RANGELANDS NRM CLUSTER

CLIMATE CHANGE IN AUSTRALIA

IMPACTS & ADAPTATION INFORMATION FOR AUSTRALIA'S NRM REGIONS

Australian rangelands and climate change – fire

Citation

Bastin G (2014) *Australian rangelands and climate change – fire*. Ninti One Limited and CSIRO, Alice Springs.

ISBN: 978-1-74158-248-2

Front cover image credit: Libby Kartzoff, fire at the Alice Springs Desert Park

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Acknowledgements

This project was funded by the Australian Government and was part of a collaboration between the Rangelands NRM Alliance, CSIRO, University of Canberra and Ninti One. Thanks to the following NRM regions for their review and input: Rangelands WA, Territory NRM, Alinytjara Wilurara NRM, SA Arid Lands NRM, Desert Channels Qld, South West NRM Qld and Western Local Lands Services. Thanks also to the members of the project's Scientific Advisory Panel for their advice and guidance: Steve Morton, Craig James, Stephen van Leeuwin, Ian Watterson, Colleen O'Malley and Daryl Green.

Key points

- We anticipate that fire regimes in the Rangelands Cluster region will be modified by climate change in three main ways:
  - Although annual rainfall will continue to be highly variable, a greater summer component may increase grass biomass and thereby fire risk, particularly following extended wetter periods.
  - Warmer temperatures will extend the meteorological fire season and greatly increase fire danger following successive wetter years. Within the fire season, increased periods of very high temperature and low humidity will increase periods of potential very high fire danger. This may translate to widespread intense wildfire where fuel loads are sufficient, ignition occurs and there is limited capacity to implement prior strategic controlled burning and other fuel reduction practices to reduce this risk.
  - The predicted continued spread and thickening of buffel grass will exacerbate this risk.
- Analysis of the recent fire record available from satellite-based fire-scar mapping can provide useful context for predicting what may occur under climate change. Here we use data supplied to the Australian Collaborative Rangelands Information System (ACRIS) by WA Landgate to describe the recent fire regime (extent and frequency) for bioregions within Rangelands Cluster NRM regions.
- Extensive wildfire is more common in the spinifex-dominant deserts and following two or more years of above average rainfall. This feature was last experienced in central Australia in 2011 and 2012.
- Buffel grass can greatly change the fire regime at local scale: it increases fuel loads, responds readily to fire disturbance and has the capacity to make local environments in which it thrives much more fire-prone.

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1. Introduction

Fire is extensive and common in northern Australia, particularly the tropical savanna (Figure 1.1). In the Rangelands Cluster region, extensive fire is more common in the spinifex-dominant deserts and following two years of above average rainfall. This phenomenon was last seen in central Australia in 2011 and 2012 (Figure 1.2) and, prior to that, 2002 (see Figure 3.41 in Bastin and ACRIS Management Committee 2008, p. 72). Extensive wildfire also occurred in 1976 following the wet years of the mid-1970s.

The majority of fires in the arid and semi-arid rangelands do not re-burn country that was burnt in the previous year. Thus the pattern of fire shown in Figure 1.2 was complementary in 2011 and 2012, that is, concentrated in the central and southern NT in 2011 and in the western deserts (WA and part SA) in 2012.

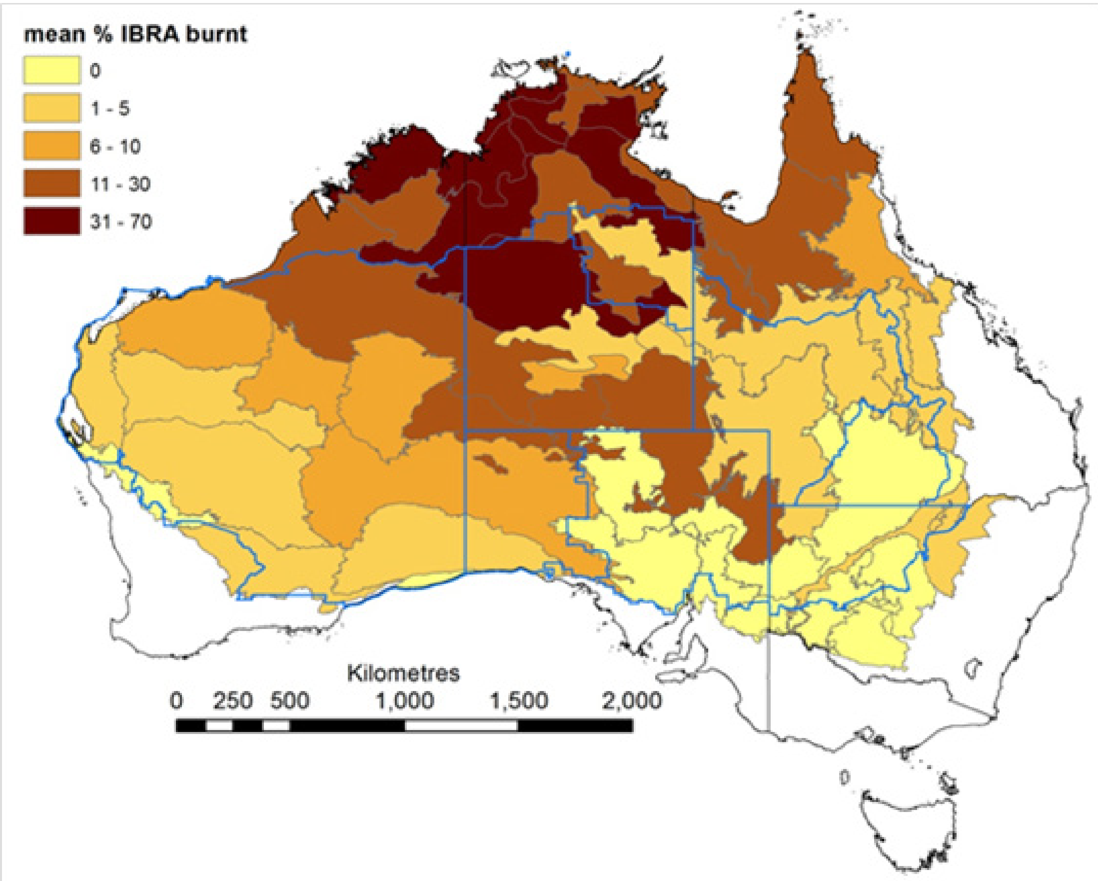

Figure 1.1 Mean percentage area of bioregions (IBRA v7) in the rangelands burnt between 1997 and 2012.

Black and blue lines show IBRA and Rangelands Cluster NRM boundaries respectively.

Source: Annual fire extent data were supplied to ACRIS by WA Landgate.

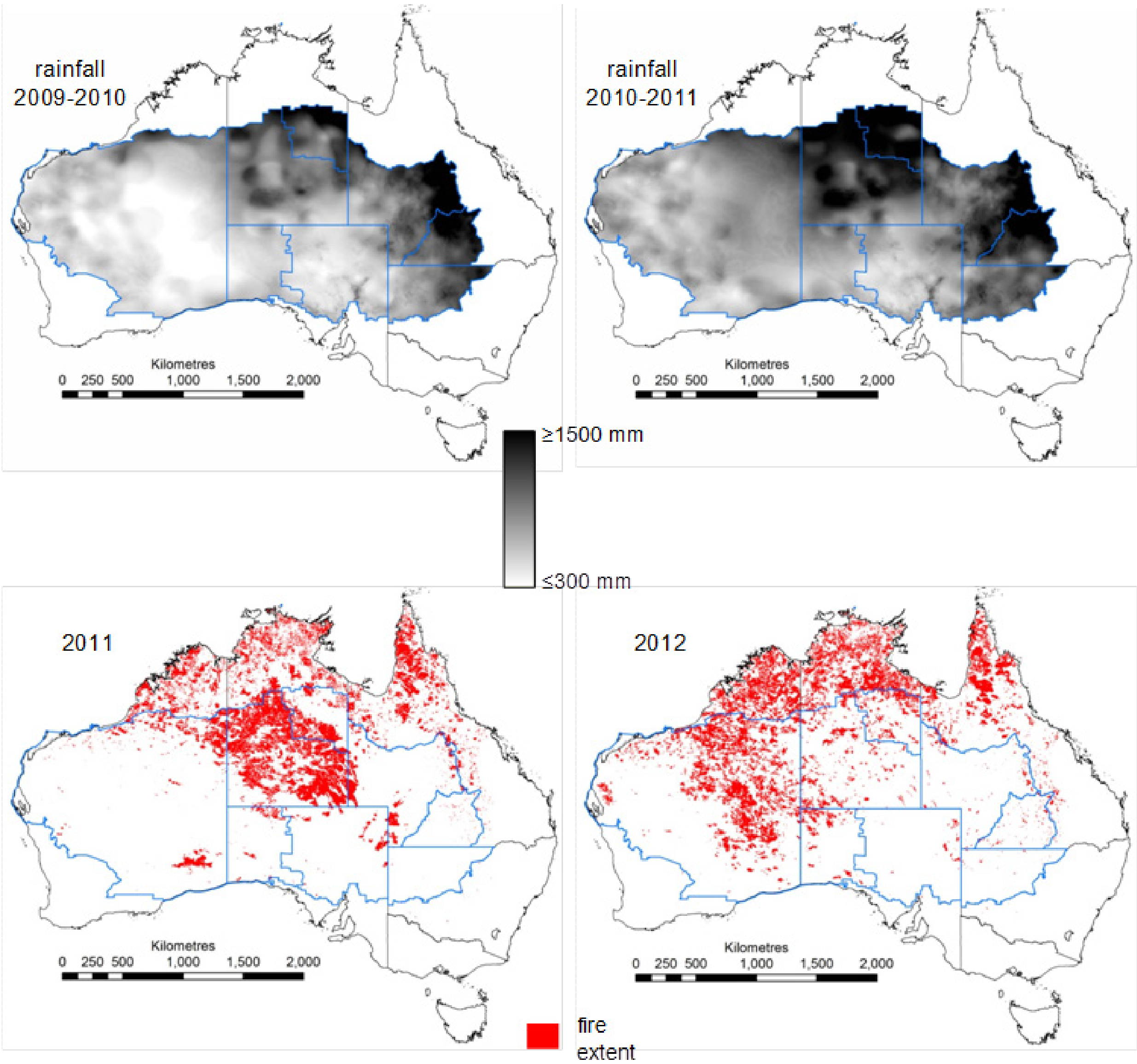

Figure 1.2 Cumulative rainfall within the Rangelands Cluster region for 2009–10 and 2010–11 (top) and area burnt in the following two years (bottom).

The paired maps (i.e. left and right) show, for the more arid rangelands, spatial correspondence between two-yearly cumulative rainfall and subsequent fire extent. Blue lines show NRM regions within the Rangelands Cluster.

Source: Maps produced from data held by ACRIS: fire data obtained from WA Landgate and rainfall data from the Bureau of Meteorology.

2. Method

Here, we briefly describe the recent fire history (1997–2012) for NRM regions in the Rangelands Cluster and comment on how this may alter with projected climate change.

3. Data sources

Fire information presented here is based on data held by the Australian Collaborative Rangelands Information System (ACRIS). ACRIS, in turn, sourced fire data from the WA Land Information Authority (WA Landgate). This agency maps fire scars monthly across all of Australia as detected in NOAA AVHRR imagery (1.1 km x 1.1 km pixel resolution). The large pixel size means that small fires and some patchy burns may be missed, but the data are ideal for detecting large-scale fire patterns across very large areas.

Maps of past fires in northern Australia are also available from the North Australian Fire Information (NAFI) web site (http://www.firenorth.org.au/nafi2/). These fire scars are mapped from 250 m MODIS imagery extending back to late 2000 and can be downloaded as monthly images (GeoTIFF) or shapefiles of burnt area.

We use the WA Landgate data for fire history because their mapping is national and for a slightly longer period (1997 compared to late 2000 for the MODIS record). The Landgate data for fire extent and frequency are also readily available within ACRIS.

Landgate has provided ACRIS with statistics on the monthly and annual extent of fire scars in each rangelands[1] bioregion (IBRA v7, Department of the Environment n.d.) between 1997 and 2012. Fire frequency is a spatial averaging of the number of times an area (pixels in a satellite image) burnt over the 16 years between 1997 and 2012 (further detail in Appendix A).

[1] The rangelands boundary as defined by ACRIS covers approximately 80% of Australia, including the savanna region (see Figure 1.3 in Bastin and ACRIS Management Committee 2008).

ACRIS reports fire history by bioregion (see www.environment.gov.au/resource/fire-product-update-2011-12 for the most recent information). Here, we adapt bioregion-level information on fire extent and frequency to the NRM regions within the Rangelands Cluster. We retain bioregions as the reporting unit because of the considerable variation in fire regime from north to south and between broadly different landscapes within larger NRM regions.

4. Findings

4.1 Regional fire statistics

4.1.1 Extent

The average percentage area of bioregions burnt in each NRM region between 1997 and 2012 is listed in Table 4.1. The minimum and maximum percentage area burnt for each bioregion during the period is also listed; this serves to show the highly variable nature of fire in some regions. Figure 4.1 contrasts the mean percentage area burnt between 1997 and 2012 for a fire-prone region (the NT part of the Tanami bioregion) and a largely fire-protected bioregion (the Nullarbor in the WA Rangelands). Yearly percentages for other bioregions are listed in Appendix B – similar comparative graphs to that shown in Figure 4.1 can be constructed from these data.

Important features are:

- Fire is more extensive and common in northern desert country within the cluster region.
- Fire is largely absent in southern pastorally dominant bioregions and particularly those with lower total biomass and/or a significant chenopod component, that is, essentially less grass and therefore less flammable fuel.
- Fire follows substantial and extended periods of rainfall (as illustrated in Figure 1.2), but burnt areas do not burn again until sufficient grass has accumulated as fuel. This is probably a shorter period (5+ years) where spinifex readily regenerates in desert bioregions, although post-fire floristic changes such as the establishment of shrubby

wattles in the Pilbara may alter the return period of the next fire. In mid-latitude pastoral bioregions (i.e. the northern part of the Rangelands Cluster) where native grasses dominate in the pasture, sufficient fuel for another fire may require >10 years – but is determined both by much above-average rainfall and grazing pressure.

- Buffel grass (*Cenchrus ciliaris*) can greatly change the fire regime at local scale, particularly in central Australia. It increases fuel loads, responds readily to fire disturbance and has the capacity to make local environments in which it thrives much more fire-prone. There is insufficient evidence yet at regional scale, but the continued spread and thickening of buffel grass may mean that less rainfall, and maybe one wet year by itself, will generate sufficient fuel to considerably increase the risk of future extensive fire.

Table 4.1 The average, minimum and maximum percentage areas of bioregions burnt within Rangelands Cluster NRM regions between 1997 and 2012. Data are adapted from burnt-area statistics supplied to ACRIS by WA Landgate.

BIOREGION	FIRE EXTENT STATISTIC		
	MEAN (%)	MIN. (%)	MAX. (%)
NSW: Western			
Brigalow Belt South	1.4	0.0	4.7
Broken Hill Complex	0.0	0.0	0.1
Channel Country	0.4	0.0	1.3
Cobar Peneplain [1]	0.1	0.0	0.2
Mulga Lands	0.1	0.0	0.4
Simpson Strzelecki Dunefields	2.2	1.2	3.2
Queensland: South West NRM			
Mulga Lands	0.3	0.0	2.2
Queensland: Desert Channels			
Channel Country	1.0	0.0	7.6
Desert Uplands [1]	3.6	0.1	21.1
Mitchell Grass Downs	0.4	0.0	1.8

BIOREGION	FIRE EXTENT STATISTIC		
	MEAN (%)	MIN. (%)	MAX. (%)
Simpson Strzelecki Dunefields	14.2	2.4	52.4
SA: Arid Lands			
Broken Hill Complex	0.2	0.2	0.2
Channel Country	1.0	0.0	3.0
Finke	7.9	0.0	23.3
Flinders Lofty Block [1]	0.1	0.0	0.2
Gawler	0.1	0.0	0.3
Simpson Strzelecki Dunefields	2.8	0.0	8.9
Stony Plains	0.2	0.0	0.4
SA: Alinytjara Wilurara			
Central Ranges	7.5	0.1	25.8
Great Victoria Desert	1.6	0.0	6.6
Nullarbor	2.0	0.1	3.4
NT: Arid Lands sub-region			
Burt Plain	5.1	0.0	31.6
Central Ranges	8.8	0.1	32.9
Channel Country	14.8	0.0	63.3
Finke	7.9	0.0	31.0
Great Sandy Desert	7.9	0.2	35.5
MacDonnell Ranges	6.0	0.0	34.9
Simpson Strzelecki Dunefields	9.4	0.0	63.6
Tanami	16.9	0.6	64.5
NT: Tablelands sub-region			
Davenport Murchison Ranges	13.9	0.0	56.8
Mitchell Grass Downs	3.7	0.1	20.9
WA: Rangelands			
Carnarvon	1.2	0.0	8.4

BIOREGION	FIRE EXTENT STATISTIC		
	MEAN (%)	MIN. (%)	MAX. (%)
Central Ranges	6.7	0.0	39.2
Coolgardie	1.4	0.0	5.3
Gascoyne	0.9	0.1	4.4
Gibson Desert	7.1	0.1	35.7
Great Sandy Desert	11.8	0.5	35.3
Great Victoria Desert	4.2	0.0	24.2
Hampton	0.6	0.1	1.2
Little Sandy Desert	5.5	0.1	38.1
Murchison	0.7	0.0	1.9
Nullarbor	1.4	0.0	11.3
Pilbara	8.5	1.1	25.8

BIOREGION	FIRE EXTENT STATISTIC		
	MEAN (%)	MIN. (%)	MAX. (%)
Tanami	18.3	0.9	52.5
Yalgoo	0.2	0.0	0.7

[1] Rangelands component of bioregion extends beyond the NRM region. Percentage area burnt may be influenced by the area outside the NRM region.

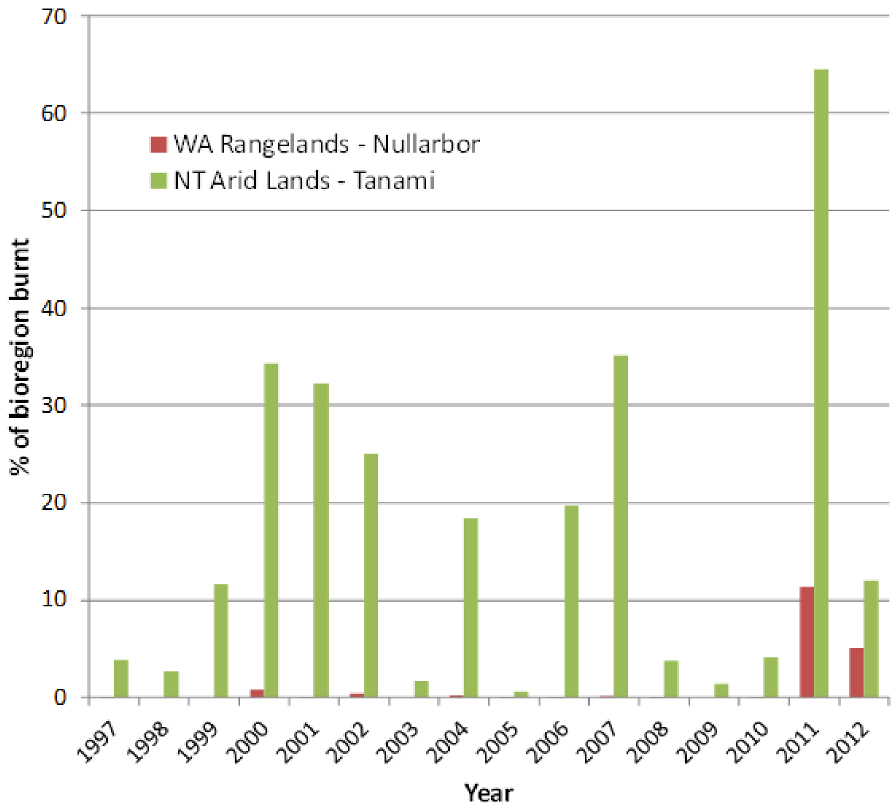

Figure 4.1 Mean percentage area burnt between 1997 and 2012 in the Tanami bioregion of the NT Arid Lands sub-region and the Nullarbor bioregions in the WA Rangelands.

Fire is much more extensive and recurrent in the northern desert country within the Rangelands Cluster.

4.1.2 Frequency

Fire frequencies are reported as the average number of fire scars, per 1.1 km x 1.1 km pixel, across each bioregion between 1997 and 2012. The arithmetic procedure for calculating fire frequency is described in Appendix A.

Where extensive fire occurred in the Rangelands Cluster region between 1997 and 2012, most areas were burnt once or twice (on average) (Figure 4.2). Fire was most frequent in the Tanami, Davenport Murchison Ranges and Gulf Fall and Uplands regions of the NT and the Mount Isa Inlier area of north-west Queensland. Fire was slightly less frequent in the Pilbara and Great Sandy Desert. As noted before, fire is much more frequent in northern Australia where, for example, all of the Pine Creek and Daly Basin bioregions have burnt 7–8 times in the 16-year period (and parts of each region burn every year).

5. Rangeland fire and climate change

There are four major biophysical factors that will contribute to any change in the future fire regime under climate change.

1. Rainfall variability is predicted to continue, although the winter component may decrease. A higher proportion of summer rainfall may increase grass biomass in the pasture and thereby increase potential fuel loads. However, continuing rainfall variability will likely mean that fuel accumulation sufficient to carry extensive wildfire will likely continue to require two (or more) years of above-average rainfall. This is particularly expected to be the case in pastoral bioregions, where varying levels of grazing intensity reduce fuel loads and their continuity in most years.

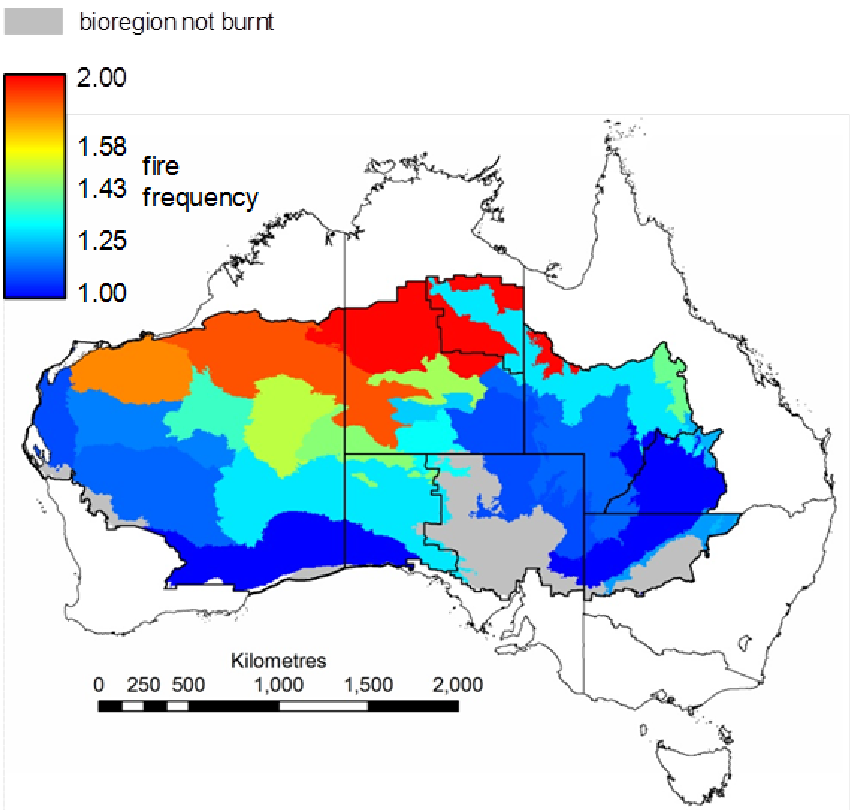

Figure 4.2 Fire frequency for bioregions within the Rangelands Cluster region burnt between 1997 and 2012. The blue lines show NRM regions (or sub-regions).

Source: Fire frequency data were supplied to ACRIS by WA Landgate.

The 'two-year rule' may be modified in pastoral areas of central and northern parts of the cluster region where C_4 grasses progressively replace C_3 species in the pasture. Grasses with the C_4 photosynthetic pathway grow more rapidly, accumulate greater biomass and are more flammable than C_3 species. Increase in C_4 grasses, including buffel grass, may mean that sufficient fuel accumulates to carry fire following one wet year.

Reduced winter rainfall and warmer temperatures throughout may see the present central Australian fire regime of decadal (plus) extensive fire move south into the northern parts of South Australia and the southern WA Rangelands.

2. Warmer temperatures will likely extend the length of the meteorological fire season and greatly increase fire danger following successive wetter years. This is more likely in the central and southern parts of the cluster region; fire risk in the north will continue to be associated with the northern monsoon and related to amount and timing of wet-season rainfall. The central Australian fire season may increase to cover the August to May period and expand by a month (or more) either side of the current summer period further south.

   Conversely, these changes will reduce the window of opportunity to safely use fire for hazard reduction burning in the relatively cooler months. This, in turn, will necessitate enhanced logistical capacity (including mobility) to best utilise suitable times for the safe use of fire.

   Increased periods of higher temperature and lower humidity will likely considerably increase periods of potential very high fire danger throughout the cluster region, and this may translate to extensive wildfire where fuel loads are sufficient, ignition occurs and there is limited capacity to implement prior strategic controlled burning and other fuel reduction practices to reduce wildfire risk.

3. At a more local scale, the continued spread and thickening of buffel grass can considerably change the fire regime. The distribution of buffel grass is likely to expand with climate change (see Scott 2014), and its colonising success and consequent likely thickening will be facilitated by recurrent fire as a disturbance factor. Where dominant in the pasture, buffel grass will fuel hotter fires with potential intensity further increased by the increased likelihood of hotter and less humid days (and nights). Buffel grass and associated intense fires will probably continue to be a greater threat on non-pastoral land but, even here, it has the potential to increase fire risk in future wetter years.

4. Vegetation productivity (and hence fuel loads) is expected to increase due to the combined effects of trends in atmospheric CO_2 (i.e. enrichment), rainfall and temperature on plant growth and shifts in species composition.

6. Adaptation strategies

Required adaptation strategies will vary with NRM region and associated land use. Likely responses will include:

1. Learn from past experience in managing and controlling episodic extensive wildfire. Widespread fire will continue to follow wetter periods, so preparing for increased fire activity is essential. This likely means implementing more of current procedures: hazard reduction burning to break up extensive fuel loads, protecting fire-sensitive habitats and other high-value assets, etc.

   Increased fire danger associated with hotter temperatures and reduced humidity may mean that larger areas burn following one wet year rather than successive years as is currently the case in much of central Australia. Fuel loads and flammability at such times may also increase with enhanced growth of C_4 grasses due to atmospheric CO2 enrichment. Thus the extent and timeliness of controlled burning and other fuel reduction mechanisms will become more critical.

   Regional knowledge and experience in managing extensive wildfire should be transportable. It is likely that the current appropriate fire management strategy for the southern NT will extend south into much of northern SA, particularly the Alinytjara Wilurara NRM region, and the southern deserts of the WA Rangelands NRM region.

2. Use prescribed fire to maximise the area it can protect. There is evidence that fuel-reduction burning in southern Australian eucalypt forests protects about one quarter of the area burnt, whereas this increases to an equal area protected in the northern savanna (Bradstock et al. 2012). The leverage factor across the fire-prone vegetation types in the Rangelands Cluster region is unknown but could be similar to (or even greater than) that for savanna.

   Local experience in prescription burning combined with temporal statistics of subsequent area burnt (derived from fire-scar mapping) should help to implement spatial and temporal burning patterns that maximise the leverage value of such programs.

3. Increased warming with associated lower humidity combined with continuing rainfall variability should present more frequent opportunities to use managed fire to control woody thickening (invasive native scrub) in pastoral country. This should be the case in parts of central Australia, south-western Queensland, western NSW, the Gascoyne–Murchison in the WA Rangelands and possibly parts of the Flinders Ranges (SA Arid Lands).

4. As highlighted above, continued spread and thickening of buffel grass will greatly alter the fire risk at a more local scale. Increased resources (labour and equipment) will be required to adequately protect vulnerable infrastructure and natural assets as this vegetation change occurs.

Appendix A Calculating fire frequency

The following notes and illustrations briefly describe how WA Landgate calculates fire frequency from mapped fire scars.

Assume that a 3 x 3 array of pixels and lines (below table) represents the area extending across a region. Burnt pixels were represented by the value ‘1’ and unburnt pixels by ‘0’. In the year 1999, two-thirds of the array was burnt, and in 2000 a little more than one-third was burnt. The fire frequency across the two years is calculated by summing pixel values.

Year 1999			Year 2000			Fire frequency		
0	1	1	0	0	0	0	1	1
0	1	1	0	1	1	0	2	2
0	1	1	0	1	1	0	2	2

Two examples of calculating fire frequencies are presented.

In Example 1, the region is represented by four pixels within the solid line.

0	1	1
0	2	2
0	2	2

The average fire frequency for this example region is (2+2+2+2)/4 = **2.0**

In Example 2, the region is represented by six pixels.

0	1	1
0	2	2
0	2	2

The average fire frequency for this region is (0+0+2+2+2+2)/6 = **1.3**

Appendix B Yearly percentage of bioregion burnt

The following table lists the percentage area of bioregions in Rangelands Cluster NRM regions burnt between 1997 and 2012. Data supplied to ACRIS by WA Landgate.

BIOREGION	AREA (KM^2)	PERCENTAGE OF BIOREGION AREA BURNT															
		1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
NSW: Western																	
Brigalow Belt South	3,630		4.73						0.97		0.01		0.12				1.08
Broken Hill Complex	37,665								0.02	0.06			0.03		0.02		0.05
Channel Country	23,355		0.43	0.06			0.03	0.61	0.29	0.22							1.34
Cobar Peneplain	37,037		0.22	0.01		0.02		0.07	0.01	0.05	0.05	0.01	0.04	0.01		0.15	0.1
Darling Riverine Plains	38,656		0.52	0			0.1	0.13	0.39	0.96	0.11		0.14	0.08		0.14	0.07
Mulga Lands	65,823		0			0.02	0.05	0.04	0.02	0.04						0.01	0.42
Murray Darling Depression	33,888		0.06		0.01	0.04		0.07	0.01	0.01	0.06	0.05	0.04			0.1	0.25
Simpson Strzelecki Dunefields	10,936															1.24	3.16
Queensland: South West NRM																	
Brigalow Belt South	14,599		0.11	1.67	0.04	1.93	1.19	0.95	3.74	0.94	1.34	0.2	0.73	15.06	0.1	7.08	14.45
Mulga Lands	145,677	0.02	0.13	0.24	0.01	0.03	0.04	0.01	0.14	0.14	0.05	0.01	0.12	0.1		0.92	2.21
Queensland: Desert Channels																	
Channel Country	189,998		0.02	0.36		0.7	0.34	0.13	0.21	0.09	0.02	0.03				7.6	1.37
Desert Uplands	42,146	2.83	2.88	1.88	3.06	5.25	0.07	0.14	0.32	0.74	0.11	1.1	4.94	6	1.85	21.12	5.05

BIOREGION	AREA (KM^2)	PERCENTAGE OF BIOREGION AREA BURNT															
		1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Mitchell Grass Downs	192,524	1.78	0.04	0.08	0.04	1.02	0.2	0.05	0.15	0.24	0.17	0.07	0.05	0.05	0.03	1.75	0.35
Mount Isa Inlier	26,296	1.1	6.48	4.42	2.17	19.11	2.41	1.11	3.32	0.86	13.74	5.46	3.4	1.35	5.79	19.88	21.73
Simpson Strzelecki Dunefields	26,219			2.35		7	4.43									52.41	4.6
SA: Arid Lands																	
Broken Hill Complex	18,687								0.2								
Channel Country	51,597			0.18			0.26		0.01						0.03	2.73	3
Finke	12,322				0		11.27	0.71								23.29	4.04
Flinders Lofty Block	38,661													0.09		0.02	0.15
Gawler	113,022				0								0.01	0		0.29	0.11
Simpson Strzelecki Dunefields	136,933			0.01			0.03									8.94	2.09
Stony Plains	129,597				0.39		0.04									0.14	0.05
SA: Alinytjara Wilurara																	
Central Ranges	27,977			5.58	25.81	5.89	19.83	0.07	0.19	0.6	0.07	0.2		0.77	0.22	16.31	22.48
Great Victoria Desert	186,133			0.23	4.29	4.12	4.73	0.29	0.04	0.53	0.01	0.63	0.09	0	0.01	1.49	6.6
Nullarbor	55,603										2.24	3.39	0.07			1.8	2.38
NT: Arid Lands																	
Burt Plain	73,797	0.1	0.02	0.3	2.42	26.43	8.08	0.17	1.8	0.22	1.63	4.72	0.06	0.08	0.31	31.56	3.93
Central Ranges	26,196			0.57	25.18	16.18	32.94	2.83	1.32	0.23	0.07	0.56		0.24	0.55	6.06	27.36
Channel Country	23,276					15.77	8.76	0							0.09	63.29	1.07
Finke	53,520	0.04		0.03		0.92	30.96	0.05			0.01					25.4	6.01
Great Sandy Desert	99,465	0.29	0.19	0.43	5.64	29.16	31.54	0.85	2.98	0.87	3.66	1.04	0.19	0.31	1.02	35.53	12.89
MacDonnell Ranges	39,294		0.01	0.01	0.24	4.71	20.08	0.41	0.03		0.02			0.02		34.9	5.64

BIOREGION	AREA (KM²)	PERCENTAGE OF BIOREGION AREA BURNT															
		1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Simpson Strzelecki Dunefields	105,748	0.08	0.19			19.77	6.59	1.24	0.12			0.01			0.14	63.61	2.01
Sturt Plateau	16,946	7.93	13.25	41.44	20.21	62.55	26.99	18.25	63.65	2.08	31.66	42.8	10.95	39.27	8.61	37.25	43.27
Tanami	203,026	3.85	2.66	11.64	34.28	32.23	25.02	1.72	18.38	0.6	19.7	35.17	3.78	1.4	4.13	64.51	12.02
NT: Tablelands																	
Davenport Murchison Ranges	49,654	0.85	1.62	0.89	30.7	48.63	9.37	2.66	16.85	0.04	10.35	19.04	4.77	0.49	4.41	56.8	15.22
Gulf Fall and Uplands	37,259	26.01	22.59	34.68	24.28	57.2	17.25	9.95	56.09	4.82	21.2	50.63	13.54	31.98	16.53	23.22	49.68
Mitchell Grass Downs	86,375	0.29	1.46	0.58	1.65	20.92	2.23	1.78	7.84	0.09	0.9	3.13	0.38	0.42	0.98	9.46	6.37
WA: Rangelands																	
Carnarvon	84,302	1.49	0.23	1.52	3.4	1.4	0.22	0.76	0.3	0.11	0.56	0.16	0.09	1.07	0.07	0.04	8.4
Central Ranges	47,015	0	0.09	10.96	39.2	4.75	14.27	0.86	0.82	0.41	4.26	1.8	0.32	0.06	0.71	0.4	28.13
Coolgardie	84,857		3.69	0.08	0.11	5.26	2.05	1	1.76	3	0.22	0.68	0.52	0.27	2.02	0.03	0.19
Gascoyne	180,753	0.8	0.48	1.25	4.36	1.88	1.34	0.41	0.23	0.26	0.44	0.18	0.15	0.19	0.05	0.09	1.6
Gibson Desert	156,289	0.71	0.15	11.44	30.83	4.61	5.75	0.78	0.87	0.57	12.99	5.73	1.12	0.43	0.42	0.98	35.74
Great Sandy Desert	295,396	16.94	0.55	18.79	23.82	12.57	7.25	2.6	10.71	1.52	25.67	6.69	5.69	4.28	0.47	16.28	35.31
Great Victoria Desert	217,942	0.33	3.85	1.57	11.96	4.5	4.29	1.33	0.72	1.1	5.8	5.52	0.51	0.73	0.25	0.04	24.17
Little Sandy Desert	110,899	4.29	0.29	5.6	18.55	0.48	2.79	0.62	0.27	1.77	6.85	7.08	0.92	0.4	0.12	0.19	38.11
Murchison	280,842	0.99	1.67	0.65	1.88	1.95	1.09	0.25	0.16	0.26	0.32	0.72	0.16	0.06	0.02	0.23	0.66
Nullarbor	137,360	0.02			0.78	0.1	0.44		0.27	0.04	0.1	0.14	0.01	0	0.02	11.33	5.16
Pilbara	178,112	20.08	2.51	9.69	25.77	9.36	9.99	3.05	3.08	1.15	15.29	8.3	4.36	7.03	3.19	1.48	10.97
Tanami	30,161	5.55	1.88	27.71	33.44	33.09	15.35	7.01	21.58	0.92	38.87	18	4.72	2.59	3.56	52.48	26.25
Yalgoo	34,726		0.15	0.01	0	0.36	0.15	0.01			0.07		0.03	0.65	0.32	0.57	0.04

Abbreviations

IN THIS REPORT	
TERM	**DEFINITION**
ACRIS	Australian Collaborative Rangelands Information System
GWW	Great Western Woodlands
IBRA	Interim Biogeographic Regionalisation for Australia
NAFI	North Australian Fire Information
NRM	natural resource management

IN ALL REPORTS IN THE SERIES	
TERM	**DEFINITION**
ABS	Australian Bureau of Statistics
AFCMP	Australian Feral Camel Management Project
BoM	Bureau of Meteorology
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
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

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 *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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