RANGELANDS
NRM CLUSTER

CLIMATE CHANGE IN AUSTRALIA
IMPACTS & ADAPTATION INFORMATION FOR AUSTRALIA'S NRM REGIONS

Australian rangelands and climate change – meteorological drought

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Territory Natural Resource Management

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desert channels QUEENSLAND

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Achieving sustainable landscapes for rural communities

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Rangelands NRM Western Australia

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Key points

- Drought is a complex phenomenon with mixed environmental, social and economic implications. Here, we report on the recent history (since 1950) of meteorological drought, which is characterised by severe rainfall deficiency over periods of 12 months or more.
- Spatially interpolated rainfall data since 1950 were examined to determine the timing and severity of rainfall deficits as an indicator of meteorological drought.
- For most regions, the longest and most severe rainfall deficit occurred in the late 1950s extending to the mid-1960s. Other periods of general rainfall deficiency occurred in the early 1980s and the mid-2000s. Deficits also occurred in the 1950s, early 1970s and parts of the 1990s for some regions.
- This analysis of rainfall deficiency for the recent past should provide a guide to the probable severity of future meteorological droughts under continuing, and perhaps enhanced, rainfall variability. Drought will continue to be a recurrent feature in the Rangelands Cluster region, so a key adaptation response for the pastoral industry is simply to be prepared: utilise reliable climate forecasting services and implement drought management strategies promptly as key dates or trigger points for decision making are reached.

Gary Bastin
CSIRO

1. Introduction

Drought is a complex environmental, economic and social phenomenon. Part of this complexity results from its differential impact across sections of society, including the agricultural sector and the community. From an environmental perspective alone, drought can be considered in terms of:

- Meteorological conditions: combinations of rainfall deficit and evapotranspiration that collectively determine meteorological drought.
- Hydrological drought: soil water deficits and reduced runoff that greatly reduces water availability at different scales, particularly for towns and cities when dams are low.
- Agricultural drought: reduced pasture and/or crop growth resulting from extended low rainfall and depleted soil water availability.

For this component, we confine our discussion to meteorological drought. There are two indices used in the United States (and elsewhere) to characterise the severity of meteorological drought, but neither appear to have currency in Australia (i.e. they are not listed on the Bureau of Meteorology web site, www.bom.gov.au). This may be due to the highly variable nature of rainfall across much of Australia and particularly in the Rangelands Cluster region.

These indices are:

1. The Palmer Drought Index (also known as the Palmer Drought Severity Index), which provides a measurement of dryness based on recent precipitation and temperature (detailed information in Palmer 1965). The index is based on water balance, including supply (precipitation), demand (evapotranspiration) and loss (runoff). Its application requires that many parameter values be set and index values appear difficult to calculate (although a FORTRAN program is available). Its suitability to the Australian rangelands is not known.
2. The Standardised Precipitation Index is a probability index that considers only precipitation. The index is endorsed by the World Meteorological Organization.

Further information on both indices is available on the web (NOAA 2013).

The Bureau of Meteorology (BoM) reports on drought in terms of rainfall deficiency, both its duration and regional extent (BoM 2014). This BoM approach is used here with regional historical rainfall data.

2. Method

Analysis and reporting of historic rainfall data is confined to the main areas of pastoral estate in each NRM region of the Rangelands Cluster (Figure 2.1).

Gridded monthly rainfall data for Australia since 1890 had been compiled within the Australian Collaborative Rangelands Information System (ACRIS) (ACRIS n.d.) and are used as a convenient (i.e. readily accessible) dataset for this analysis. Pixel size is 0.05° (~5 km by ~5 km), with the rainfall amounts for individual grid cells interpolated from long-term recording stations. Grid-cell data are used here to allow spatial averaging of rainfall for pastoral districts within NRM regions (or part regions, Figure 2.1). This provides a more reliable estimate of district-wide rainfall anomaly, as an indicator of meteorological drought, than the point-based analysis of rainfall in Bastin (2014).

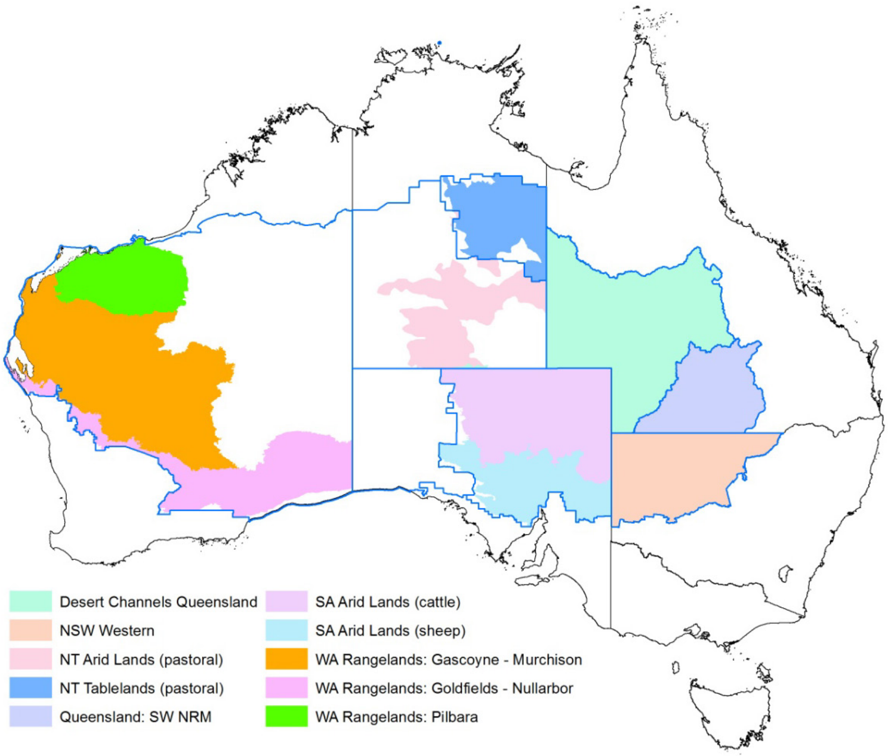

Figure 2.1 Pastoral areas within NRM regions of the Rangelands Cluster used for reporting recent periods of meteorological drought.

Blue lines show NRM regions / sub-regions.

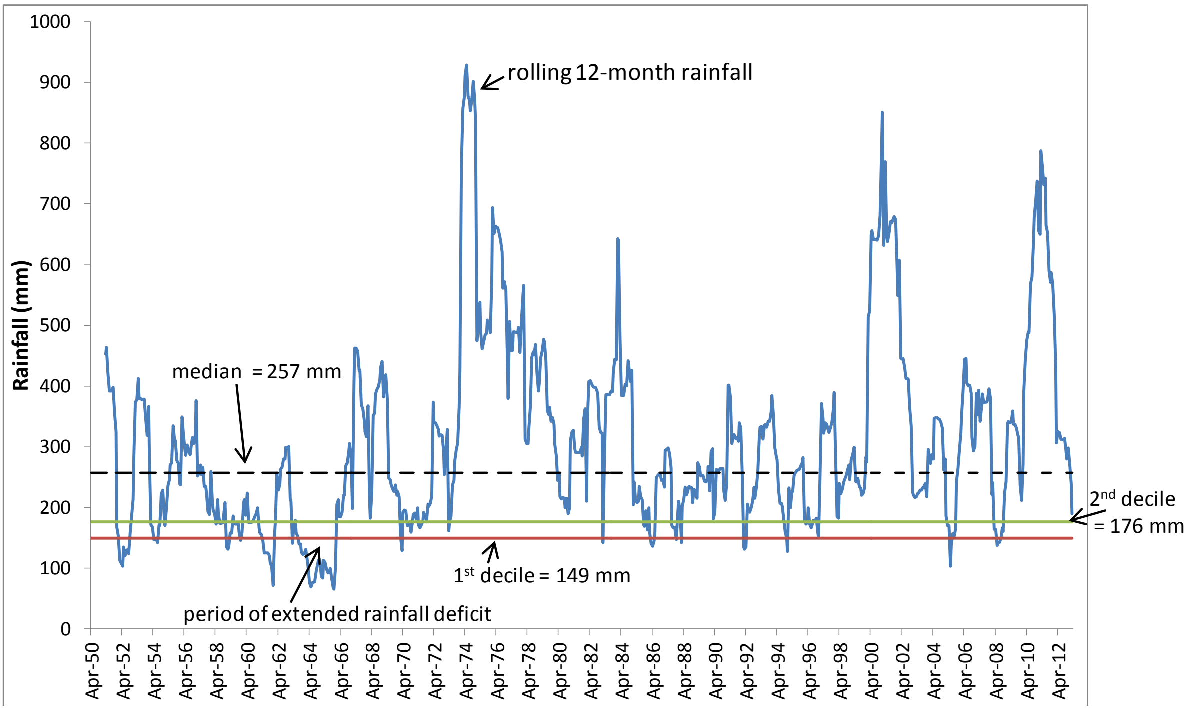

Figure 2.2 Spatially averaged monthly rainfall for the pastoral region of the NT Arid Lands sub-region accumulated on a rolling 12-month basis since April 1950. Horizontal lines show the first, second and fifth deciles for the same region based on April–March rainfall between 1890–91 and 2012–13.

The data were processed in the following way:

1. Spatially interpolated rainfall data were summed for each April–March rainfall year.[1]
2. Yearly rainfall data (1890–91 to 2012–13) were spatially averaged for each pastoral NRM region (Figure 2.1) and rainfall amounts corresponding with the first, second and fifth deciles determined. The fifth decile is the median.
3. Monthly rainfall data between April 1950 and March 2013 (63 years, 756 months) were similarly spatially averaged for each pastoral NRM region.
4. The monthly spatial averages were summed (in Excel) on a rolling 12-month basis (i.e. April 1950 to March 1951, May 1950 to April 1951, … , April 2012 to March 2013) and the accumulated amounts compared with the first and second deciles and the median (Figure 2.2). Periods with accumulated 12-month rainfall below the first or second deciles were likely associated with considerable moisture deficit and could usefully indicate meteorological drought.
5. Periods longer than one year with cumulative monthly rainfall less than the first decile were determined (Table 5.1). These indicate the most severe (meteorological) drought conditions since 1950 and give some guide to the future under predicted enhanced rainfall variability.

[1] ACRIS uses an April–March rainfall year to avoid splitting northern monsoonal rainfall across calendar years.

3. Data source

For these analyses we used an ACRIS dataset which stores interpolated monthly rainfall data for Australia since 1890. The historic period used in these analyses was April 1950 to March 2013 (as per point 1 above, ACRIS uses an April–March rainfall year to avoid splitting northern monsoonal rainfall across calendar years). Recent monthly rainfall grids are available at BoM (n.d.).

4. Caveats

Caveats and limitations associated with this analysis include:

1. Deciles of rainfall anomaly provide a statistical indication of probable past meteorological drought. They cannot indicate actual drought conditions in terms of duration and severity, nor levels of hardship for those affected at the time.
2. Rainfall data are interpolated from sparse recording stations for much of the Rangelands Cluster region and can only approximate the actual amount received at specific locations. Additionally, rainfall data were averaged across quite large NRM regions and this conceals often quite large variation in rainfall received. Both factors mean that actual monthly rainfall anomaly for some locations may have varied from that calculated.

5. Findings

5.1 Regional drought

Rolling 12-monthly rainfall and likely past periods of moderate to severe meteorological drought are shown for other pastoral NRM regions in Figure 5.1–5.9 (see Figure 2.1 for locations). The longest dry periods are summarised in Table 3-1.

Table 5.1 Some characteristics of regional meteorological drought since 1950

PASTORAL NRM REGIONS	FIRST DECILE (MM)	SECOND DECILE (MM)	LONGEST DRY PERIOD BASED ON DECILE 1 RAINFALL	COMMENTS
NSW: Western CMA	145	177	16 months ending April 1966	Several very dry periods with the most negative rainfall anomalies occurring in December 1957, September 1965, January 1973, November 1982 and March 2003.
Queensland: South West NRM	232	273	16 months ending June 2003	12-month rainfall less than the first decile extending either side of January 1952, July 1958, November 1965, May 1980, January 1983, September 1985 and March 2003.
Queensland: Desert Channels	187	229	18 months ending November 1969	Several 12-month periods with less than decile 1 rainfall: January 1952, October 1965, January 1967, July 1969, February 1983, December 2002.
SA Arid Lands: south of the Dog Fence (mainly sheep)	93	102	18 months ending September 1983	Many 12-month periods with < decile 1 rainfall. More significant events included October 1957, August 1961, July 1964, October 1970, January 1973, October 1977, February 1983 and October 2002.
SA Arid Lands: north of the Dog Fence (i.e. cattle)	69	79	18 months ending July 1965	Several periods of accumulated rainfall below the first decile, most notably in the 1960s. Other periods include November 1970, January 1973, February 1983, July 1985, December 1994, May 2005, December 2006 and May 2008.
NT Arid Lands (pastoral area)	149	176	22 months ending November 1965	Severe rainfall deficiency in the first half of the 1960s. Other occasions include March 1952 and May 2005.
NT Tablelands sub-region (pastoral area)	339	390	22 months ending December 1952; part of this period includes the preceding ‘winter’ months which are normally dry	Several periods with < decile 1 rainfall, most notably the 1952 period in the previous column. Other periods include March 1958, December 1961 and the early 1990s (1990 and 1992).
WA Rangelands: Goldfields – Nullarbor pastoral area	116	142	17 months ending April 1977	Longer periods of severe rainfall deficiency (i.e. 12-month totals < decile 1) in the early 1970s and 1976–77. Other dry periods included January 1953, December 1957 and late 1961. The rainfall data (Figure 5.7) suggest that rainfall is increasing (despite considerable year-to-year variability) and recent dry years have been above decile 1 rainfall.
WA Rangelands: Gascoyne – Murchison	127	157	20 months ending November 1977	An extended very dry period in 1977 with other very dry periods in March 1970 and April 1991. As for the Goldfields – Nullarbor region, the data suggest that yearly rainfall is increasing (although still highly variable, Figure 5.8).
WA Rangelands: Pilbara pastoral area	165	203	18 months ending December 1972, although this includes the preceding normally dry winter months	Very dry periods in March 1953, July 1959, April 1970, late 1972, January 1991 and May 2005.

5.1.1 NSW: Western CMA

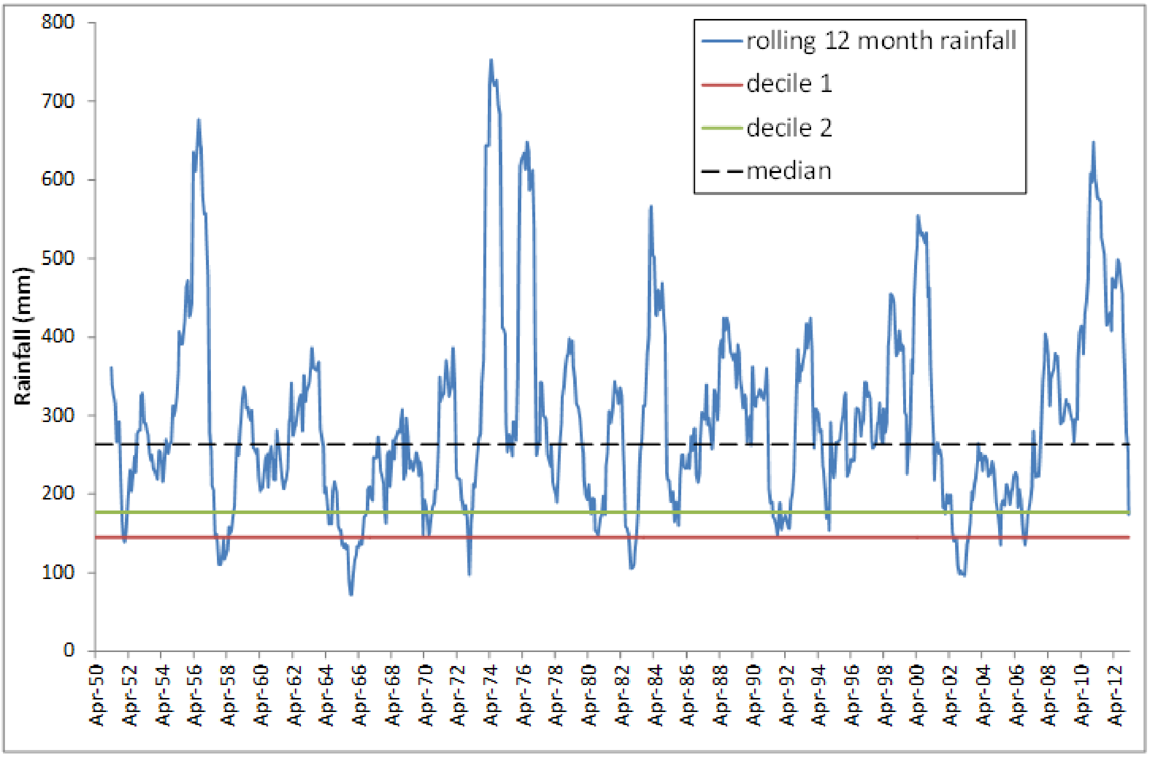

Figure 5.1 Spatially averaged monthly rainfall for the NSW Western CMA region accumulated on a rolling 12-month basis since April 1950. Horizontal lines show the first, second and fifth deciles for the same region based on April–March rainfall between 1890–91 and 2012–13.

5.1.2 Queensland: South West NRM

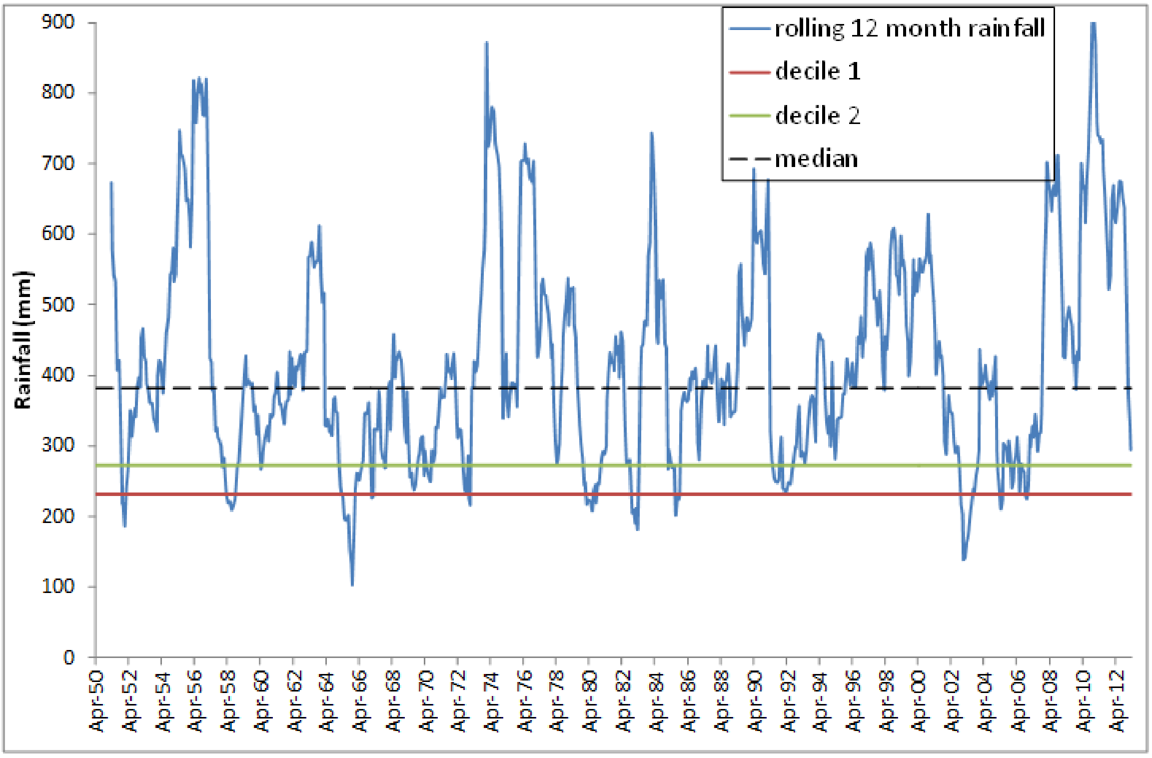

Figure 5.2 Spatially averaged monthly rainfall for the Queensland South West NRM region accumulated on a rolling 12-month basis since April 1950. Horizontal lines show the first, second and fifth deciles for the same region based on April–March rainfall between 1890–91 and 2012–13.

5.1.3 Queensland: Desert Channels

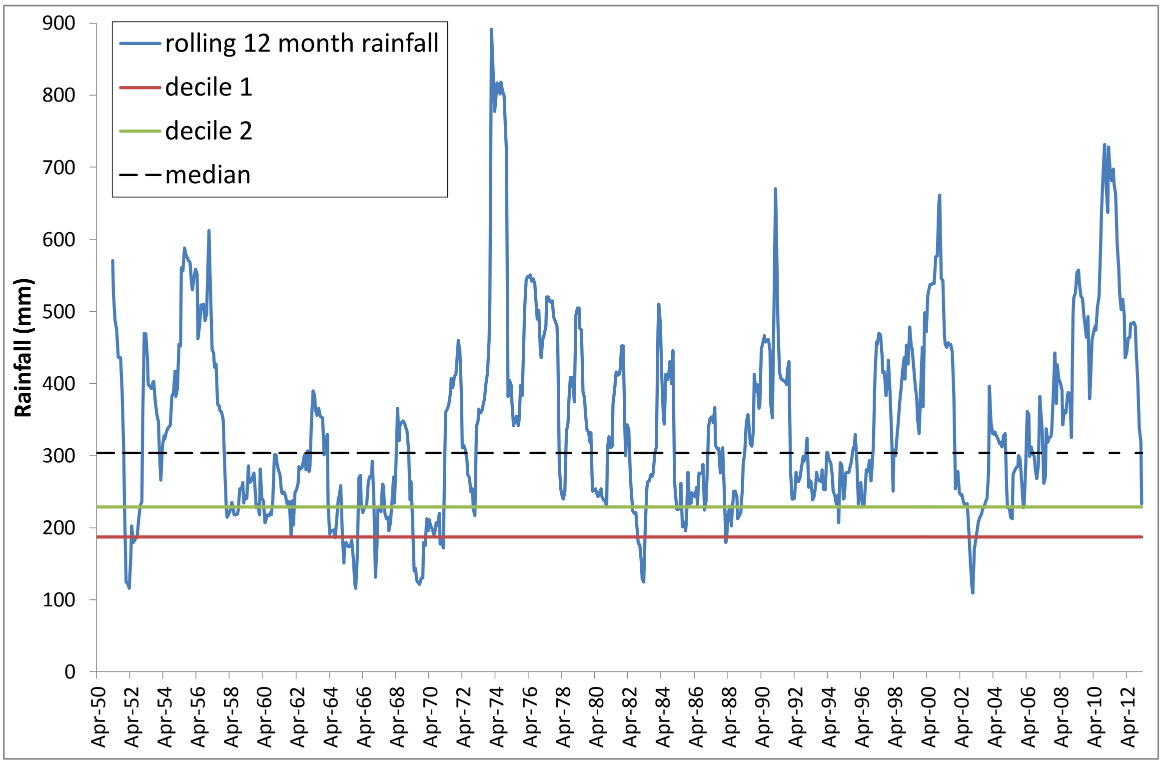

Figure 5.3 Spatially averaged monthly rainfall for the Queensland Desert Channels region accumulated on a rolling 12-month basis since April 1950. Horizontal lines show the first, second and fifth deciles for the same region based on April–March rainfall between 1890–91 and 2012–13.

5.1.4 South Australian Arid Lands southern sheep zone

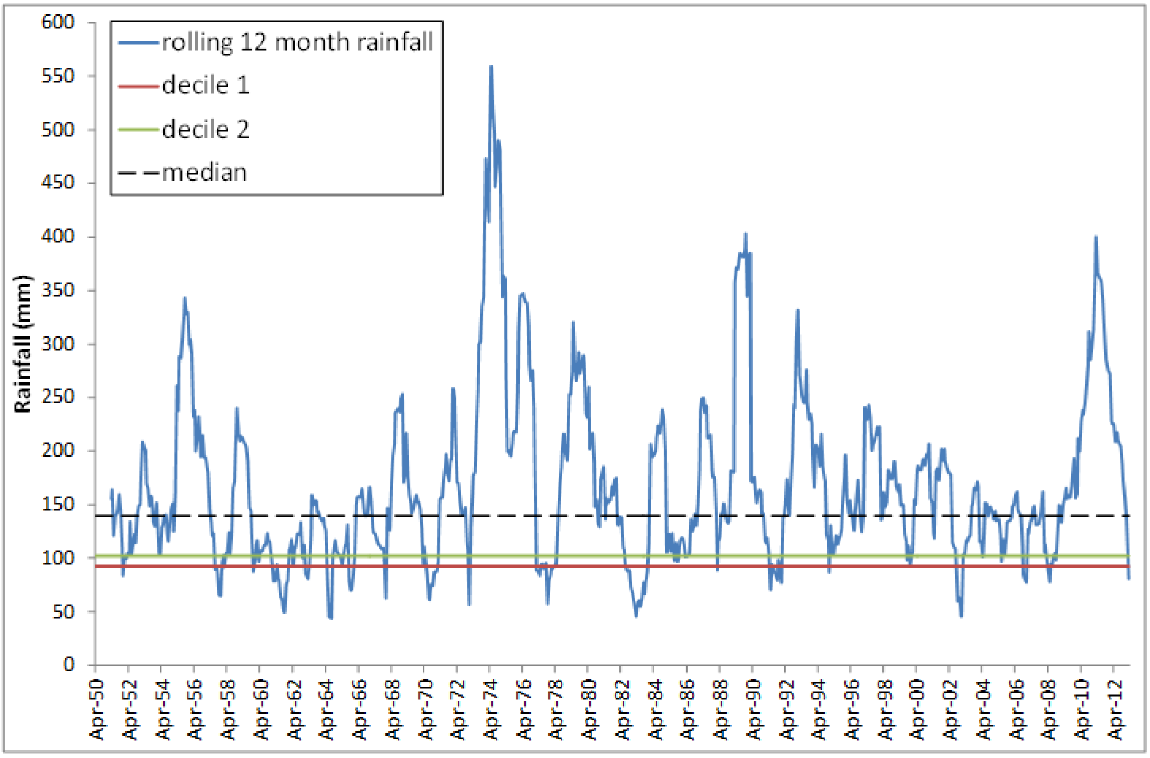

Figure 5.4 Spatially averaged monthly rainfall for the SA Arid Lands southern sheep region accumulated on a rolling 12-month basis since April 1950. Horizontal lines show the first, second and fifth deciles for the same region based on April–March rainfall between 1890–91 and 2012–13.

5.1.5 South Australian Arid Lands northern cattle zone

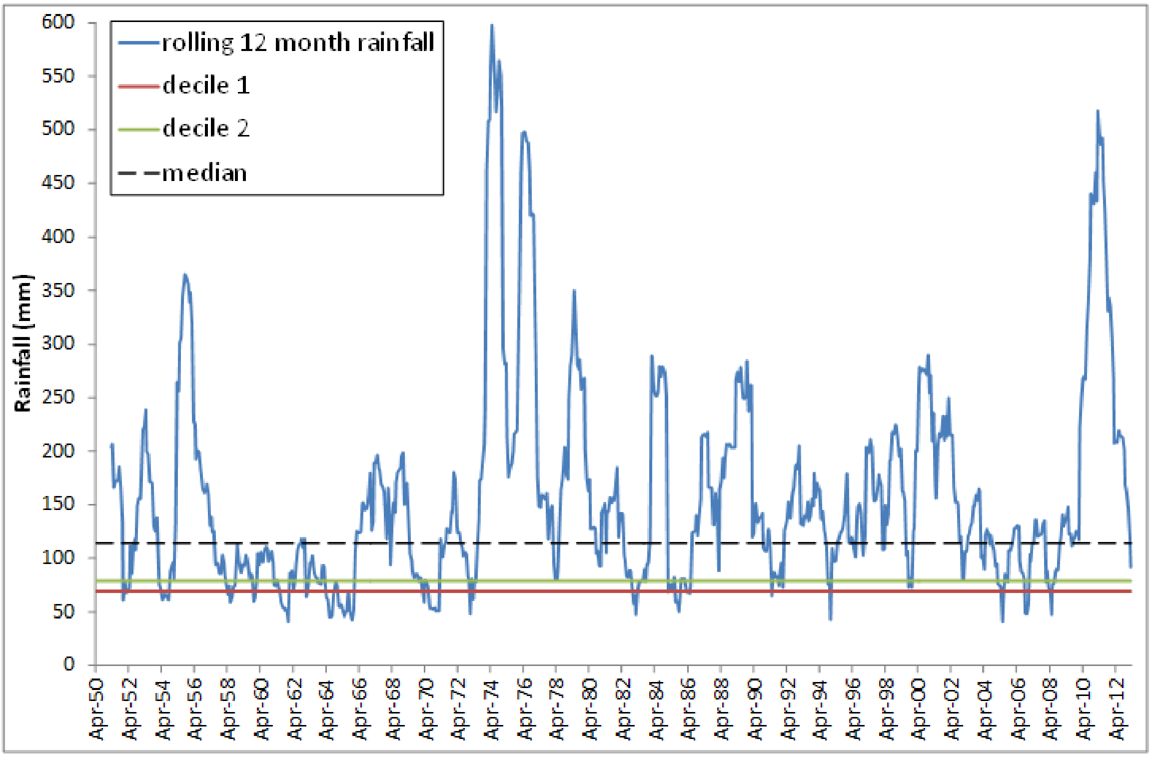

Figure 5.5 Spatially averaged monthly rainfall for the SA Arid Lands northern cattle region accumulated on a rolling 12-month basis since April 1950. Horizontal lines show the first, second and fifth deciles for the same region based on April–March rainfall between 1890–91 and 2012–13.

5.1.6 NT Tablelands sub-region (pastoral area)

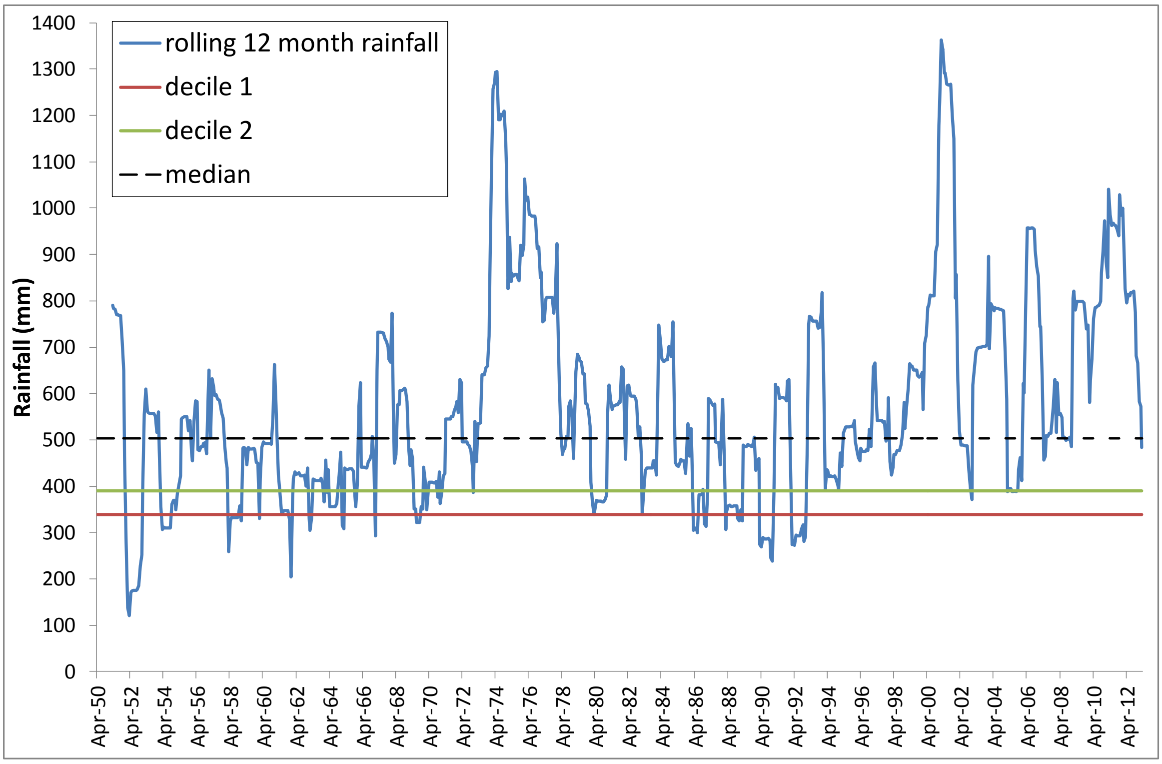

Figure 5.6 Spatially averaged monthly rainfall for the pastoral region of the NT Tablelands sub-region accumulated on a rolling 12-month basis since April 1950. Horizontal lines show the first, second and fifth deciles for the same region based on April–March rainfall between 1890–91 and 2012–13.

5.1.7 WA Rangelands: Goldfields – Nullarbor pastoral area

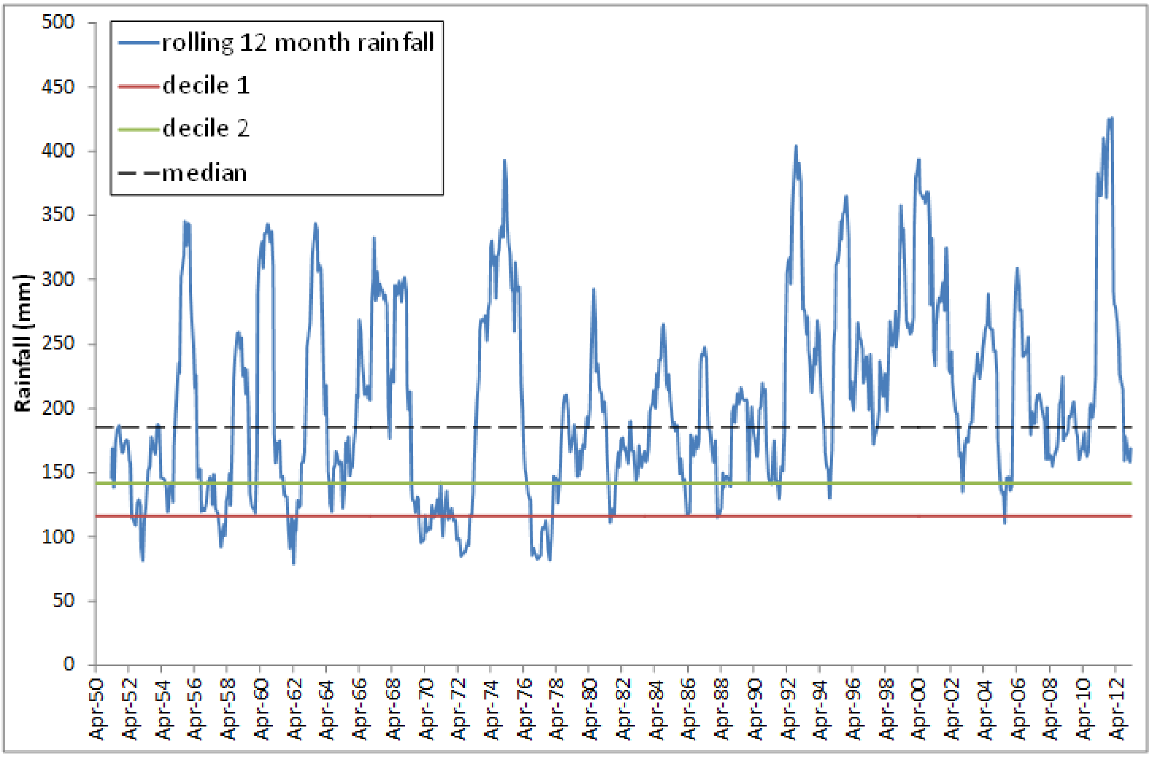

Figure 5.7 Spatially averaged monthly rainfall for the Goldfields – Nullarbor pastoral region of the WA Rangelands accumulated on a rolling 12-month basis since April 1950. Horizontal lines show the first, second and fifth deciles for the same region based on April–March rainfall between 1890–91 and 2012–13.

5.1.8 WA Rangelands: Gascoyne – Murchison pastoral area

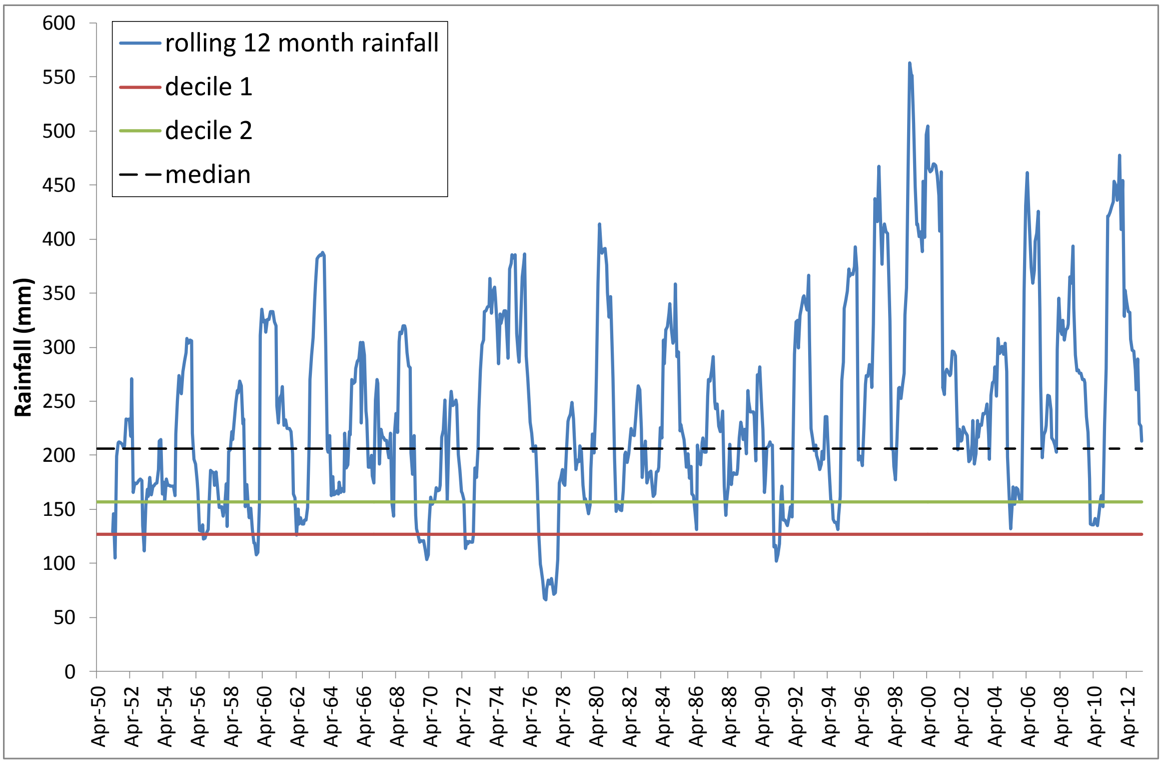

Figure 5.8 Spatially averaged monthly rainfall for the Gascoyne – Murchison pastoral region of the WA Rangelands accumulated on a rolling 12-month basis since April 1950. Horizontal lines show the first, second and fifth deciles for the same region based on April–March rainfall between 1890–91 and 2012–13.

5.1.9 WA Rangelands: Pilbara pastoral area

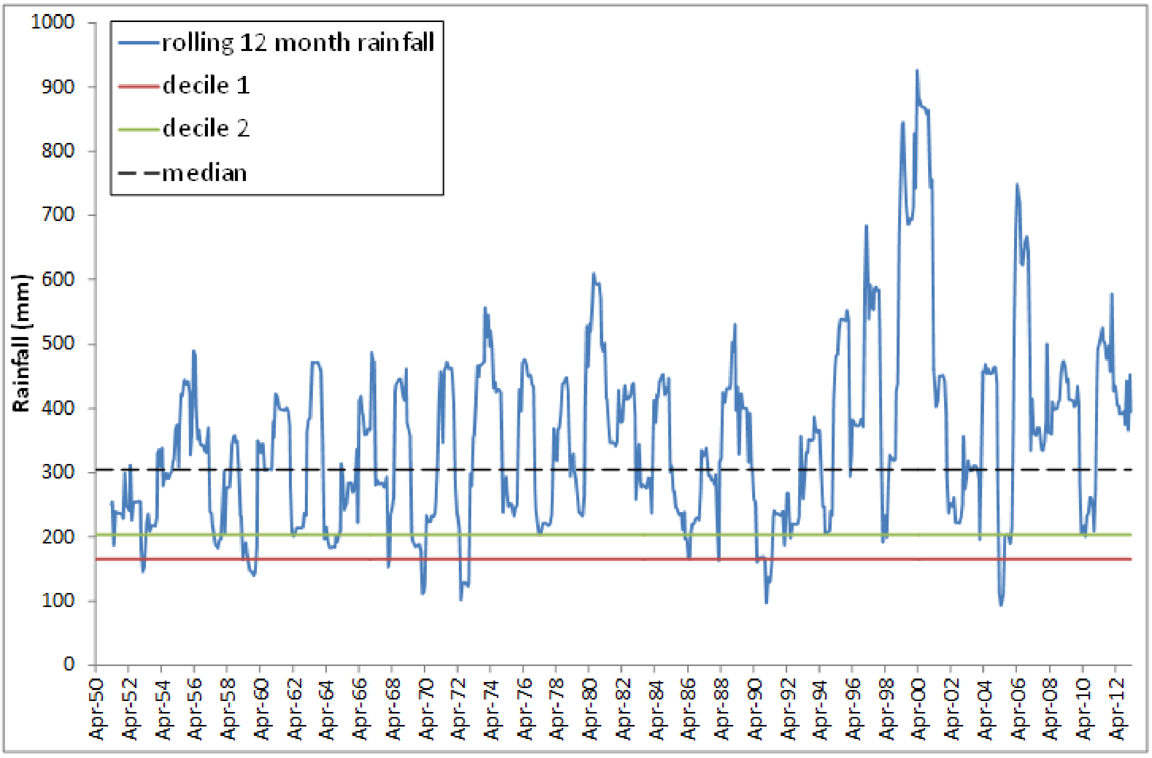

Figure 5.9 Spatially averaged monthly rainfall for the Pilbara pastoral region of the WA Rangelands accumulated on a rolling 12-month basis since April 1950. Horizontal lines show the first, second and fifth deciles for the same region based on April–March rainfall between 1890–91 and 2012–13.

6. Key adaptation strategies

Short-term rainfall deficit (up to one year) can occur at any time in the Rangelands Cluster region. Longer term deficits are linked to the major drivers of weather and climate (the well known El Niño Southern Oscillation [ENSO] and the perhaps less familiar Indian Ocean Dipole[2], etc.), and the skill in predicting the timing and consequences of these phenomena is increasing. One anticipated feature of future climate change is that drought will be characterised by a more intense El Niño pattern associated with persistent high pressure systems across much of Australia.

Pastoralists and their advisers should make increasing use of such information and forecasting services in preparing for probable increased frequency and severity of drought. This will likely be more effective if capacity is developed to better interpret probabilistic forecast information and incorporate it into management decisions.

[2] The Indian Ocean Dipole (IOD) is an irregular oscillation of sea-surface temperatures in which the western Indian Ocean becomes alternately warmer then colder than the eastern part of the ocean. In this respect, it is analogous to the ENSO in its effect on Australian rainfall. When the IOD is in its negative phase, with cool Indian Ocean water west of Australia and warm Timor Sea water to the north, winds are generated that pick up moisture from the ocean and then sweep down towards southern Australia to deliver higher rainfall. In the IOD positive phase, the pattern of ocean temperatures is reversed, weakening the winds and reducing the amount of moisture picked up and transported across Australia. The consequence is that rainfall in the south-east is well below average during periods of a positive IOD (Wikipedia 2014).

One of the most fundamental adaptation strategies for pastoralists is simply being prepared for drought: that is, to implement drought management strategies promptly as key dates or trigger points for decision-making are reached. An associated adaptation strategy may require the pastoral industry collectively to adopt a more conservative approach to stocking rates and land management so as to better protect the natural resource base where the future location and timing of drought is uncertain.

Abbreviations

IN THIS REPORT	
TERM	**DEFINITION**
ACRIS	Australian Collaborative Rangelands Information System
BoM	Bureau of Meteorology
CMA	Catchment Management Authority
ENSO	El Niño Southern Oscillation
NRM	natural resource management

IN ALL REPORTS IN THE SERIES	
TERM	**DEFINITION**
ABS	Australian Bureau of Statistics
AFCMP	Australian Feral Camel Management Project
BS	bare soil
DKCRC	Desert Knowledge Cooperative Research Centre
DSI	Dust Storm Index
EI	Ecoclimatic Index
EMU	Ecosystem Management Understanding™
FIFO	fly in, fly out
GAB	Great Artesian Basin
GCM	General Circulation Model
GDM	Generalised Dissimilarity Modelling
GHG	greenhouse gas
GW	Groundwater
GWW	Great Western Woodlands
IBRA	Interim Biogeographic Regionalisation for Australia
ICLEI	International Council for Local Environmental Initiatives
IPCC	Intergovernmental Panel on Climate Change
LEB	Lake Eyre Basin
LGM	last glacial maximum
MOF	manual observation frequency
mya	million years ago
NAFI	North Australian Fire Information

IN ALL REPORTS IN THE SERIES	
TERM	**DEFINITION**
NCCARF	National Climate Change Adaptation Research Facility
NPV	non-photosynthetic vegetation: senescent pasture and litter
OH&S	occupational health and safety
PV	photosynthetic vegetation: green
RCP	Representative Concentration Pathways
SAAL	South Australia Arid Lands
SDM	species distribution modelling
SW	Surface water
TGP	total grazing pressure
TM	Thematic Mapper
Western CMA	Western Catchment Management Authority
Western LLS	Western Local Land Service

Glossary

IN ALL REPORTS IN THE SERIES	
TERM	**DEFINITION**
Adaptive capacity	The ability to change and therefore reduce gross vulnerability; includes issues such as mobility, financial resources and education
Bioregion	A large, geographically distinct area of land that has groups of ecosystems forming recognisable patterns within the landscape
C_3 and C_4 plants	The different methods plants use to convert carbon dioxide from air into organic compounds through the process of photosynthesis. All plants use C_3 processes; some plants, such as buffel grass and many other warm climate grasses, also use C_4 processes. C_4 plants have an advantage in a warmer climate due to their higher CO_2 assimilation rates at higher temperatures and higher photosynthetic optima than their C_3 counterparts
Contentious species	A species that presents special challenges for determining the adaptation response to climate change, because it is both a threat and a beneficial species (Friedel et al. 2011, Grice et al. 2012)
Dust Storm Index (DSI)	The Dust Storm Index is based on visibility records made by Bureau of Meteorology (BoM) observers. The DSI provides a measure of the frequency and intensity of wind erosion activity at continental scale. It is a composite measure of the contributions of local dust events, moderate dust storms and severe dust storms using weightings for each event type, based upon dust concentrations inferred from reduced visibility during each of these event types.
DustWatch	DustWatch is a community program that monitors and reports on the extent and severity of wind erosion across Australia and raises awareness of the effects of wind erosion on the landscape and the impacts of dust on the community.

IN ALL REPORTS IN THE SERIES	
TERM	**DEFINITION**
Ecological refugia	Refugia defined according to the water requirements of the species they protect. The conservation significance of ecological refugia, and the priority assigned to their conservation, depends on the level of knowledge available for the species they support.
Evolutionary refugia	Those waterbodies that contain *short-range endemics* or *vicariant relics*. Evolutionary refugia are most likely to persist into the future and should be accorded the highest priority in NRM adaptation planning.
Generalised Dissimilarity Modelling (GDM)	A method of modelling based on compositional turnover of a group of species at a location; it considers whole biological groups rather than individual species
Gross vulnerability of a system	The combination of exposure and sensitivity of system
Heatwave	Continuous period beyond a week when a particular threshold temperature is exceeded
Hyporheic water flows	Below-surface flows
Indicators of exposure	Factors such as days above a certain temperature, days without rainfall, population density
Indicators of sensitivity	How sensitive a system is to hazards; indicators include the types of dwellings people live in and the percentage of the population with certain health characteristics
'No regrets' strategies	These strategies yield benefits even if there is not a change in climate
Novel ecosystem	Species occurring in combinations and relative abundances that have not occurred previously within a given biome (Hobbs et al. 2006)
Rainfall event	One or more closely spaced rainfalls that are large enough to produce a significant vegetation response

IN ALL REPORTS IN THE SERIES	
TERM	**DEFINITION**
Refugia	Habitats that biota retreat to, persist in and potentially expand from under changing environmental conditions
Return period	The number of days from the end of one rainfall event to the start of the next
Reversible strategies	Flexible strategies that can be changed if predictions about climate change are incorrect
Safety margin strategies	Strategies that reduce vulnerability at little or no cost
Species Distribution Modelling (SDM)	A species-specific approach whereby observational records are used to model the current potential distribution of a species
Short-range endemics	Species that occur only within a very small geographical area
Soft strategies	Strategies that involve the use of institutional, educational or financial tools to reduce species vulnerability to climatic change
Species invasiveness	A species that causes environmental or socioeconomic impacts, is non-native to an ecosystem or rapidly colonises and spreads (see Ricciardi and Cohen 2007). In the Invasive animals report it refers to non-native species (that is, those introduced to Australia post-1788) that have caused significant environmental or agricultural changes to the ecosystem or that are believed to present such a risk.
Strategies that reduce time horizons	Strategies that reduce the lifetime of particular investments
Vicariant relicts	Species with ancestral characteristics that have become geographically isolated over time

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