lead to depletion of the critical palatable perennial pasture component.

**Current, evidence-based resource information is important**

Understanding the current state and trend in rangeland condition is important to optimise business outcomes while sustaining the long-term productivity of the resource.

Information and knowledge about pastoral systems are the basis for sound adaptive management. Baseline surveys and long-term monitoring provide the evidence needed to generate management strategies for sustainability. DAFWA works with a range of stakeholders to assess pastoral rangeland condition trends and to produce management information.

**Management practice will determine sustainability of resource use**

Well-managed rangeland pasture is fundamental to environmental and economic sustainability. Important management strategies include:

- monitoring rangeland vegetation condition
- balancing the short-term nutritional needs of livestock with sustaining the pasture base in the long term
- using information and technologies.

**Viable pastoral businesses are needed for sustainable resource management**

Sustainable use of the pastoral rangeland resource requires a viable rangeland economy. It is difficult to manage the long-term resource condition without viable pastoral businesses.
Innovation for sustainable resource use is important

Innovation is important for solving problems faced by the pastoral sector. Adopting new technologies and systems can improve the productivity of the rangelands resource, reduce costs of production and produce high quality products for increasingly discerning customers. For example, innovation in irrigation development can mitigate grazing pressure on the natural resource base.

Pastoral participants need to work together

Achieving sustainable pastoralism is the responsibility of all participants in the system, including pastoral managers, supporting businesses, policymakers, researchers and consumers.
Appendix A
Calculating seasonal quality

Assessment method
To calculate seasonal quality, DAFWA uses a scoring system based on long-term rainfall and its seasonal distribution (summer and winter) to indicate site seasonal quality. Seasonal quality provides an indication of the relative value of rainfall over a defined period for vegetation growth as a basic resource for livestock and fauna (forage and shelter) and for soil protection (Bastin & ACRIS 2008). The seasonal quality categories are based on terciles — a division of the rainfall data into three equal groups — derived from interpolated rainfall data for WARMS sites (see ‘Assessing change’ in Section 1.3 and Section 3.2), using the ranked amount of rainfall in the growing season(s) before the monitoring period, compared to the long-term rainfall record.

A single, seasonal quality category to summarise rainfall amounts and season (summer or winter) over the appropriate period is assigned to each monitoring site. Winter is defined as April to September and summer is October to March. Rainfall data are obtained from the gridded rainfall surfaces (bom.gov.au/jsp/awap/rain/archive.jsp) and are defined for a given year or assessment period relative to the long-term rainfall record (1900–2015). To define the terciles, the set of rainfall data for the period under consideration is arranged from lowest to highest and then partitioned into three groups, each containing one-third of the data. For example, if there are 30 years of record, each group would contain 10 years. The lowest third of the data values are defined as the lowest tercile (tercile 3), the middle third are the middle tercile (tercile 2) and the upper third are the upper tercile (tercile 1).

For WARMS grassland sites, summer rainfall is considered more important than winter rainfall for determining site dynamics; for shrubland sites, winter rainfall is considered more important. Individual tercile categories for summer and winter rainfall are used to derive a combined score for each year. The combined scores for each year over the interval are aggregated to produce a single score for each site. Tercile categories are derived from this aggregate score to provide seasonal quality categories of above average (tercile 1), average (tercile 2) or below average (tercile 3). For grassland sites, the combined score ranges from 1, the worst scenario — a winter tercile 3 (below average) followed by a summer tercile 3 (below average) — to 9, the best scenario — a winter tercile 1 (above average) followed by a summer tercile 1 (above average) (Table A1). The higher the combined score, the more favourable the seasonal quality.

Table A1 Matrix for deriving a combined score for seasonal quality for each year for grassland sites, based on the sequence of winter and summer rainfall

<table>
<thead>
<tr>
<th></th>
<th>Winter tercile 1 (Above average)</th>
<th>Winter tercile 2 (Average)</th>
<th>Winter tercile 3 (Below average)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer tercile 1 (Above average)</td>
<td>9</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>Summer tercile 2 (Average)</td>
<td>7</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Summer tercile 3 (Below average)</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>
For shrubland sites, the combined score ranges from 1, the worst scenario — a summer tercile 3 followed by a winter tercile 3 — to 9, the best scenario — a summer tercile 1 followed by a winter tercile 1 (Table A2). In the transitional zone from summer to winter rainfall dominance, the LCDs of Gascoyne – Ashburton Headwaters, Upper Gascoyne and Wiluna use a slightly different matrix to account for summer rainfall (Table A3). In either situation, the higher the combined score, the more favourable the seasonal quality.

Table A2 Matrix for deriving a combined score for seasonal quality for each year for shrubland sites, based on the sequence of summer and winter rainfall

<table>
<thead>
<tr>
<th></th>
<th>Winter tercile 1 (Above average)</th>
<th>Winter tercile 2 (Average)</th>
<th>Winter tercile 3 (Below average)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer tercile 1 (Above average)</td>
<td>9</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>Summer tercile 2 (Average)</td>
<td>8</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Summer tercile 3 (Below average)</td>
<td>6</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>

Table A3 Matrix for deriving a combined score for seasonal quality for each year for shrubland sites in the transitional zone, based on the sequence of summer and winter rainfall

<table>
<thead>
<tr>
<th></th>
<th>Winter tercile 1 (Above average)</th>
<th>Winter tercile 2 (Average)</th>
<th>Winter tercile 3 (Below average)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer tercile 1 (Above average)</td>
<td>9</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Summer tercile 2 (Average)</td>
<td>7</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Summer tercile 3 (Below average)</td>
<td>6</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>

Seasonal quality can be assessed for individual years, using the 12-month rainfall data for a particular year to indicate the between-year variation. Additionally, a single seasonal quality category can be assessed for a site for a multiyear period, such as the interval between monitoring assessments (see Section 3.2). For multiyear periods, a seasonal quality rating is calculated for each year and these ratings are aggregated to produce a single category for the entire interval between assessments. This category summarises rainfall amounts and timing (winter or summer) over the period between one WARMS site assessment and the next, and assists in interpreting any changes. For this report, seasonal quality is assessed on a 12-month basis and for one or more monitoring assessment periods.
**Glossary**

Words used in definitions that are themselves defined in the glossary are printed in bold.

**Abundance**: the total number of individuals of a species in an area, population or plant community

**Annual**: a plant which grows from seed and completes its life cycle, including flowering and seeding, within one year or less; some annuals can live longer than one year when growing conditions are favourable; see also short-lived perennial

**Arid**: a region or climate where lack of sufficient moisture severely limits growth and production of vegetation; the actual limit of sufficient moisture varies according to temperature in the specific location

**Available forage**: the proportion of forage production that is accessible for use by a specified kind or class of grazing animal

**Bioregion**: a large, geographically distinct area of land with common characteristics, such as geology, landform patterns, climate, ecological features and plant and animal communities; see Department of the Environment

**Canopy**: the vertical projection downward of the aerial portion of vegetation, usually expressed as a percentage of the ground occupied

**Canopy cover**: the percentage of ground covered by a vertical projection of the outermost perimeter of the natural spread of plant foliage; small openings within the canopy are generally included

**Carrying capacity**: the number of livestock units a paddock or management area can carry over the long term, while maintaining or improving land condition

**Cattle unit (CU)**: a standard unit used (1) to compare the feed requirements of different classes of livestock; (2) to assess the carrying capacity and potential productivity of a given area of grazing land; a CU is generally accepted as a full grown steer or dry cow of about 450 kilograms liveweight. One CU equals seven dry sheep equivalents (DSE)

**Continuous grazing**: the grazing of a specific area (station, paddock) by livestock throughout the year

**Decreaser**: a plant species, often of the original (pristine) vegetation, which will decrease in relative amount with continued disturbance, such as grazing; see also increaser

**Density**: the number of individuals of a certain species per unit area; it is not a measure of cover

**Desirables or desirable species**: those species in a given pasture type that are usually productive, highly palatable and perennial; generally decrease in frequency as grazing pressure increases because they are preferentially grazed by cattle; also called decreasers

**Driver**: an aspect of a system that causes or contributes to a change on another aspect of the system

**Drought**: a prolonged period without rain, compared to the norm, leading to a shortage of water for vegetation or livestock

**Dry sheep equivalent (DSE)**: a standard unit used to compare the feed requirements of different classes of stock; based on the feed energy required to maintain a 45 kilogram Merino wether

**Effective rainfall**: rainfall that infiltrates the soil and is available to plant roots (that is, it is not lost to evaporation, run-off or deep drainage); in its simplest form, effective rainfall is precipitation above a threshold of a fixed event size (for example, 50mm), below which plants stop growing; it is not the same everywhere or all the time because factors, such as rainfall sequence and timing, temperature, soil type and slope, affect how much rain must be received before plants can take it up

**Erosion**: detachment and movement of soil or rock fragments by water or wind

**Forage**: browse and herbage which is available as food for grazing animals or for harvesting for feed (that is, hay or silage)
**Forage supply:** the amount of forage available to grazing animals in a given area in a given period. Dry forage is a static quantity, and green, growing forage is a dynamic quantity.

**Frequency:** the ratio between the number of sample units containing a species and the total number of sampling units; expressed as a percentage.

**Functional group:** an aggregation of land systems, based on similar landform, dominant land unit or pasture type, and underlying vegetation; a primary functional group can be split according to the overstorey; the 110 land systems in the Kimberley are classified into 10 functional groups; south of the Kimberley, the 444 land systems are classified into 50 functional groups; for example, see table below.

<table>
<thead>
<tr>
<th>Functional group</th>
<th>Functional group description</th>
<th>Land system</th>
<th>Area (km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td>Hills and ranges with open woodland</td>
<td>Burramundi, Clifton, Elder, Forrest, Headley, Looingnin, Lubbock, Pompey, Precipice, St George, Wickham</td>
<td>22 732</td>
</tr>
<tr>
<td>1b</td>
<td>Hills and ranges woodland</td>
<td>Buldiva, Dockrell, Pinkerton, Webber</td>
<td>26 784</td>
</tr>
<tr>
<td>2a</td>
<td>Hills – lowlands – undulating plains – woodlands spinifex grass</td>
<td>Fork, Foster, Franklin, Karunjie, Macphee, Pago, Ruby 2</td>
<td>17 998</td>
</tr>
</tbody>
</table>


**Grassland:** a vegetation community dominated by grasses, grass-like plants or forbs; characterised by perennial tussock and hummock grasses, occurring primarily in the Kimberley and Pilbara; in the Pilbara, there is a gradual change from tussock or hummock grass understoreys in northern pastures to predominantly shrub understoreys in southern pastures.

**Grazing intensity:** the cumulative impact of grazing animals on rangeland vegetation in a given period.

**Grazing pressure:** the demand–supply ratio between dry matter requirements of herbivores (livestock, and native and introduced herbivores) and the forage supply in a pasture at a specific time. Where grazing pressure is high for sustained periods (forage removal is greater than forage production), the population size, diversity and distribution of desirable perennials can be decreased and the ability to regenerate may also be reduced.

**Grazing system:** a specialised form of grazing management which defines the periods of grazing and non-grazing (rest). The usual systems are set-stocking, cell (rotational) grazing and seasonal spelling.

**Hummock grass:** spinifexes that grow together as large rounded mounds or ‘hummocks’ that can be up to several metres across; often form a ring around a central dead or decaying patch.

**Increaser:** plant species, often of the original (pristine) vegetation, which will increase in relative amount, at least for a time, with continued disturbance, such as grazing; see also decreaser.

**Intermediates or intermediate species:** those species in a given pasture type that include moderately or slightly palatable perennial grasses, shrubs and trees and palatable annuals; may increase under heavy grazing at first because livestock concentrate on the more desirable species but if the desirable species are grazed out, intermediate species will also start to decline.

**Land conservation district (LCD):** community groups constituted under section 22(1) of the Soil and Land Conservation Act 1945; comprise pastoral leasehold land, defined conservation areas, which may have formed part of the pastoral estate prior to declaration as conservation areas, and unallocated Crown land (UCL).

**Landscape function:** the way in which landscapes acquire, use, cycle and lose physical and biological resources.
**Land system:** a recurring pattern of vegetation, topography and soils in the landscape

**Monitoring:** the process of making repeated observations, assessments or measurements in the same area, and analysing and interpreting data to judge progress towards meeting management objectives; observations can be direct, for example, by measuring attributes at fixed sites in the field, or indirect, for example, by acquiring data from remotely sensed images

**Pastoral value:** the value of a pasture or an individual species for **pastoralism**, based on the quality and quantity of livestock forage it provides

**Pastoralism:** the husbandry of domesticated grazing animals on native or introduced pasture

**Pasture type:** a distinct mix of plant species, soil type and landscape position

**Perennial:** a plant which lives for three or more years; see also **short-lived perennial**

**Potential Carrying Capacity (Potential CC):** the estimated long-term carrying capacity for a paddock or station if all **pasture types** are in good **rangeland vegetation condition** and the area is fully developed (particularly with respect to water point distribution and placement) and available to livestock

**Preferential grazing:** where livestock selectively graze more-palatable species before less-palatable species; may lead to the more-palatable species being grazed out of a pasture

**Preferred species:** plant species that are preferred by all (or a group of) animals and are grazed by first choice; preference can vary between cattle and sheep

**Present Carrying Capacity (Present CC):** the **Potential CC** discounted for an assessed decline in **rangeland vegetation condition**, based on defined ‘discount factors’ for each **land system**

**Rangeland:** the internationally recognised term for land supporting vegetation suitable for grazing; where livestock are grazed extensively on native vegetation; where rainfall is considered to be too low or erratic for agricultural cropping or for improved pastures

**Rangeland vegetation condition:** the present status of an area of **rangeland** in terms of specific values or potentials; the current status of the vegetation compared to the optimal status which could be expected given the potential of the area; rangeland vegetation condition is assessed as:

- **good:** perennials present include all or most of the palatable plant species expected; some less-palatable species may be present; total perennial groundcover is close to optimal for the site
- **fair:** moderate loss of palatable perennials or increases in unpalatable species, but most palatable species are still present; foliar cover is below optimal for the site unless palatable species have increased, in which case foliar cover is similar to good condition rangeland
- **poor:** conspicuous loss of palatable perennials; foliar cover has either decreased through loss of perennials (common in grasslands), or is stable or increased because of an invasion of unpalatable species

**Rangeland plant population change:** the change in direction of health or condition of plant populations, described by changes in the frequency or density of indicator plant species; not an absolute measure of **rangeland vegetation condition**; usually expressed as increased, stable or decreased

**Resilience:** the ability of a plant, pasture or ecosystem to withstand disturbance

**Resource capability:** the capability of a resource, such as land or vegetation, to sustain a particular use without degradation

**Rotational grazing:** a grazing scheme where livestock are moved from one grazing unit (paddock) on the same station to another
**Savanna:** area of grassland (generally tropical or subtropical) with scattered trees; a dry climate, punctuated by a distinct summer wet season, encourages the growth of grasses and discourages the growth of trees.

**Short-lived perennial:** annual species able to live for more than one year when growing conditions are favourable.

**Shrubland:** a vegetation community characterised by shrubs with a variable mulga or eucalypt overstorey; occur primarily in the Gascoyne, Murchison, Goldfields and Nullarbor; in the Pilbara, there is a gradual change from **tussock** or **hummock grass** understoreys in northern pastures to predominantly shrub understoreys in southern pastures.

**Soil surface condition:** the soil’s capacity to retain water and ensure soil stability.

**Stocking rate:** the number of specific kinds and classes of animals utilising a unit of area for a specific time period; normally expressed as animal type per unit area, for example, five wethers per hectare, two steers per hectare.

**Total grazing pressure:** the ratio of the total demand for forage by all herbivores (livestock, and native and introduced herbivores) to the forage supply; it is low in periods when forage is abundant, and vice versa.

**Trend:** the direction of change in health or condition of a base resource.

**Tussock grass:** a grass that has stems bunched together forming a grass clump or ‘tussock’.

**Undesirable species:** those species in a pasture type that are generally unpalatable, including woody weeds and other weedy, prickly or toxic species which invade overgrazed pasture; largely ignored by livestock, undesirable species tend to increase under prolonged heavy grazing and in large numbers, indicate poor **rangeland condition**; also called **increasers**.

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**Utilisation:** the percentage of pasture grown in a year that is consumed or destroyed by livestock; may refer to a single plant species or a whole vegetation community.

**WARMS:** Western Australian Rangeland Monitoring System; a set of permanent rangeland monitoring sites in pastoral Western Australia; established by the then Department of Agriculture Western Australia in the early 1990s.

**Woodlands:** a vegetation ecosystem that contains widely spaced trees with their crowns not touching; in the Western Australian rangelands, woodlands support an understorey of shrubs and herbaceous plants including grasses.