



RANGELANDS
NRM CLUSTER



IMPACTS & ADAPTATION
I N F O R M A T I O N
FOR AUSTRALIA'S NRM REGIONS



Australian rangelands and climate change – rainfall variability and pasture growth



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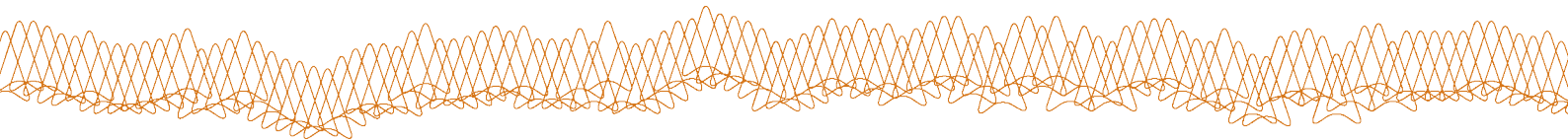
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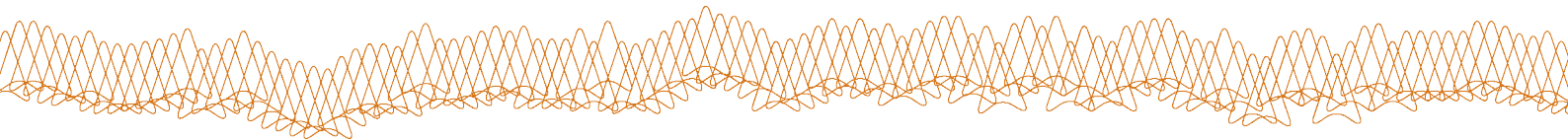
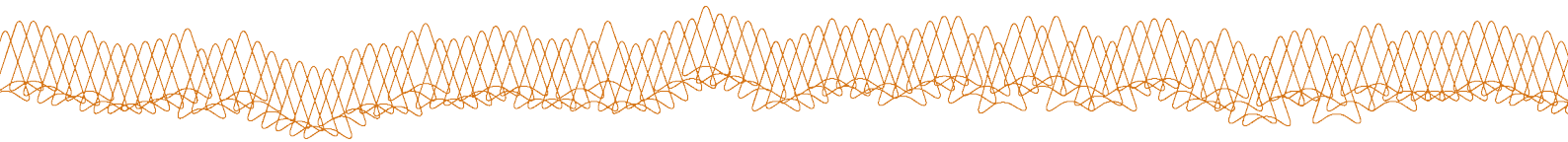
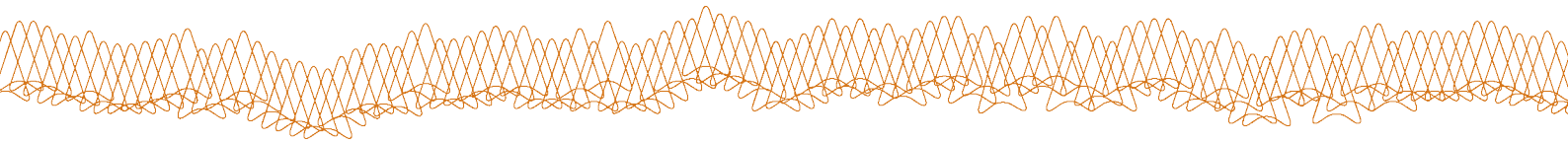


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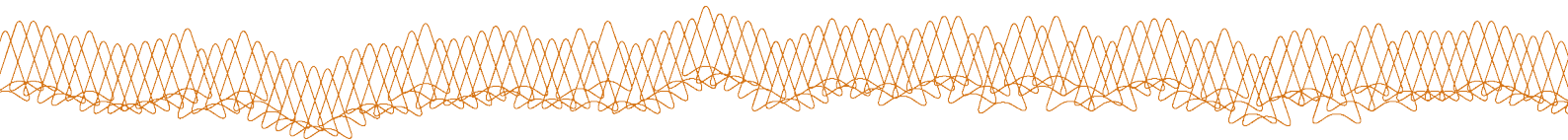




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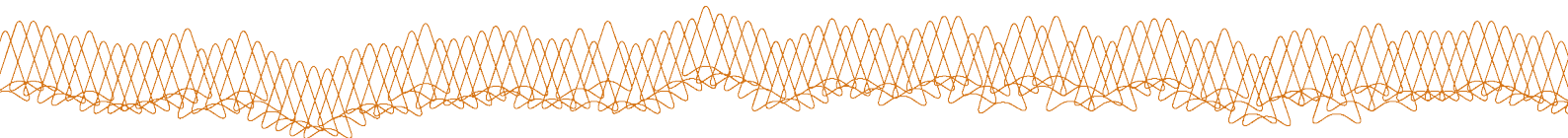
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Key points

- The frequency of probable past pasture growth events based on daily rainfall gives some indication of what lies ahead for the Rangelands Cluster region under the climate change projection of continuing high natural variability in rainfall.
- For this analysis, >25 mm of rain over consecutive wet days is considered the minimum requirement for pasture growth to occur across much of the Rangelands Cluster region, and a >50 mm event over the same period should provide ideal growing conditions – particularly where grazed land is maintained in good condition. There are exceptions, of course, to this general guide. Smaller events (e.g. as low as 10 mm) may be effective in cooler weather and for specific locations / vegetation types (e.g. new leaf growth in chenopod shrublands on the Nullarbor Plain). At the other end of the scale, degraded rangeland may respond minimally to >50 mm events.
- The last 60 years of rainfall data show that periods of rainfall suitable for marginal to ideal growing conditions were infrequent throughout much of the Rangelands Cluster region. The median return period (in days) between >25 mm and >50 mm events lengthens for locations with lower and more variable annual rainfall – that is, to the south (Port Augusta, Cook, Kalgoorlie) and towards the more arid interior (Coober Pedy, Marree, Birdsville, Oodnadatta).
- The median return period for >50 mm events is close to one year for the more arid parts of the cluster region.
- Given the highly episodic nature of rainfall across inland Australia, no trends in return period for specific rainfall amounts were detected.
- The reported probabilities are unlikely to improve under forecast continuing rainfall variability. Projected temperature increases will increase soil moisture losses through greater evaporation and evapotranspiration. This will mean that smaller continuous daily rainfalls (>10 and >25 mm events) will be less effective for pasture growth, particularly during hotter weather. At such times, even >50 mm events that are well separated in time may become marginal for effective growth. In short, a continuing cautious approach to stocking levels, strict control of total grazing pressure and drought preparedness are required into the future.
- We provide a template spreadsheet for users to calculate their own return-period statistics for any rainfall amount and location where historic daily rainfall data are available. This tool summarises periods of continuous daily rainfall; it cannot calculate rainfall intensity. The URL is http://www.nintione.com.au/resource/AustralianRangelandsAndClimateChange_RainfallVariabilityPastureGrowth_RainfallTemplate.xlsx.

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1. Introduction

Native pastures support pastoral production throughout much of the Rangelands Cluster region. Appropriate stocking rates that ensure safe levels of pasture utilisation and maximise the opportunity of forage species to respond to episodic rainfall when received underpin the continued sustainable use of the rangelands for livestock production. What does the future hold in terms of projected climate change?

Winter rainfall is expected to decline in the southern part of the Rangelands Cluster region, and spring rainfall may also decrease (Watterson et al. in press). Changes to rainfall in other seasons, and annually, are possible but the direction of change is uncertain. There is high confidence, however, that past high natural variability in rainfall will continue, and this may mask any trend in average rainfall for some decades to come, particularly in the summer season.

We cannot be certain as to what these projections mean in terms of future pasture growth and the forage base for livestock. However, we do know that both variability and uncertainty will continue to prevail. Analysis and interpretation of past rainfall records may provide useful context for better understanding the future.

In this section, we examine the frequency with which past probable growth events occurred using the daily rainfall data for selected rainfall recording stations throughout the Rangelands Cluster. Pasture growth models (e.g. GRASP at paddock scale and AussieGRASS¹ at landscape scale) estimate forage availability on a monthly to annual basis and provide a much more sophisticated interpretation of historic rainfall. However, these modelling approaches were not

available to this project and we simply use various amounts of continuous daily rainfall to indicate likely growth events. This approach, via a spreadsheet template, could easily be expanded and adopted for continuing use by NRM planners within their regions.

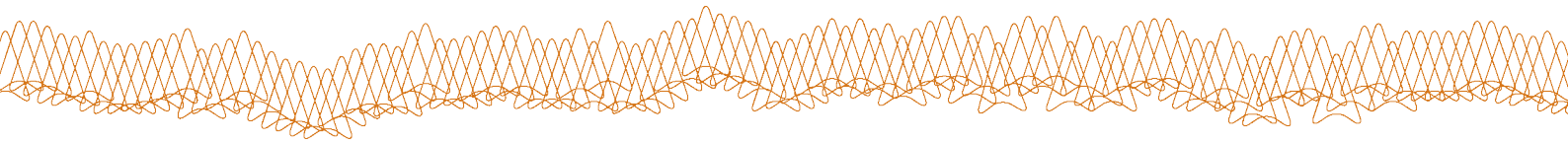
1.1 Rainfall as a proxy for growth events

From a biological perspective, sequences of daily rainfall can be treated as events, defined here as one or more closely spaced rainfalls which are large enough to produce a significant vegetation response – i.e. a substantial pulse of plant growth which produces forage for livestock (Noy-Meir 1973; Stafford Smith and Morton 1990; Ludwig et al. 1997; Stafford Smith and McAllister 2008). This translates, for example, into events of about 50 mm in a week in the Alice Springs region. Based on an event size of 50 mm or more, several events may occur within one year, but it is also possible for several years to pass without a larger event (Pickup and Stafford Smith 1993).

There are no definitive or established rules for estimating pasture growth from rainfall alone although, as described above, sophisticated pasture growth models such as GRASP can predict biomass production following variable amounts of rainfall at paddock scale for specified soil types. As a far simpler approach, the following analyses use threshold amounts of cumulative rainfall over successive days as a qualitative indicator of probable pasture growth. Timing of rainfall (i.e. seasonality), rainfall intensity, soil and vegetation type, soil moisture availability and land condition (particularly the amount of palatable perennial grasses) will all affect actual pasture response to rainfall. Thus the interpretations drawn from analysis of rainfall event-size should be used cautiously as part of NRM planning.

For this analysis, >10 mm, >25 mm and >50 mm of rain over consecutive days are treated as events of varying effectiveness. In central Australia, an event of 25 mm or more is probably marginal for effective growth, particularly in summer when evapotranspiration is high. For the same location, a >50 mm event should equate with ideal growing conditions, particularly where land is in good condition and perennial pasture plants can

¹ The Australian Grassland and Rangeland Assessment by Spatial Simulation (AussieGRASS) is a tool developed to monitor, at regional scale, key biophysical processes associated with pasture degradation and recovery. It also provides early warning of when and where regional livestock numbers may be out of balance with likely forage supply. Further information available at www.longpaddock.qld.gov.au/about/researchprojects/aussiegrass/index.html (accessed 23/4/2014).



readily respond to such rainfall. Contrasting with this, an event as small as 10 mm during the cooler winter months in the southern Rangelands (e.g. the Nullarbor), may allow for an effective vegetation response.

Yearly rainfall in the northern part of the Rangelands Cluster is concentrated in the summer months with the wet season arbitrarily defined as extending from mid October to mid April. Elsewhere, rainfall is generally aseasonal with pasture growth occurring throughout the year if/when sufficient rainfall is received (and presuming that frosts do not limit winter herbage growth).

2. Method

Daily rainfall data were accessed through SILO² for 36 recording stations throughout or close to the boundary of the cluster region (Figure 2.1). Data between 1950 and 2013 were imported to spreadsheets, and:

- the occurrence of continuous daily rainfalls exceeding 10 mm, 25 mm and 50 mm were identified (for northern stations, summer rainfall only and for mid-latitude stations, rainfall analysis included the continuous and wet-season records)
- for each rainfall threshold, the event date (last day of continuous rainfall), event size (mm rainfall) and number of wet days were summarised

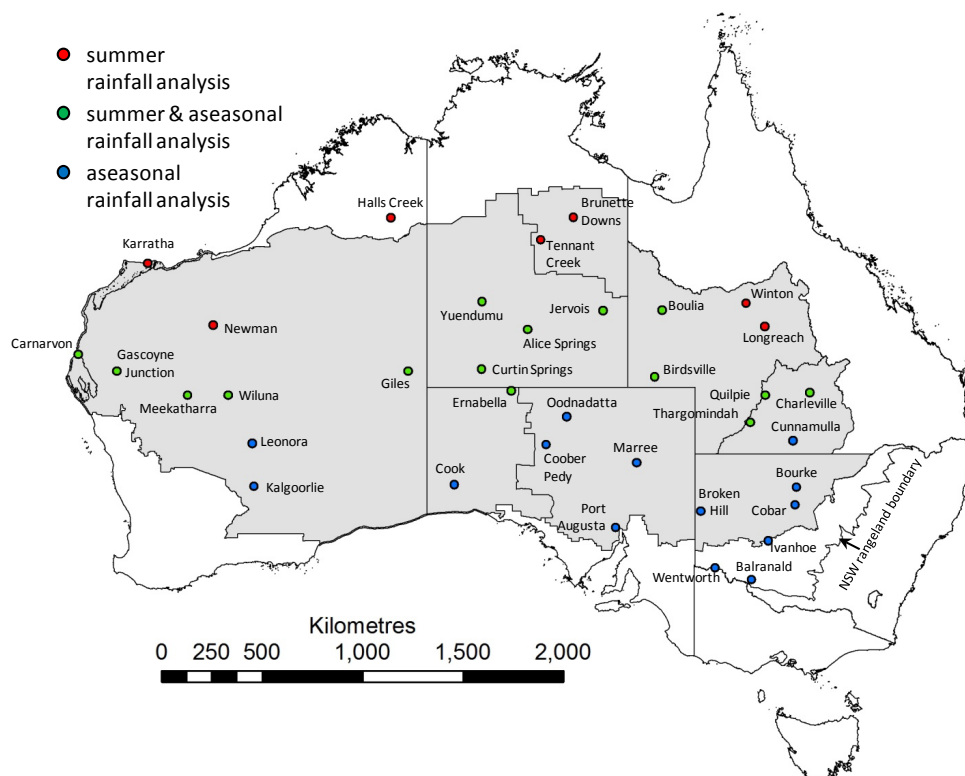
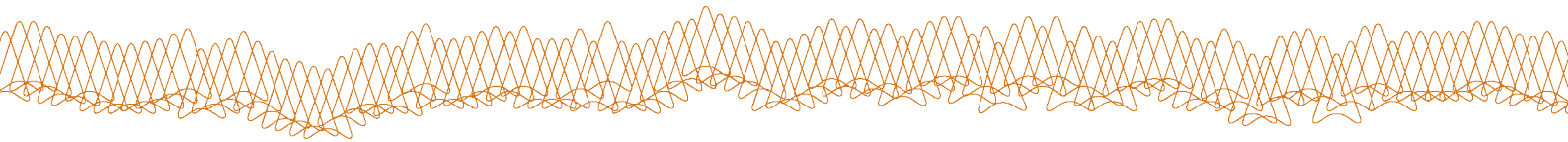


Figure 2.1 Recording stations in the Rangelands Cluster region used to analyse the return period of different-sized rainfall events

² <http://www.longpaddock.qld.gov.au/silo/ppd/index.php>, accessed 8 November 2013



- the return period, defined as the number of days from the end of one rainfall event to the start of the next, was also calculated and summarised (as the median number of days between events for each location and the frequency of events on a monthly basis).

Rainfall analysis for mid-latitude stations (green dots) used both wet-season (summer) rainfall and the continuous record.

3. Data source

SILO patched-point daily rainfall data are readily available for many locations in the Rangelands Cluster. Data files can be downloaded from the Longpaddock URL provided above in footnote 2 or from the Bureau of Meteorology (BoM) web site (www.bom.gov.au). Long-term (pre-1950) recording stations are generally more numerous in the pastorally occupied parts of the cluster region than in the deserts.

An Excel spreadsheet template³ accompanying this report provides for ready analysis of daily rainfall according to the specified event thresholds. A brief explanation is provided in the 'read me' worksheet of the template. For daily rainfall delivered using the 'rainfall' format through the Longpaddock URL in footnote 2, simply copy and paste rainfall values to the 'rf (mm)' column of the 'ex SILO' worksheet (date range 1/1/1889 to 7/11/2013). Summary statistics are automatically updated in the following event-threshold worksheets ('10 mm', '25 mm' and '50 mm').

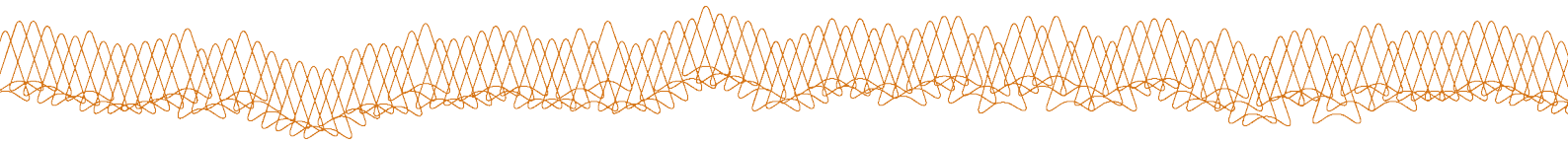
³

http://www.nintione.com.au/resource/AustralianRangelandsAndClimateChange_RainfallVariabilityPastureGrowth_RainfallTemplate.xlsx.

4. Caveats

Caveats and limitations associated with this analysis include:

1. The assumption that the specified rainfall threshold does actually indicate the described growth event for the location being considered. For example, 25 mm is a marginal growth event and 50 mm an ideal event for Alice Springs. Countering this limitation, many event sizes have exceeded the specified threshold (see following Figure 6.1 example for Alice Springs), thereby increasing the probability of the indicated effectiveness of the event.
2. Effective pasture growth is primarily interpreted with regard to the pastoral industry (i.e. probable forage availability for grazing). Analysis of historic rainfall for desert locations is included to increase geographic spread throughout the Rangelands Cluster. The value of threshold event sizes for promoting growth in spinifex communities and other desert vegetation is uncertain.
3. Land (or rangeland) condition is an important factor in how well vegetation responds to rainfall, particularly when events are small and well separated in time. For example, events of 50 mm or more in central Australia will promote a much larger growth of forage where perennial grasses are present than where grass and herbage species have to germinate and grow from a bare-ground situation.
4. Season and associated temperature effects are ignored in this analysis. Growth response may be limited by cooler winter temperatures in the southern and central parts of the cluster region, but evapotranspiration will also be lower providing a longer period of soil moisture availability. Temperature is not a major limitation for plant growth in the warmer months and evapotranspiration is increased. C₃ plants grow more rapidly in the cool months at the start of the growing season, while growth of C₄ plants (such as tropical grasses) peaks later in the warmer parts of the season.



5. Each event is defined by continuous daily rainfall. This means that one or more dry days in an otherwise wet period ends the initial event and may lead to a subsequent event close in time. This may overstate the number (and frequency) of events, reduce the event size and shorten the return period between events compared with a more flexible approach to defining events (e.g. allowing one or more dry days during an extended wet period). This bias is likely to be more common in wetter years and is not considered a major limitation to interpreting the following results.
6. Rainfall analysis is based on the period 1/1/1950 to 30/04/2013. More recent rainfall analysis requires that formulas in the template spreadsheet are varied accordingly. This requires copying column formulas down for additional rows (in each event-size worksheet) and extending the relevant array sizes for summary statistics (again, each event-size worksheet).

5. Findings

5.1 Analysis of Alice Springs rainfall

We use the Alice Springs rainfall record to illustrate comprehensive summary statistics for various-sized rainfall events. A subset of these statistics is summarised for all locations within the Rangelands Cluster in the following section with further summary data tabulated in Appendix A, Tables A1 and A2.

5.1.1 Event size and duration

The duration of rainfall events increased as event size increased (Table 5.1). The 10th and 90th percentiles of each parameter were correspondingly related.

There were 443 separate events for the 10 mm threshold, 182 events for the 25 mm threshold and 69 events greater than 50 mm during the 63-year period.

Approximately 70% of events exceeded 60 mm (and extended over three or more days) for the 50 mm event-threshold (Figure 5.1).

There was no consistent decadal pattern in the number of 25 mm or 50 mm events (Figure 5.2); basically, the 1970s was a wetter period, and the 1950s, 1960s and 1990s had a reduced number of 50 mm events.

Table 5.1 Summary statistics for event size (mm rainfall) and length (days) for various thresholds of continuous daily Alice Springs rainfall, 1950–2012

PARAMETER	EVENT SIZE (THRESHOLD)								
	10 mm			25 mm			50 mm		
	10%	median	90%	10%	median	90%	10%	median	90%
Rainfall (mm)	11.4	21.4	63.4	27.0	42.8	113.6	53.4	81.6	200.5
Rain days	1	3	5	2	3	6	2	4	7

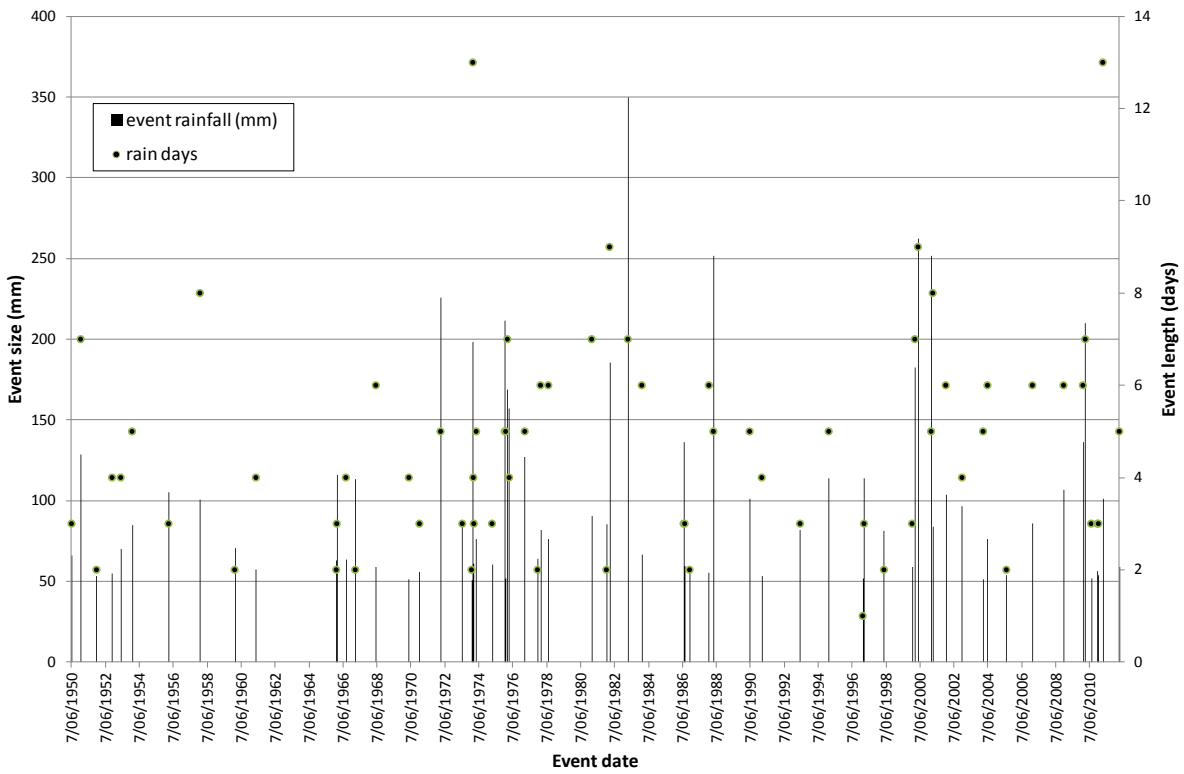


Figure 5.1 Timing, size and length of Alice Springs rainfall events between 1950 and 2012 that comprised more than 50 mm of continuous daily rainfall

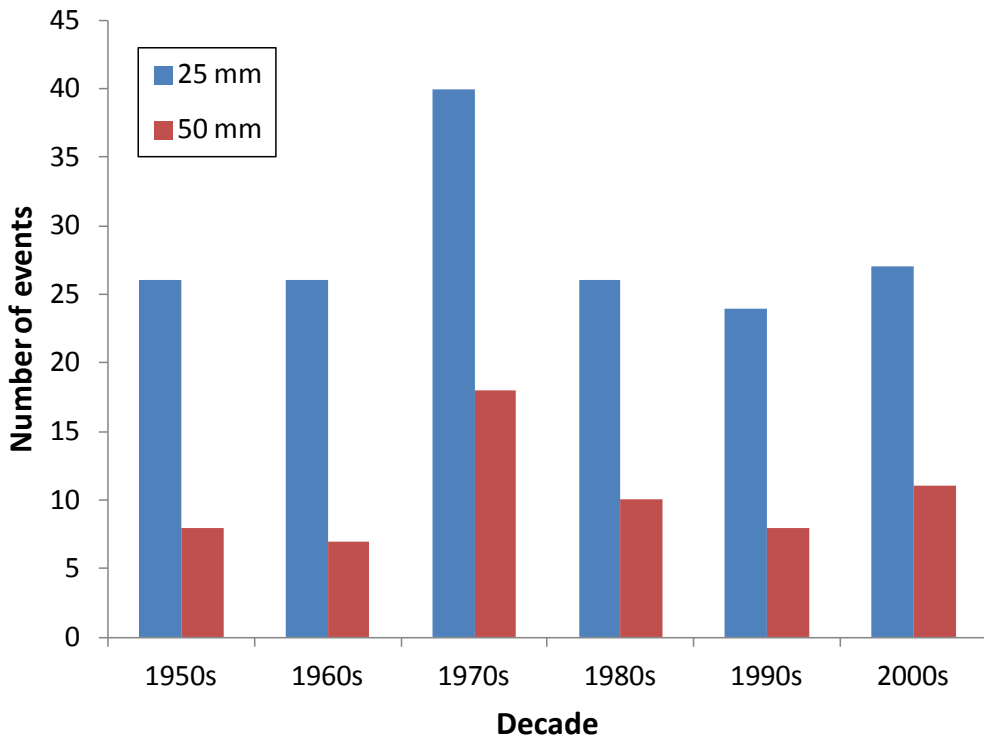
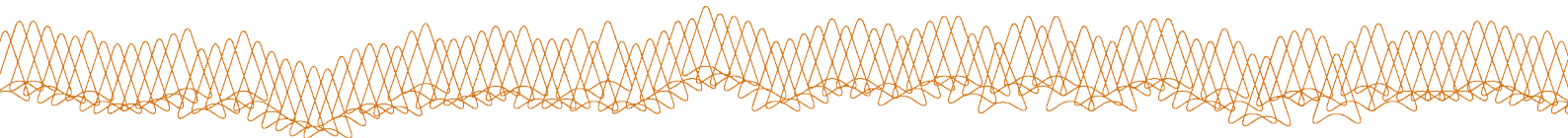


Figure 5.2 Decadal occurrence of >25 mm and >50 mm rainfall events for Alice Springs



5.2 Return period of events

Based on the requirement for continuous daily rainfall, 25 mm rainfall events were separated by a median return period of 82 days (Table 5.2). This increased to 272 days for 50 mm events. Significantly, 33 of the 63 calendar years between 1950 and 2012 did not have a 50 mm event.

Table 5.2 Median return period (days) for continuous daily rainfall events of varying size at Alice Springs

PARAMETER	MEDIAN RETURN PERIOD (DAYS) FOR EVENT SIZE OF:		
	10 mm	25 mm	50 mm
Continuous rainfall record 1950 to 2012	28	82	272
Wet season rainfall 1950–51 to 2012–13	25	40	60
Number of calendar years without an event	2	11	24
Number of wet seasons without an event	1	10	25

Return periods are based on the continuous rainfall record and summer (wet season) rainfall. The number of calendar years and wet seasons missing an event between 1950–51 and 2012–13 is also listed.

The return period for 25 mm and 50 mm events shortens to 40 and 60 days respectively for summer rainfall (mid-October to mid-April). Of the 63 wet seasons between 1950–51 and 2012–13, 10 failed to have a 25 mm event and 25 missed a 50 mm event.

As described above, there were 182 events of 25 mm (or more) rainfall over continuously wet days between 1950 and 2012. Fifty-eight of these events were separated by less than a month (Figure 5.3, left-hand graph) with these more frequent occurrences associated with sequences of wetter years. The frequency of >25 mm events progressively decreased as the separation between events increased, with 11 events being separated by more than a year. This progressive separation of marginal growth events was associated with individual dry years and runs of drier years (i.e. drought).

Corresponding frequencies for a 50 mm (or more) event were lower (Figure 5.3, right-hand graph). There were 69 events for the 63-year record; 17 of these were separated by one to two months (most commonly in 1974 and 2010, particularly wet years) and 24 by more than one year.

Truncating the rainfall record to wet-season rainfall generated 179 events of >25 mm rainfall (96 events of >50 mm). Most of the smaller events were separated by

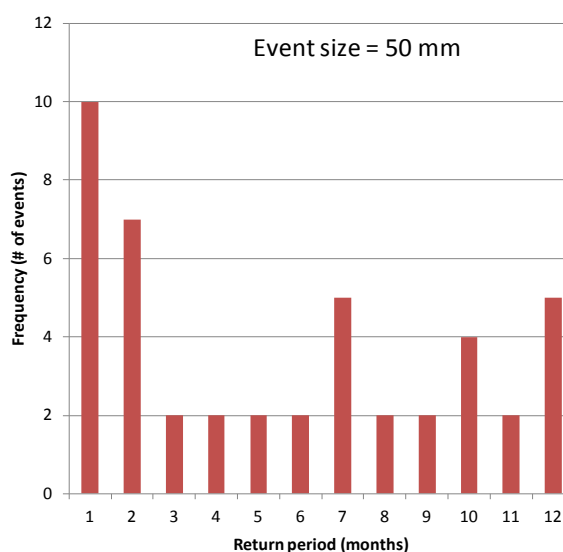
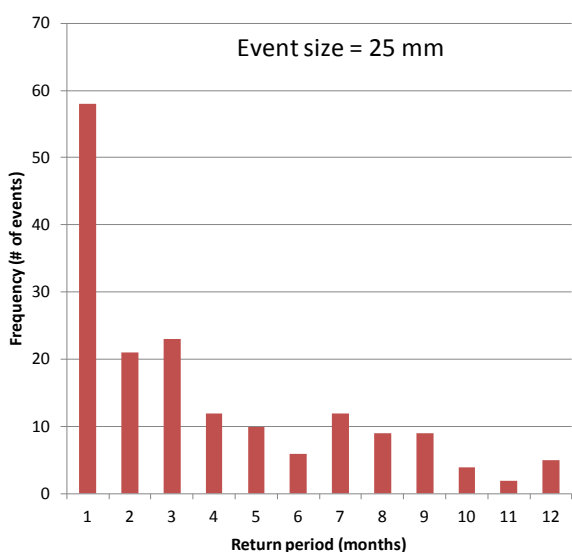
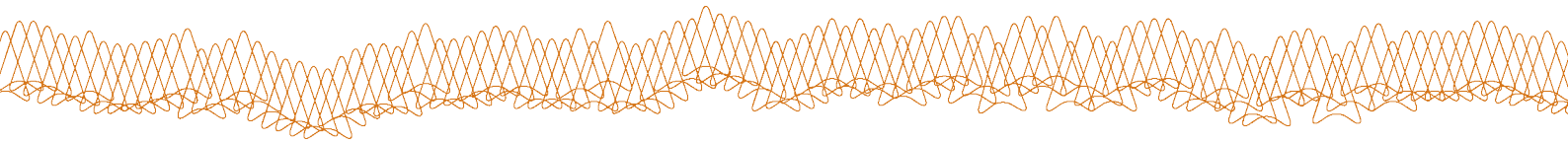


Figure 5.3 Frequency of return periods (months) for 25 and 50 mm rainfall events based on Alice Springs rainfall



less than a month within each wet season, with ~85% of events being separated by three or less months. Most of the >50 mm events were separated by two months within each wet season, and 70% of all events within each wet season occurred within three months of each other.

These results illustrate that probable marginal and ideal growing conditions (based on receiving either >25 mm or >50 mm rainfall over consecutive rainy days) are infrequent and widely separated in time for Alice Springs. This simple analysis is embedded within cycles of wetter and drier sequences that are separated by ten or more years (Figure 5.4).

Since 1950, the median return period for marginal and ideal growth events (i.e. >25 mm and >50 mm respectively) was shorter during the summer months but was still of the order of 1.5 to 2 months. Significantly also, ten years (16% of occurrences) did not experience even a marginal growth event over this period.

The take-home message is that, for Alice Springs, rainfall events sufficient for marginal and better pasture growth is infrequent and generally widely separated in time. This situation is unlikely to change under climate change predictions of continued high natural variability.

The frequency and median return periods of probable marginal and ideal growth events are embedded within considerable year-to-year rainfall variability.

5.3 Regional analysis of rainfall

The median return period of >25 and >50 mm events plus the number of calendar years (or wet seasons) without either event are mapped in Figures 5.5 and 5.6, and summarised in Tables 5.3–5.10 (arranged by location within NRM region). Wet-season data are presented for those stations having distinct dominance of summer rainfall (red dots in Figure 2.1). Data for all other stations are based on the continuous rainfall record.

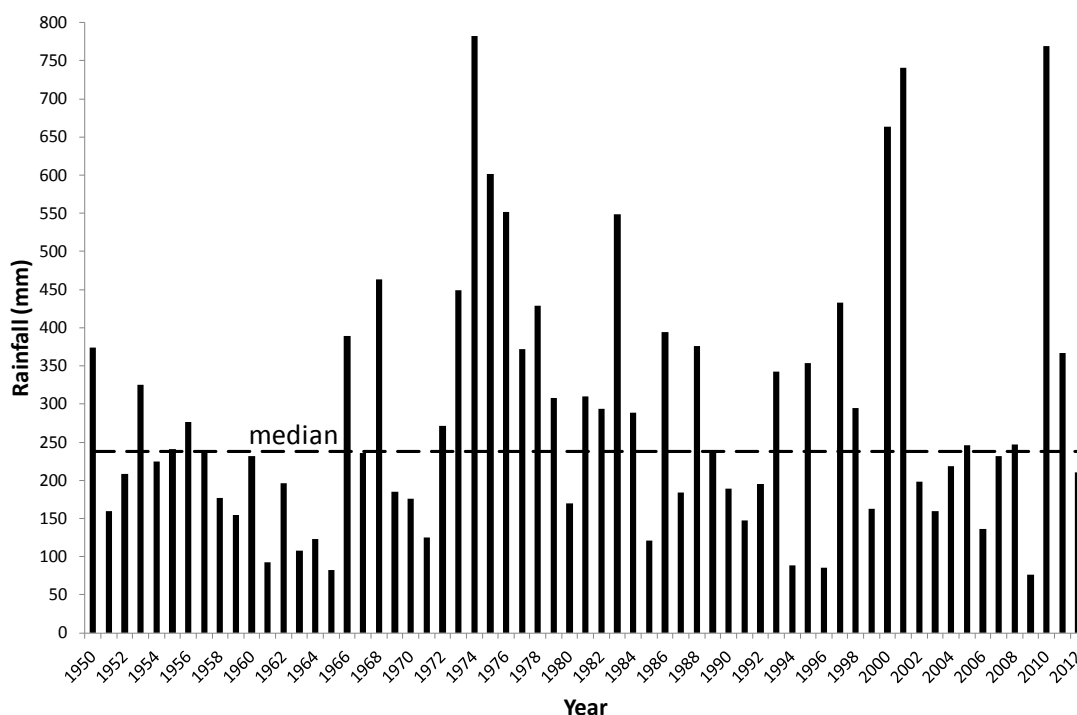
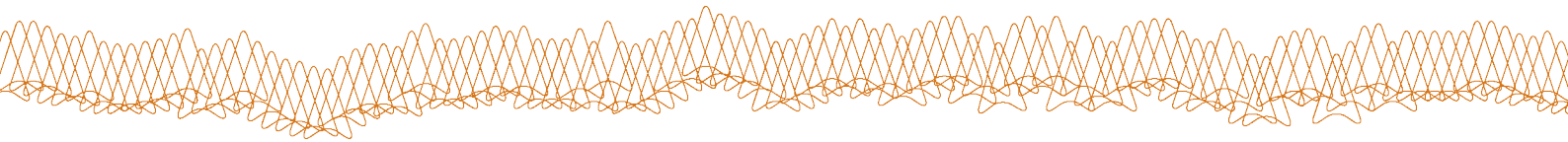
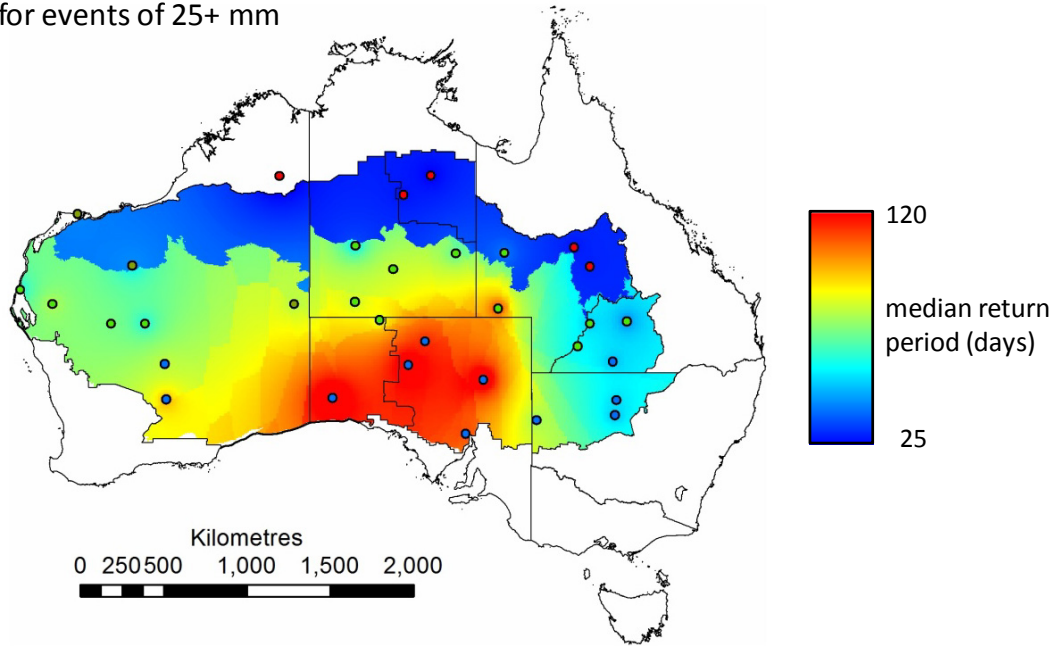


Figure 5.4 Yearly and median rainfall for Alice Springs between 1950 and 2012



Median return period (days)
for events of 25+ mm



Percent of years (or wet seasons) missing
a 25 mm event between 1950 and 2012

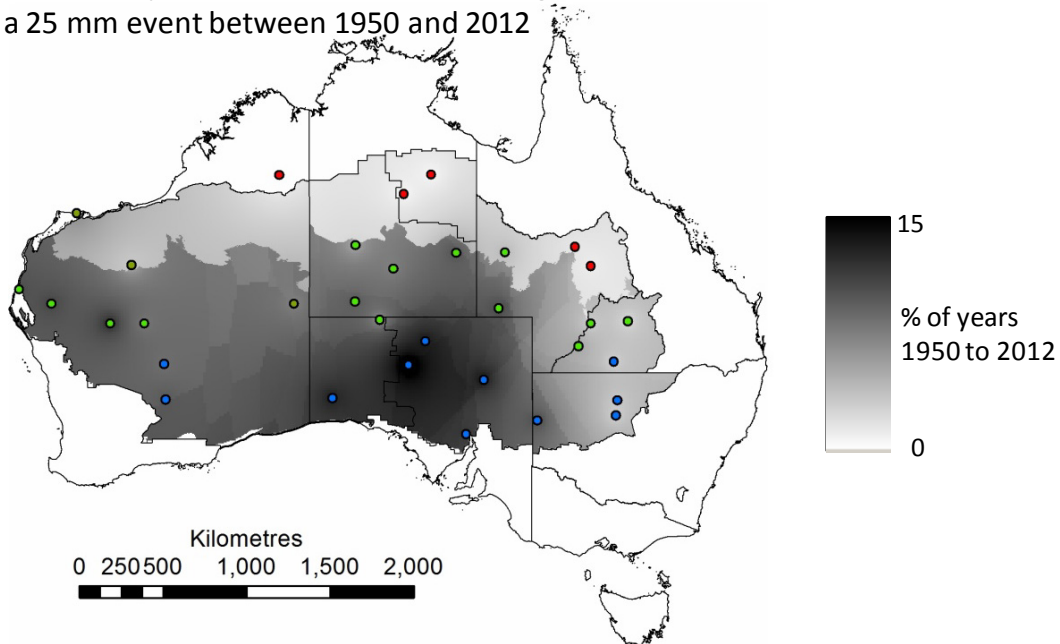
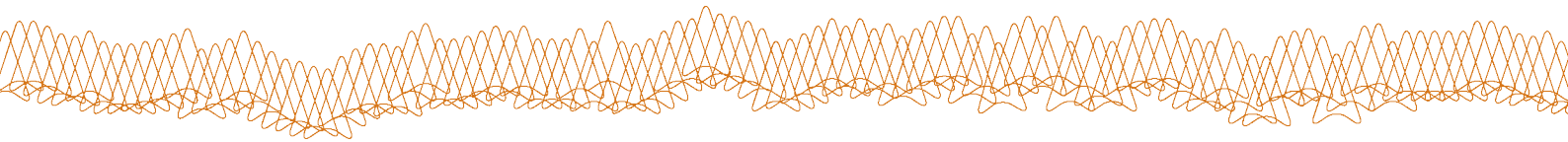
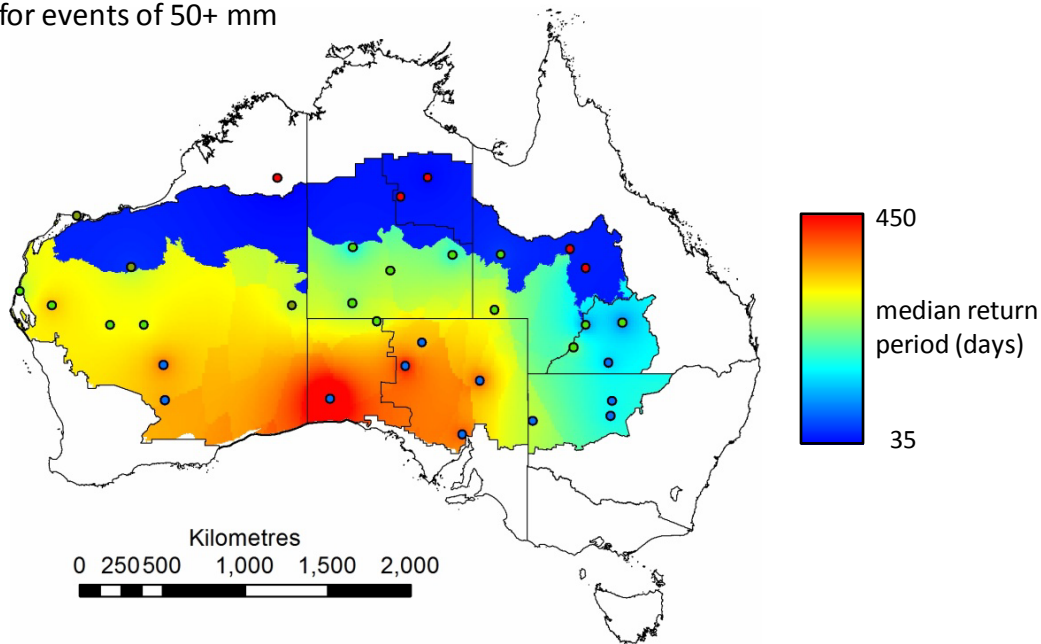


Figure 5.5 Top: interpolated median return period of >25 mm rainfall events over continuously wet days based on the continuous rainfall record 1950–2012 or summer (wet season) rainfall for the northern part of the Rangelands Cluster; Bottom: percentage of years 1950–2012 not having a >25 mm event in the calendar year (or summer wet season for the northern part of the Rangelands Cluster region)



Median return period (days)
for events of 50+ mm



Percent of years (or wet seasons) missing
a 50 mm event between 1950 and 2012

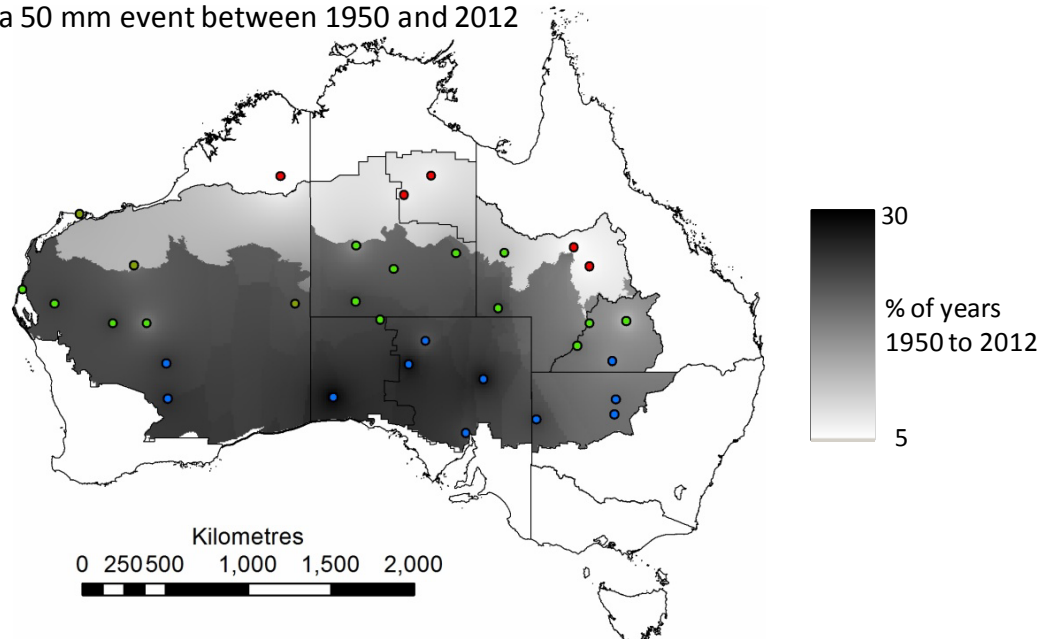
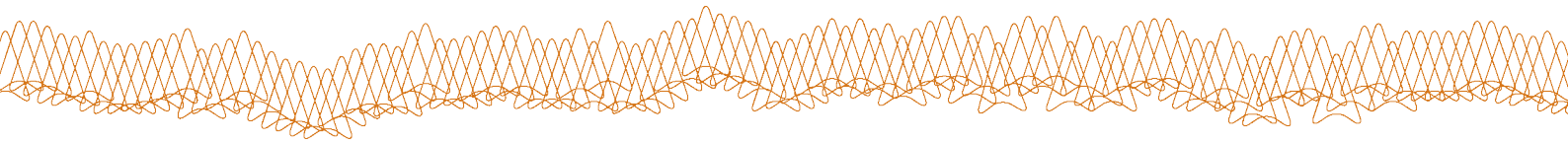


Figure 5.6 Top: interpolated median return period of >50 mm rainfall events over continuously wet days based on the continuous rainfall record 1950–2012 or summer (wet season) rainfall for the northern part of the Rangelands Cluster; Bottom: percentage of years 1950–2012 not having a >50 mm event in the calendar year (or summer wet season for the northern part of the Rangelands Cluster region)



The maps were produced using linear distance-weighted interpolations of the values for locations listed in Tables 5.3–5.10. These maps are intended as a pictorial guide only; that is, interpolated values indicate possible (not actual) values between stations. Interpolated values should be used cautiously for downscaling to parts of NRM regions.

The maps and following tables show that:

- The median return period lengthens for locations with lower and more variable annual rainfall, that is, to the south (Port Augusta, Cook, Kalgoorlie) and towards the more arid interior (Coober Pedy, Marree, Birdsville, Oodnadatta).
- The median return period for >50 mm events in parts of the arid zone is extreme: ~1 year or more for Cook, Coober Pedy, Marree, Oodnadatta, Port Augusta, Leonora, Gascoyne Junction and

Kalgoorlie, and >200 days for 13 other locations, including Alice Springs. Some of these recording stations are outside the pastoral zone and thus of reduced value for indicating the frequency of probable pasture growth events.

- Lower evapotranspiration in southern Australia may mean that continuous daily rainfalls of >25 mm produce more forage than in northern and central Australia. This is particularly the case on the Nullarbor where cool rainy periods occur in winter, and here cumulative wet periods of >10 mm may promote pasture growth.
- Generally, however, the last 60+ years of rainfall data show that periods of rainfall suitable for marginal to ideal pasture growth conditions are infrequent throughout much of the Rangelands Cluster region.

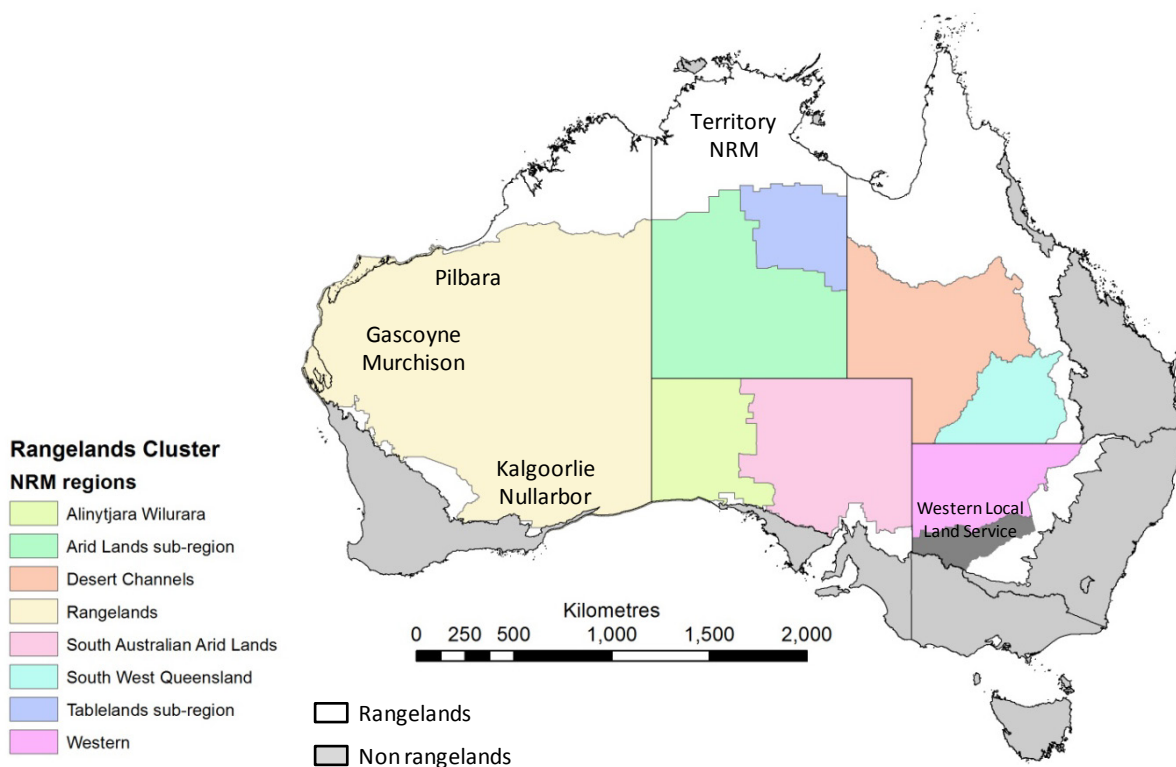
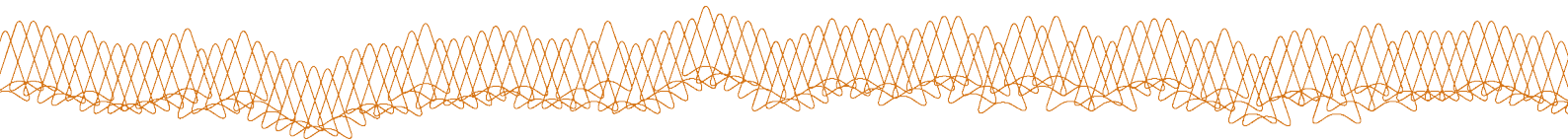


Figure 5.7 NRM regions in the Rangelands Cluster

Also shown is the Rangelands boundary as defined by the Australian Collaborative Rangelands Information System, the current Western Local Land Service in NSW and the extent of Territory NRM in the NT.



- These probabilities are unlikely to improve under forecast continuing rainfall variability. A continuing cautious approach to stocking levels, strict control of total grazing pressure and drought preparedness are required into the future.

The frequency of monthly return periods for recording stations and type of analysis is summarised in Appendix A. These data are similar to those described for Alice Springs in Figure 5.3 and essentially indicate the likely frequency of marginal and ideal growing conditions throughout the year (or summer wet season for northern locations).

As for Alice Springs, both >25 and >50 mm events were more common in wetter years for most recording stations (i.e. higher frequencies for the one- and two-month separations).

5.3.1 NSW: Western Local Land Service region (includes former Western CMA)

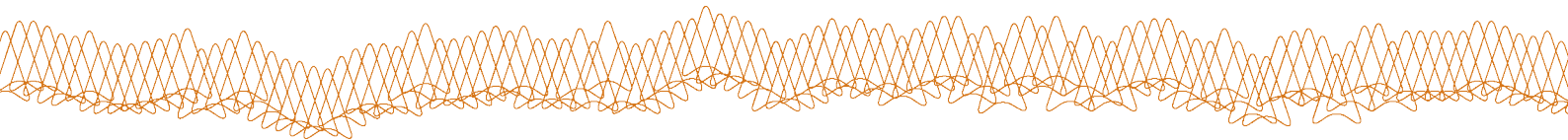
Analysis of the continuous rainfall record, 1950–2012, is shown in Table 5.3 (see Figure 5.7 above for the location of NRM regions).

Comments:

- Bourke rainfall is indicative of the Mulga Lands bioregion where a >50 mm event is probably required to initiate worthwhile pasture growth, although >25 mm events in the cooler winter months should promote useful herbage growth.
- The Cobar rainfall is relevant to the Cobar Peneplain where, due to invasive native scrub and general land degradation, >50 mm of rainfall is probably required to promote useful pasture growth, with 25 mm or more being valuable in the cooler months.
- Broken Hill rainfall is representative of the Broken Hill Complex bioregion, where a >25 mm event should encourage new leaf growth on chenopod shrubs, and >50 mm provides an ideal pasture growth event.
- The Ivanhoe, Balranald and Wentworth rainfall figures provide a regional spread through the Murray–Darling Depression bioregion (mixed woodlands, mallee and chenopod shrublands) where >25 mm of rain should promote pasture growth on sandy soils and freshen chenopods. Larger rainfall events (i.e. >50 mm) are ideal for worthwhile pasture growth. In winter, smaller falls (10 mm or more) should also encourage pasture growth.
- The Balranald rainfall is also representative of the western Riverina where >25 mm is useful, and lesser amounts in winter (10 mm or more) may result in a limited response by perennial chenopods and other herbage species.

Table 5.3 Median event size (mm), return period (days) between continuous daily rainfall events exceeding 10, 25 or 50 mm and number of years without an event during the 1950–2012 period for locations in the NSW Western Local Land Service region.

LOCATION	EVENT SIZE THRESHOLD (MM)			RETURN PERIOD (DAYS)			NO. YEARS WITHOUT EVENT		
	10 mm	25 mm	50 mm	10 mm	25 mm	50 mm	10 mm	25 mm	50 mm
Balranald	19.0	36.6	68.2	18	54	296	0	4	42
Bourke	22.1	38.8	72.1	20	50	171	0	4	31
Broken Hill	19.6	37.7	66.8	29	74	287	0	18	40
Cobar	21.6	38.5	66.7	18	44	166	0	3	31
Ivanhoe	19.0	36.9	67.1	21	61	282	0	8	43
Wentworth	18.0	35.2	64.8	26	104	379	0	15	46



5.3.2 Queensland: South West NRM

Analysis of the continuous rainfall record, 1950–2012, for four locations is presented in Table 5.4.

Comments:

- The Mulga Lands is the most extensive bioregion in this NRM region, and Charleville, Cunnamulla and Quilpie provide a good geographic spread of rainfall stations through this broad land type. Woody density has thickened across much of the bioregion, and a long history of heavy grazing by livestock, kangaroos and goats has also degraded pastures. Rainfall events of >50 mm are probably required to promote effective pasture growth, although >25 mm in the cooler months should also produce a growth response.

Thargomindah is near the boundary of the Mulga Lands and Channel Country (and also close to the neighbouring Desert Channels NRM region). Rainfall events of 50 mm or more are probably required to produce good pasture growth, and >25 mm events will provide a lesser response.

5.3.3 Queensland: Desert Channels

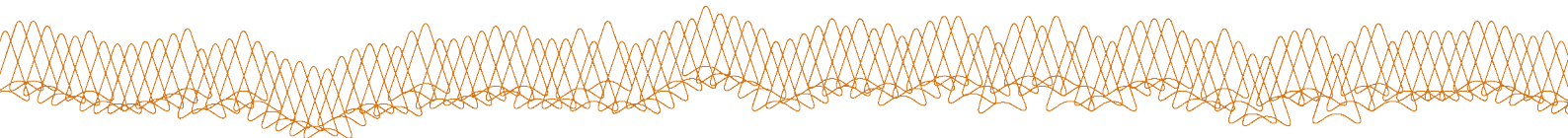
Analysis of the continuous rainfall record, 1950–2012, and summer period (1950–51 to 2012–13) for Longreach and Winton is shown in Table 5.5.

Comments:

- Boulia, Longreach and Winton provide a geographic spread of rainfall pattern through the Mitchell Grass Downs bioregion. Restricting rainfall analysis to the summer months (wet season) shortens the return interval on >25 and >50 mm events. The high evapotranspiration rates associated with this grassland region mean that >50 mm events are required to initiate significant pasture growth. Smaller events of 25 mm or more will then prolong the growing season and may promote a limited herbage response in the cooler months (normally, the dry season).
- Birdsville, at the western edge of the Channel Country and close to the Simpson Desert, is a truly arid location with almost a year (median interval) separating significant pasture growth events (i.e. >50 mm) and 62% of the years between 1950 and 2012 not experiencing one of these larger rainfall events. Substantial herbage growth does of course result from widespread flooding following good rains in the catchment of the desert channels. Smaller rainfall events (>25 mm) will promote forage growth on sandy country and in the gilgais and watercourses of the stony Channel Country as a result of run-on from adjacent slightly higher areas.

Table 5.4 Median event size (mm), return period (days) between continuous daily rainfall events exceeding 10, 25 or 50 mm and number of years without an event during the 1950–2012 period for locations in the South West NRM region.

LOCATION	EVENT SIZE THRESHOLD (MM)			RETURN PERIOD (DAYS)			NO. YEARS WITHOUT EVENT		
	10 mm	25 mm	50 mm	10 mm	25 mm	50 mm	10 mm	25 mm	50 mm
Cunnamulla	23.5	40.1	76.8	20	45	128	0	3	24
Charleville	24.1	44.0	68.4	15	35	73	0	2	13
Quilpie	22.8	43.3	70.4	22	47	70	0	3	24
Thargomindah	22.6	39.1	75.4	26	54	275	0	9	33



5.3.4 South Australia: Arid Lands

Analysis of the continuous rainfall record, 1950–2012, is listed in Table 5.6.

Comments:

- Coober Pedy, Marree and Oodnadatta are located in the extensive Stony Plains bioregion, with the Simpson and Strzelecki Deserts situated to the east and north of the Stony Plains. Medium-sized rainfall events (>25 mm) should promote a reasonable pasture response in both broad land types with growth in the Stony Plains resulting from run-on to gilgais, drainage lines and watercourses. The larger events (>50 mm) will enhance this response, but Table 5.6 demonstrates that these good rainfalls are rare in this arid part of Australia.

- Port Augusta is at the edge of the Gawler bioregion and adjacent to the Flinders Ranges, and summary statistics from analysis of its rainfall may have some indicator value for both pastoral regions. For land in good condition, >25 mm events should generate worthwhile pasture growth, with >10 mm events being of some value on sandy country and in the cooler winter months. Larger (>50 mm) events are rare and provide a bonus for forage growth when received.

Table 5.5 Median event size (mm), return period (days) between continuous daily rainfall events exceeding 10, 25 or 50 mm and number of years without an event during the 1950–2012 period for locations in the Desert Channels NRM region.

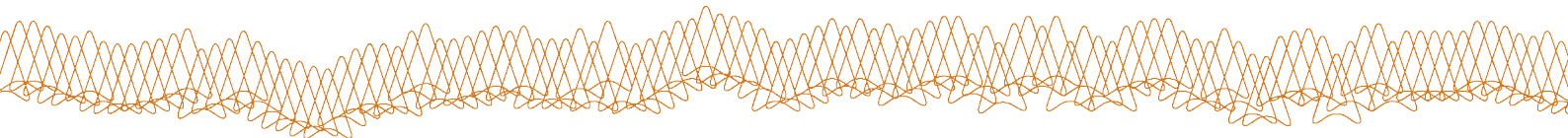
LOCATION	EVENT SIZE THRESHOLD (MM)			RETURN PERIOD (DAYS)			NO. YEARS WITHOUT EVENT		
	10 mm	25 mm	50 mm	10 mm	25 mm	50 mm	10 mm	25 mm	50 mm
Birdsville	21.9	40.5	68.5	46	123	331	3	18	39
Boulia	23.3	43.0	74.1	27	63	281	0	9	31
Longreach	25.6	44.5	77.9	18	36	70	0	2	12
Winton	24.4	49.8	82.3	17	32	87	1	6	14

Based on analysis of wet-season rainfall (i.e. mid-October to mid-April)

LOCATION	MEDIAN RETURN PERIOD FOR EVENT SIZE		NO. YEARS WITHOUT EVENT	
	25 mm	50 mm	25 mm	50 mm
Longreach	29	53	1	7
Winton	27	56	2	6

Table 5.6 Median event size (mm), return period (days) between continuous daily rainfall events exceeding 10, 25 or 50 mm and number of years without an event during the 1950–2012 period for locations in the SA Arid Lands NRM region.

LOCATION	EVENT SIZE THRESHOLD (MM)			RETURN PERIOD (DAYS)			NO. YEARS WITHOUT EVENT		
	10 mm	25 mm	50 mm	10 mm	25 mm	50 mm	10 mm	25 mm	50 mm
Coober Pedy	17.1	36.7	72.6	44	152	499	6	33	50
Marree	18.8	37.3	70.9	45	158	443	9	24	49
Oodnadatta	20.5	38.4	69.3	46	119	344	1	23	31
Port Augusta	17.3	35.3	59.0	31	113	422	0	19	36



5.3.5 South Australia: Alinytjara Wilurara

Analysis of the continuous rainfall record, 1950–2012, is presented in Table 5.7.

Comments:

- The Ernabella rainfall summary has some indicator value for likely forage availability and security for small-scale cattle enterprises on Aboriginal country in the far north of the region. Where land can be maintained in good condition, >25 mm events should produce a limited growth response and >50 mm events an ideal response. However, these larger events are infrequent, and 60% of years since 1950 (to 2012) failed to receive such rainfall.
- Cook, on the Transcontinental Railway, is in the Nullarbor region where large rainfall events are very rare (median return period of almost two years for >50 mm events and 80% of recent years not experiencing such an event). The vegetation has obviously adapted to persist under such low rainfall, and cool moist days in winter (e.g. >10 mm of rainfall) can apparently produce useful new leaf growth on chenopod shrubs. Medium-sized events (>25 mm) will likely produce a herbage response by annual species, particularly in the cooler months.

5.3.6 Northern Territory: Arid Lands sub-region

Analysis of the continuous rainfall record, 1950–2012, is listed in Table 5.8.

Comments:

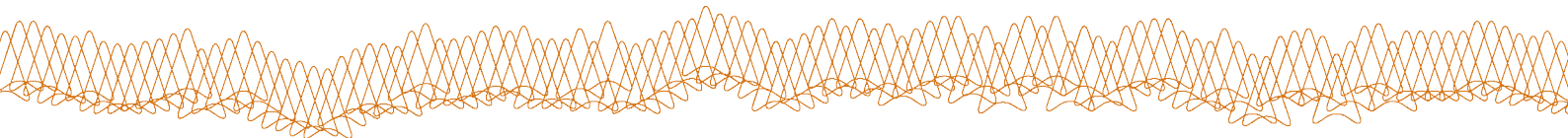
- Alice Springs, Yuendumu and Jervois rainfall summaries have some indicator value for the Burt Plain pastoral bioregion (although Jervois is actually in the far western part of the Channel Country bioregion). Alice Springs is also relevant to the MacDonnell Ranges and northern Finke bioregions. Where pastoral land is in good condition, 25 mm events constitute a marginal growth event, and >50 mm should provide for ideal growing conditions. Water redistribution (i.e. run-on to lower slopes and watercourses) is particularly important for promoting growth beyond actual rainfall received. The smaller events (~25 mm) will encourage greater herbage and grass response on sandy soils and in the cooler months.
- Similar comments apply to the Curtin Springs rainfall history (western part of the Finke bioregion), but the medium-sized events (i.e. 25 mm) may promote greater pasture growth because there is an increased probability of receiving such rainfall in the

Table 5.7 Median event size (mm), return period (days) between continuous daily rainfall events exceeding 10, 25 or 50 mm and number of years without an event during the 1950–2012 period for locations in the Alinytjara Wilurara NRM region.

LOCATION	EVENT SIZE THRESHOLD (MM)			RETURN PERIOD (DAYS)			NO. YEARS WITHOUT EVENT		
	10 mm	25 mm	50 mm	10 mm	25 mm	50 mm	10 mm	25 mm	50 mm
Cook	17.3	35.2	65.6	40	155	711	1	22	50
Ernabella	21.6	38.1	75.9	25	80	278	0	8	38

Table 5.8 Median event size (mm), return period (days) between continuous daily rainfall events exceeding 10, 25 or 50 mm and number of years without an event during the 1950–2012 period for locations in the NT Arid Lands NRM sub-region.

LOCATION	EVENT SIZE THRESHOLD (MM)			RETURN PERIOD (DAYS)			NO. YEARS WITHOUT EVENT		
	10 mm	25 mm	50 mm	10 mm	25 mm	50 mm	10 mm	25 mm	50 mm
Alice Springs	21.4	42.8	81.6	28	82	272	2	11	33
Curtin Springs	21.0	40.2	75.3	29	77	222	0	16	39
Jervois	23.1	43.0	80.7	30	62	160	2	17	33
Yuendumu	22.8	44.9	83.1	20	43	130	0	6	21



cooler months of the year when evaporation is reduced.

5.3.7 Northern Territory: Tablelands sub-region

Analysis of both annual rainfall (1950–2012) and wet-season rainfall (1950–51 to 2012–13) is shown in Table 5.9.

Comments:

- Brunette Downs rainfall data are relevant to the extensive Mitchell Grass Downs on the Barkly Tableland, where >50 mm rainfall events are probably required to initiate substantial pasture growth in the wet season, and follow-up medium-sized events (~25 mm) extend the growing season.
- Tennant Creek rainfall data apply to the less pastorally productive Davenport Murchison Ranges bioregion where, again, >50 mm events are required for worthwhile pasture growth but >25 mm events may have some value with moisture redistribution (runoff and run-on) associated with the greater relief of the more useful grazing country in this bioregion.

For both locations, excluding the cooler (normally dry season) months from analysis shortens the median return period for larger events and reduces the number of years (wet seasons) failing to record such an event.

5.3.8 Western Australia: Rangelands

Analysis of the continuous rainfall record, 1950–2012, for all locations and wet-season rainfall (1950–51 to 2012–13) for northern recording stations is listed in Table 5.10.

Comments:

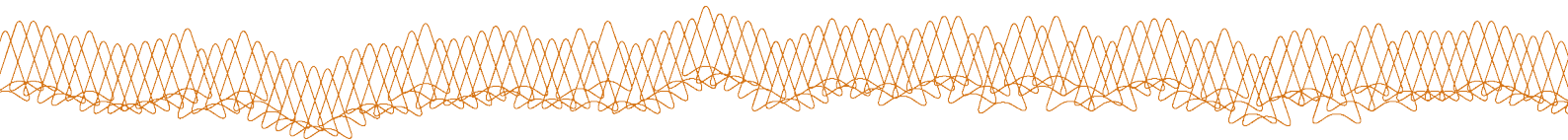
- The Leonora, Meekatharra and Wiluna rainfall data apply to the Murchison bioregion, an extensive area of mainly low mulga woodlands. It is likely that rainfall events of 25 mm or more should initiate some pasture response where grazing land is in satisfactory condition, particularly in the cooler months when evaporation is reduced. Larger (>50 mm) events will be more beneficial but, as for most of the arid rangelands, these larger rainfall pulses are infrequent with a median return period greater than nine months and almost two-thirds of years between 1950 and 2012 missing such an event.
- Kalgoorlie is on the boundary between the Murchison and Coolgardie bioregions, the latter comprising perennial chenopods where palatable species provide an important forage source for sheep (less so for cattle). Again, >25 mm rainfall events should be valuable where land is in better condition, with this value enhanced by a greater probability of rainfall occurring in the cooler months. Extending into the Nullarbor bioregion to the east, lesser rains (even 10 mm or more over

Table 5.9 Median event size (mm), return period (days) between continuous daily rainfall events exceeding 10, 25 or 50 mm and number of years without an event during the 1950–2012 period for locations in the NT Tablelands NRM sub-region.

LOCATION	EVENT SIZE THRESHOLD (MM)			RETURN PERIOD (DAYS)			NO. YEARS WITHOUT EVENT		
	10 mm	25 mm	50 mm	10 mm	25 mm	50 mm	10 mm	25 mm	50 mm
Brunette Downs	28.2	51.9	76.2	13	20	38	0	2	12
Tennant Creek	25.6	48.5	92.3	15	25	64	0	1	20

Based on analysis of wet-season rainfall (i.e. mid-October to mid-April)

LOCATION	MEDIAN RETURN PERIOD FOR EVENT SIZE		NO. YEARS WITHOUT EVENT	
	25 mm	50 mm	25 mm	50 mm
Brunette Downs	23	36	0	9
Tennant Creek	27	47	0	9



several days during winter) have increasing value for forage growth (see comments above with regard to rainfall statistics for Cook in the Alinytjara Wilurara region).

- The Carnarvon and Gascoyne Junction rainfall summaries are relevant to the Carnarvon bioregion, another pastoral region of mainly acacia or chenopod shrublands. Similar comments describing the Murchison bioregion apply: >25 mm rainfall events are useful, particularly as significant rainfall is received in the cooler months, and larger events approaching 50 mm are particularly beneficial. Again, however, larger amounts of extended rainfall are rare in this region (median return period approaching one year).
- It is probable that relatively large (>50 mm) rainfall events are required to initiate significant pasture growth in the Pilbara (Newman and Karratha rainfall

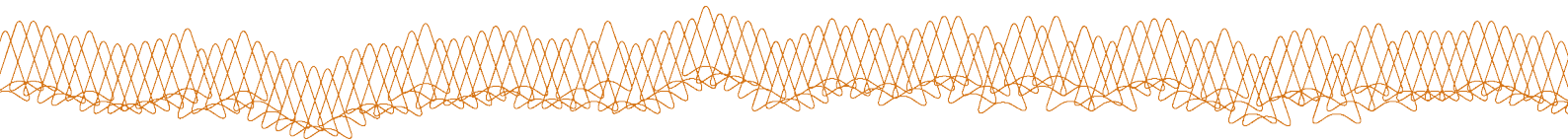
records) with smaller events (>25 mm) extending the growing season if received within sufficient time to maintain adequate soil moisture for plant growth. The topography of the region has a mediating effect on rainfall received through localised redistribution (i.e. runoff and run-on). Rainfall effectiveness is also limited by generally high evapotranspiration rates, although its effect on resultant pasture growth is countered by the C₄ photosynthetic pathway of much of the herbage layer.

Table 5.10 Median event size (mm), return period (days) between continuous daily rainfall events exceeding 10, 25 or 50 mm and number of years without an event during the 1950–2012 period for locations in the southern WA Rangelands NRM sub-region.

LOCATION	EVENT SIZE THRESHOLD (MM)			RETURN PERIOD (DAYS)			NO. YEARS WITHOUT EVENT		
	10 mm	25 mm	50 mm	10 mm	25 mm	50 mm	10 mm	25 mm	50 mm
Carnarvon	22.4	41.6	71.2	23	56	255	1	17	37
Gascoyne Junction	19.8	38.8	68.2	26	82	364	1	18	39
Giles	20.9	41.8	76.8	26	77	266	1	11	35
Halls Creek	26.6	45.6	87.1	8	14	38	0	0	9
Kalgoorlie	19.0	36.4	63.5	31	104	366	0	16	42
Karratha	28.1	53.0	86.0	22	49	117	3	8	21
Leonora	20.0	37.3	64.6	31	82	410	0	13	41
Meekatharra	20.0	45.0	68.6	29	72	305	0	22	40
Newman	22.2	44.2	75.9	21	50	246	0	6	28

Based on analysis of wet-season rainfall (i.e. mid-October to mid-April)

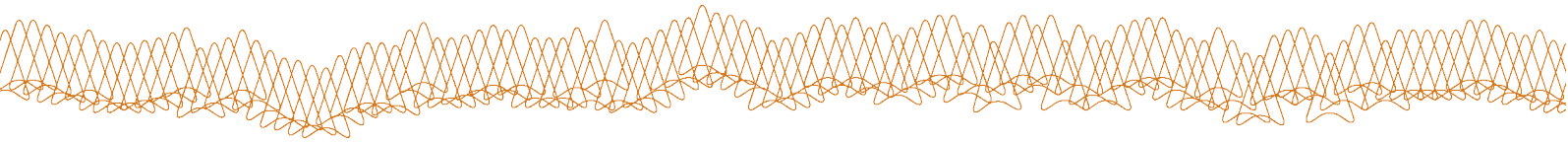
LOCATION	MEDIAN RETURN PERIOD FOR EVENT SIZE		NO. YEARS WITHOUT EVENT	
	25 mm	50 mm	25 mm	50 mm
Halls Creek	19	31	0	5
Karratha	42	54	11	21
Newman	43	63	5	19



6. Key adaptation strategies

Comments relevant to the pastoral industry

- Manage for a dry year – stock conservatively and control total grazing pressure.
- Maintain good levels of ground cover for prevailing seasonal conditions – this slows runoff and aids infiltration when rains come.
- Projected hotter temperatures will increase evapotranspiration and decrease rainfall effectiveness, particularly during hot spells. At such times, even 50 mm events that are well separated in time may become marginal for effective growth. This emphasises the importance of maximising rain use efficiency (following dot point).
- Maintain (or encourage regeneration) of palatable perennial forage species on productive land types – perennials respond more rapidly to infrequent/episodic rainfall.

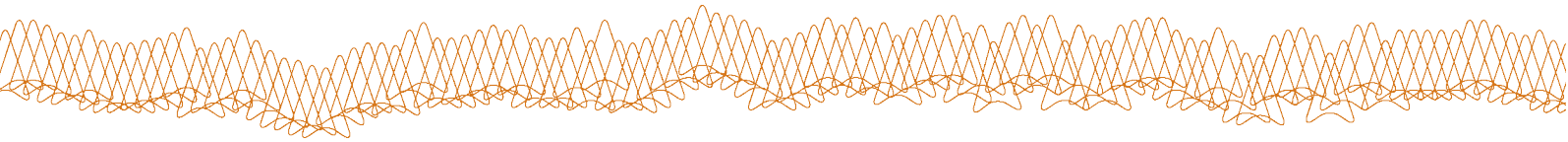


Appendix A Frequency of rainfall-return period and total number of rainfall events

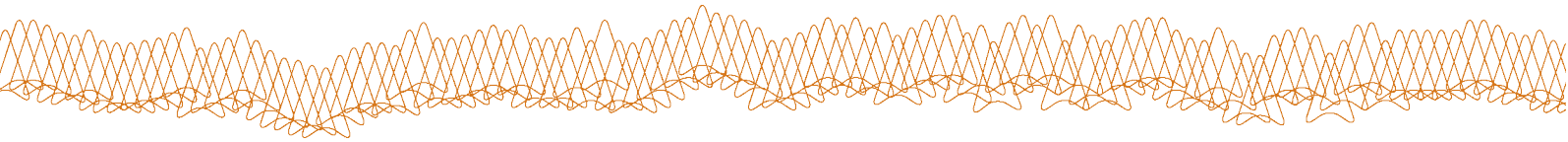
The following tables summarise the frequency of monthly return periods by event size for recording stations. The total number of events of each magnitude between 1950 and 2012 is tallied in the final column. These data indicate the likely frequency of >25 mm and >50 mm growing events throughout the year. For most stations, higher frequencies for shorter return periods (1–2 months) were associated with particularly wet years. Conversely, longer separation periods occurred in drier years (or continuous dry years).

A1. Yearly rainfall: >25 mm

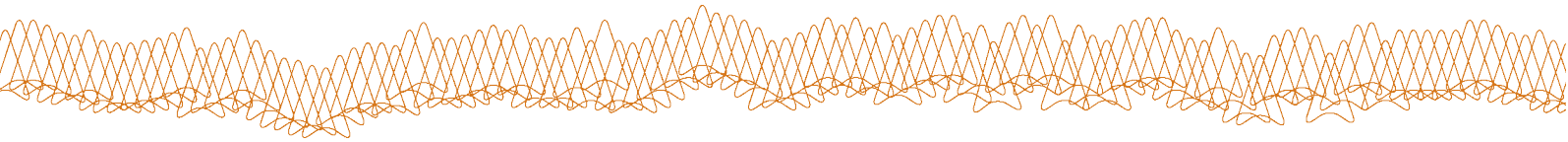
RECORDING STATION	RETURN PERIOD (MONTHS)												NO OF EVENTS
	1	2	3	4	5	6	7	8	9	10	11	12	
NSW: Western CMA													
Balranald	75	38	15	14	17	8	10	11	8	6	4	6	216
Bourke	93	55	36	23	14	12	8	5	6	4	5	2	267
Broken Hill	41	31	21	15	6	6	12	2	5	2	5	0	164
Cobar	124	67	40	33	14	12	9	3	5	2	1	2	315
Ivanhoe	75	33	29	18	13	7	10	8	7	4	4	3	218
Wentworth	37	24	12	6	17	8	13	4	8	4	3	2	152
Queensland: South West NRM													
Charleville	173	91	36	26	15	9	15	3	3	1	2	2	378
Cunnamulla	127	62	33	30	17	8	10	3	3	3	5	3	307
Quilpie	104	60	31	17	12	6	15	9	7	4	3	3	274
Thargomindah	77	40	27	21	10	9	8	8	6	5	5	1	225
Queensland: Desert Channels													
Birdsville	25	14	11	12	8	5	10	5	3	3	8	5	126



RECORDING STATION	RETURN PERIOD (MONTHS)												NO OF EVENTS
	1	2	3	4	5	6	7	8	9	10	11	12	
Boulia	62	31	16	13	9	9	5	8	5	5	9	6	187
Longreach	153	68	33	17	10	9	12	9	6	4	6	0	329
Winton	141	48	18	14	8	8	10	15	6	7	2	2	285
South Australia: Arid Lands													
Coober Pedy	15	10	5	7	4	4	3	4	1	3	3	1	84
Marree	16	6	12	8	6	7	3	3	4	5	3	4	98
Oodnadatta	15	18	11	12	8	8	1	4	0	5	8	6	108
Port Augusta	20	23	14	13	6	8	11	5	2	5	2	4	131
South Australia: Alinytjara Wilurara													
Cook	15	14	11	5	6	10	3	5	4	7	5	1	104
Ernabella	53	23	18	17	10	8	11	6	12	6	5	2	179
Northern Territory: Arid Lands sub-region													
Alice Springs	58	21	23	12	10	6	12	9	9	4	2	5	182
Curtin Springs	46	28	12	10	7	8	7	9	7	6	5	3	161
Jervois	60	28	20	12	8	4	12	7	5	5	1	3	180
Yuendumu	90	49	23	8	8	8	10	5	14	6	3	6	236
Northern Territory: Tablelands sub-region													
Brunette Downs	175	45	18	3	3	5	2	13	9	14	9	6	304
Tennant Creek	144	37	18	12	5	5	5	12	13	9	10	4	275
Western Australia: Rangelands													
Carnarvon	67	16	13	10	8	2	8	9	8	7	1	3	165
Gascoyne Junction	43	21	9	9	4	2	6	4	8	6	5	6	140
Giles	53	29	15	10	12	9	8	10	4	11	3	3	178
Halls Creek	262	35	18	7	5	8	6	12	13	10	7	3	386

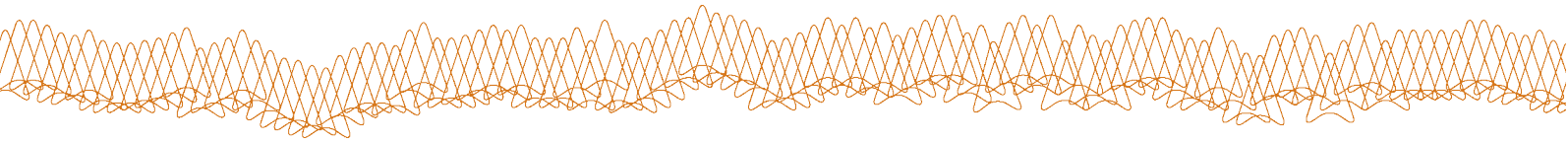


RECORDING STATION	RETURN PERIOD (MONTHS)												NO OF EVENTS
	1	2	3	4	5	6	7	8	9	10	11	12	
Kalgoorlie	29	31	10	12	11	15	6	7	5	6	4	2	151
Karratha	78	37	14	8	7	6	11	5	9	1	7	10	201
Leonora	42	26	16	18	6	5	14	8	8	2	4	3	163
Meekatharra	44	21	11	16	6	4	5	5	7	2	3	1	143
Newman	80	31	16	9	8	8	7	6	10	8	8	8	204
Wiluna	69	34	15	12	6	6	11	9	3	8	6	3	193

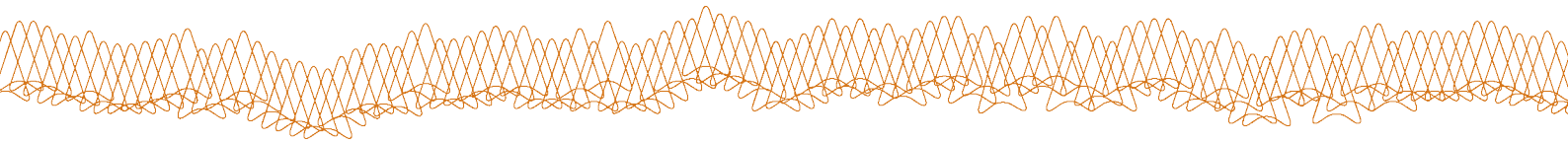


A2. Yearly rainfall: >50 mm

RECORDING STATION	RETURN PERIOD (MONTHS)												NO OF EVENTS
	1	2	3	4	5	6	7	8	9	10	11	12	
NSW: Western CMA													
Balranald	6	8	2	1	1	0	0	1	1	4	2	1	45
Bourke	19	5	12	3	2	3	2	3	3	4	7	2	87
Broken Hill	12	3	5	2	1	0	0	0	2	0	3	3	49
Cobar	23	12	2	3	3	3	4	5	0	5	3	1	88
Ivanhoe	4	8	4	2	3	0	1	0	3	2	0	3	51
Wentworth	6	3	0	0	4	1	1	0	2	1	0	0	39
Queensland: South West NRM													
Charleville	44	27	12	5	3	3	11	4	6	8	7	9	151
Cunnamulla	27	7	6	7	5	4	4	2	3	3	10	5	101
Quilpie	39	15	5	3	1	1	1	3	5	5	8	6	110
Thargomindah	14	5	4	3	0	2	3	2	2	7	3	5	70
Queensland: Desert Channels													
Birdsville	7	2	3	0	1	3	3	1	1	2	2	3	48
Boulia	17	6	1	2	2	1	4	3	2	3	4	9	77
Longreach	45	21	14	5	0	3	2	7	14	5	12	7	146
Winton	44	20	9	8	5	4	3	7	2	5	11	12	142
South Australia: Arid Lands													
Coober Pedy	1	0	1	2	0	0	0	2	0	0	0	2	24
Marree	6	1	2	1	0	0	0	0	0	0	3	1	25
Oodnadatta	3	2	2	3	1	1	0	2	1	1	1	5	37



RECORDING STATION	RETURN PERIOD (MONTHS)												NO OF EVENTS
	1	2	3	4	5	6	7	8	9	10	11	12	
Port Augusta	1	0	1	1	0	0	0	0	2	0	0	3	21
South Australia: Alinytjara Wilurara													
Cook	2	2	0	0	1	3	0	0	1	0	1	0	22
Ernabella	9	3	4	3	0	5	0	0	3	3	2	6	54
Northern Territory: Arid Lands sub-region													
Alice Springs	10	7	2	2	2	2	5	2	2	4	2	5	69
Curtin Springs	6	9	4	5	3	1	0	2	1	5	2	1	56
Jervois	17	11	7	0	2	2	4	2	3	2	1	5	76
Yuendumu	22	16	7	5	4	0	5	5	8	6	3	8	104
Northern Territory: Tablelands sub-region													
Brunette Downs	75	20	5	3	2	3	0	5	9	10	8	10	161
Tennant Creek	49	14	9	1	1	1	3	4	6	9	7	8	128
Western Australia: Rangelands													
Carnarvon	9	6	2	0	5	1	0	5	3	5	2	0	59
Gascoyne Junction	5	2	1	1	2	0	2	4	2	3	0	1	46
Giles	8	12	3	1	2	2	1	2	2	4	4	2	65
Halls Creek	78	19	9	6	2	4	0	4	7	14	14	8	172
Kalgoorlie	4	0	2	2	1	2	3	1	1	2	1	3	44
Karratha	28	11	9	6	3	1	1	4	7	5	6	5	105
Leonora	6	1	3	2	0	2	0	2	0	1	0	4	44
Meekatharra	15	3	1	3	0	0	0	4	2	0	4	1	57
Newman	13	10	2	3	2	3	4	1	6	4	4	9	82
Wiluna	7	7	1	2	2	0	1	3	2	2	4	2	57



Abbreviations

IN THIS REPORT

TERM	DEFINITION
BoM	Bureau of Meteorology
NRM	natural resource management

IN ALL REPORTS IN THE SERIES

TERM	DEFINITION
ABS	Australian Bureau of Statistics
ACRIS	Australian Collaborative Rangelands Information System
AFCMP	Australian Feral Camel Management Project
BS	bare soil
CMA	Catchment Management Authority
DKCRC	Desert Knowledge Cooperative Research Centre
DSI	Dust Storm Index
EI	Ecoclimatic Index
EMU	Ecosystem Management Understanding™
ENSO	El Niño Southern Oscillation
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

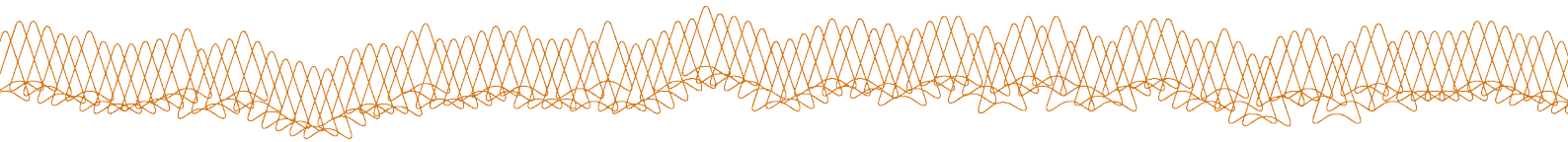
TERM	DEFINITION
NCCARF	National Climate Change Adaptation Research Facility
NPV	non-photosynthetic vegetation: senescent pasture and litter
OH&S	occupational health and safety
PV	photosynthetic vegetation: green
RCP	Representative Concentration Pathways
SAAL	South Australia Arid Lands
SDM	species distribution 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 THIS REPORT	
TERM	DEFINITION
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

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
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 <i>short-range endemics</i> or <i>vicariant relics</i> . 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
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 Distribution Modelling (SDM)	A species-specific approach whereby observational records are used to model the current potential distribution of a species
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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