



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 – pastoral production and adaptation



Citation

Bastin G, Stokes C, Green D and Forrest K (2014) *Australian rangelands and climate change – pastoral production and adaptation*. Ninti One Limited and CSIRO, Alice Springs.

Copyright

© Ninti One Limited 2014. Information contained in this publication may be copied or reproduced for study, research, information or educational purposes, subject to inclusion of an acknowledgement of the source.

Disclaimer

The views expressed herein are not necessarily the views of the Commonwealth of Australia, and the Commonwealth does not accept responsibility for any information or advice contained herein.

ISBN: 978-1-74158-250-5

Front cover image credit: Ninti One



An Australian Government Initiative



NINTI ONE RANGE
LANDS
CLUSTER



Government of South Australia

Alinytjara Wilurara Natural Resources
Management Board



Government of South Australia

South Australian Arid Lands Natural
Resources Management Board



South West NRM Ltd
Achieving sustainable landscapes
for rural communities



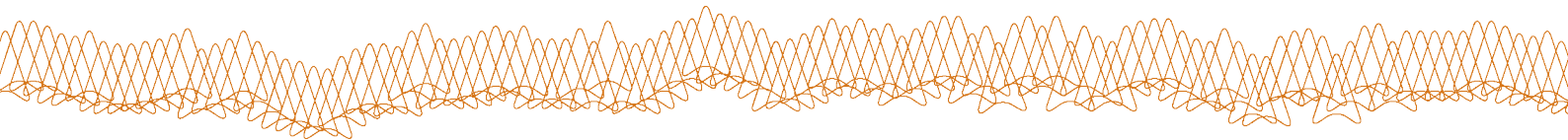
**UNIVERSITY OF
CANBERRA**



**INSTITUTE FOR
APPLIED ECOLOGY**



**Local Land
Services
Western**



Contents

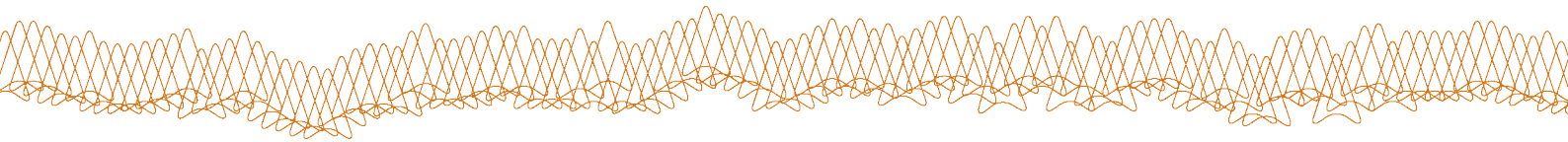
Acknowledgements.....	3
Key points.....	4
1. Introduction.....	6
2. Method.....	6
3. Data sources.....	6
4. Caveats.....	7
5. Findings.....	7
5.1 Adaptation responses.....	7
6. Key adaptation strategies.....	11
Abbreviations.....	22
Glossary.....	23
References.....	25
Further reading.....	26

List of Tables

Table 5.1 Summary of climate change impacts on livestock production systems.....	8
Table 5.2 Options for adapting to climate change in the livestock industry.....	8
Table 5.3 Plausible management responses to predicted climate change of a currently viable cattle breeding and opportunistic fattening property north of Alice Springs.....	9

List of Figures

Figure 5.1 Potential adaptation pathways to address climate change impacts for merino wool producers in the southern rangelands.....	11
--	----



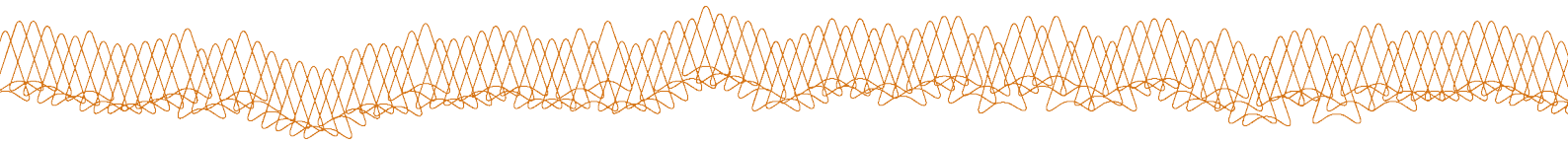
Acknowledgements

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, Daryl Green and Digby Race.



Key points

- We anticipate that both gradual and transformational adaptation responses are required to suitably respond to likely climate change impacts on pastoral land use in the Rangelands Cluster region. Appropriate transformational change will probably require a fundamental shift in the current thinking (paradigm) about how rangelands are managed towards a more conservative risk-based approach to the use of natural resources. This will be a gradual process that requires facilitation, structural change and perhaps supporting legislation to achieve the best long-term outcomes for the pastoral industry and the natural resources on which grazing is based. It is unlikely that current best-management practices will remain so under projected climate change.
- We use a linked vulnerability and resilience framework (Maru et al. 2014) to illustrate how the range of available pastoral adaptations might best be implemented across the different NRM regions in the Rangelands Cluster.
- Among the climate change projections, hotter maximum temperatures and associated heatwaves, continuing highly variable rainfall and the probable occurrence of both more frequent drought and intense rainfall are considered the most adverse factors affecting future pastoralism.
- Good practical examples and appropriate technical advice are available to guide required short to medium timeframe adaptation responses to continuing rainfall variability and recurrent drought (e.g. out to about 2030). Examples of such packaged information include the Grazing Land Management program and Ecosystem Management Understanding™. Longer term adaptation may require a fundamentally more conservative approach to stocking rates, adjusting stocking rates as local pasture productivity changes (whether increases or decreases) and increasing the robustness of pastures by encouraging regeneration of palatable perennial forage (where possible). Repairing formerly productive, but now degraded, country may also have increased prominence as maximising rain use efficiency becomes more important through increased evaporation and reduced soil water availability.
- Hotter maximum temperatures and increased frequency and duration of heatwaves will place greater emphasis on human safety and wellbeing and animal welfare (particularly when stock is being handled). Both aspects may need to be more formally recognised and planned as part of routine station management.
- Longer periods of hotter weather will also require increased robustness in stock water supply. There will be a reduced safety margin around existing supplies as livestock consume more water in such periods. Repairs following failure will become more time critical before stock risk perishing or being exposed to conditions that threaten their welfare and production. Human occupational health and safety will also be paramount when attempting repairs to failed water infrastructure during heatwaves.
- Increased rainfall intensity has the potential to damage station infrastructure and increase erosion. The latter can be partly mitigated by maintaining minimum critical levels of ground cover on the most vulnerable soil types. Reducing the actual and financial risk of infrastructure damage may require its relocation to less vulnerable areas, a degree of over-engineering (by present-day standards) and increased use of insurance.
- Higher temperatures negatively affect pasture growth by reducing the efficiency with which plants use water, but this will be partly offset by the beneficial effects of rising atmospheric CO₂ on pasture. Tropical and subtropical grasses with the C₄ photosynthetic pathway are likely to expand ranges southward at the expense of existing C₃ grasses. The digestibility and nutritive value of pastures are likely to decline from the combined effects of rising temperatures, increasing CO₂ and increases in C₄ grasses, so overall animal production may decrease. This can be alleviated for cattle by introducing/increasing *Bos indicus* genetics and increased use of nutritional supplements. C₄ grasses are more flammable, and more extensive and frequent fires that burn hotter may result.



- Finally, we include in Appendix A a broad range of management options that may provide appropriate adaptation responses to anticipated climate change impacts. This list is meant to be illustrative rather than exhaustive.

Gary Bastin
CSIRO



1. Introduction

Grazing of livestock is the most extensive land use in the Rangelands Cluster region. Projected changes in climate will impact the future way in which pastoralism occurs and adaptations will be required, both at enterprise scale and regionally. Climate change projections relevant to continuing pastoral land use include:

- continued substantial warming for mean, maximum and minimum temperatures, meaning increased evaporation and evapotranspiration, that is, reduced soil moisture availability.
- more frequent and intense heatwaves.
- continuing high variability in annual rainfall with the prospect of less rainfall in winter and spring. This will particularly influence seasonal pasture growth and forage availability in the southern part of the cluster region. In the central and northern parts of the cluster region, grasses with the C_4 photosynthetic pathway are likely to increase at the expense of C_3 vegetation.
- increased intensity of heavy rainfall, which will particularly threaten infrastructure (water points, fences, roads, etc.) on flood-prone and more erodible parts of pastoral leases.
- a probable increase in the frequency and severity of drought.
- increased periods of high fire-danger weather that will likely translate to variable levels of fire activity following wetter years.

Put simply, changes in pastoral management to cope with this more severe climate may take two different forms:

1. Gradual and progressive changes to the way things are done. Examples include:
 - changing heat-sensitive operations to the relatively cooler months of the year: e.g. join merino rams and ewes in the cooler months to reduce the risk of heat-induced sterility; similarly, shift shearing from summer if that is the current practice

- relocating fences and tracks away from more erodible country.

2. Transformational change:

- moving to a radically different form of livestock production, e.g. from merino wool production to tropically adapted beef cattle
- drought-proofing: conservative stocking, perennial-based pastures, repairing formerly productive but now degraded land, total control of various sources of grazing pressure
- diversifying sources of income within and beyond the pastoral enterprise.

Longer term transformations in the face of climate change may also require changed institutional structures, particularly with regard to pastoral tenure and the way that pastoral leases are currently administered, including monitoring of land condition.

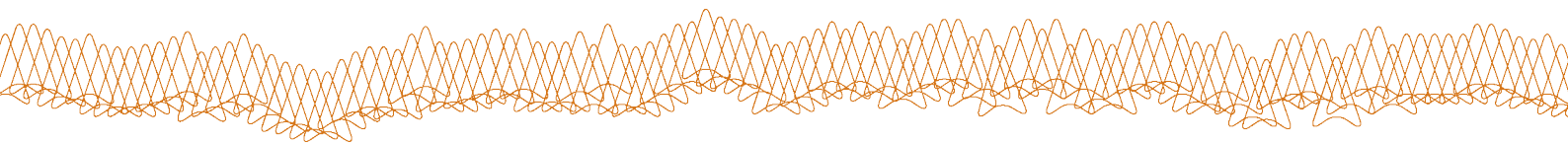
This brief report uses a linked vulnerability and resilience framework (Maru et al. 2014) as outlined in the socioeconomic sub-project (Measham 2014) to indicate how the range of available pastoral adaptations might best be implemented across the different NRM regions in the Rangelands Cluster.

2. Method

This section draws on known literature relevant to pastoral adaptation with regard to climate change, well established examples of good pastoral management in highly variable environments (e.g. Lange et al. 1984; Purvis 1986; Landsberg et al. 1998; Bastin 2014a, 2014b, 2014c, 2014d, 2014e, 2014f) and the observations and experience in different rangelands regions of two of us over recent decades (Daryl Green and Gary Bastin).

3. Data sources

The primary data sources for this sub-project are not presented here but are provided in Purvis (1986), Landsberg et al. (1998), James and Bubb (2008), McKeon et al. (2009) and Stokes et al. (2012). The commentary is based on that literature.



4. Caveats

The major caveat or underpinning assumption to this pastoral management report is that there is no simple or single recipe to successful pastoral management in the highly variable rangelands environment (where variability occurs in both time and space). Rather, a systems approach is required where appropriate (and successful) management strategies are founded on a comprehensive understanding, at both enterprise and regional scales, of the capability (and limitations) of the available natural resource (i.e. soil and vegetation) to grazing and a fundamental recognition of the requirement for conservative use of these available resources through time. Thus, various and mixed management tactics may be applied but these are underpinned by such sentiments as ‘managing for every year as though it were dry’, ‘living within one’s means’, ‘recognising and driving down the cost of production’ while building the business on the principle that ‘sensible investment should be based on those parts of the station that have the long-term potential to repay this investment’ (including, for example, repair of formerly productive grazing land).

Thus possible adaptive actions described in the following content should not be selected singularly based on perceived attractiveness or ease of implementation. Rather, they should be considered as parts of a palette of possible action which, when combined and used within a philosophy of conservative resource use, may result in a regional grazing system that is more resilient to projected climate change.

5. Findings

The probable impacts of climate change on the natural resource base (particularly vegetation) and related livestock production in the northern part of the Rangelands Cluster region are listed in Table 5.1. This summary was prepared for the northern cattle industry, and the information broadly applies to cattle producers in the Desert Channels (Queensland), Tablelands and Arid Lands sub-regions of the NT and the Pilbara (WA Rangelands). The information presented should be

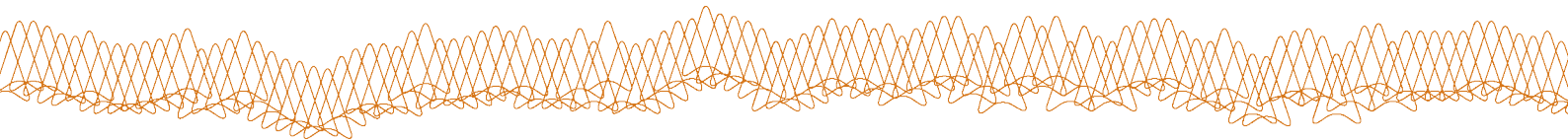
cautiously extrapolated to more southern parts of the Rangelands Cluster.

The table indicates that hotter temperatures and changes in rainfall variability are likely to have the most profound effects on cattle production. Direct effects include magnified pasture responses to rainfall changes, for both increases and decreases. For example, a 5% decline in rainfall could reduce pasture production by 7% (see McKeon et al. 2009 for further information). Changes in rainfall variability will indirectly affect the security of stock water supply (Table 5.1).

5.1 Adaptation responses

A wide range of tactical responses to projected climate change relevant to pastoral production is listed in Appendix A. These are arranged by the anticipated major components of climate change. As argued above, individually selected tactics are unlikely to be successful in isolation. Rather, a systems approach to devising strategic responses founded on an owner’s (or manager’s) fundamental philosophy to managing natural resources in a highly variable climate is required. Logically related management actions (or tactics, tools) should then follow. This is illustrated with broad guidelines for northern cattle producers in Table 5.2 and more specifically (Table 5.3) for a family-owned cattle station in the Arid Lands sub-region of the southern NT.

A further consideration is the time frame over which management philosophies and the cascading assemblage of related strategies and tactics (i.e. responses) apply. In the short to medium term (10–30 years), largely reactive responses that counter increasing vulnerability may be more appropriate (Maru et al. 2014, illustrated in Figure 5.1 for merino wool growers in the southern Rangelands Cluster region). Longer term, systemic or major structural changes are probably required at both enterprise and regional scales to enhance environmental, economic and social components of resilience. For some regions, this may amount to transformational change, for example, movement from traditional wool production based on merinos to meat sheep (Dorpers, Damaras, etc.) or, more radically, breeding tropically adapted beef cattle



for fattening beyond the rangelands (Figure 5.1). Such change has already occurred in the Pilbara, is ongoing in the Gascoyne–Murchison region of WA and may be the future for a large part of western NSW.

Table 5.1 Summary of climate change impacts on livestock production systems.

This table is adapted from material prepared for the northern cattle grazing lands (Stokes et al. 2012) and is most appropriate to the northern half of the Rangelands Cluster region.

PLANTS AND NATURAL RESOURCES	LIVESTOCK
Carbon dioxide	
Increased pasture growth per unit of available water and nitrogen (and light)	No direct effects
Reduced forage quality (protein and digestibility)	
Species-specific CO ₂ responses cause shifts in vegetation composition (e.g. favour nitrogen fixers and deep-rooted plants)	
Temperature	
Reduced water use efficiency and increased evaporation	Increased heat stress and greater water requirements
Decreased forage quality (digestibility)	Livestock concentrate more around water points
Earlier start to spring growth in cooler climates	
Southern expansion of weeds and pasture species (e.g. less nutritious tropical grasses)	Southern expansion of tropical pests and diseases
Rainfall and other changes in climate	
Changes in forage production magnify percentage changes in rainfall	Changes affect availability of water for livestock
Changes in seasonal rainfall affect seasonality of forage availability (e.g. declining spring/autumn rainfall would reduce the length of growing seasons)	
Increased rainfall intensity and inter-annual variability create greater	

challenges for managing forage supplies and limiting soil erosion	
Greater risks of flooding in some areas	
Broader context and other issues	
Uncertainty over climate change impacts and adaptation options could create reluctance and delays in taking pre-emptive action, exacerbating impacts	
Changes in regional/international competition from geographic differences in effects of climate change (magnitude of impacts/benefits and adaptability of beef industry)	
Changing demand for livestock products as a result of climate change and consumer attitudes to greenhouse gas (GHG) efficiency of food products (i.e. methane emissions by ruminants)	
Cost-price squeeze from GHG reduction measures that increase input and processing costs (indirect)	
Potential shifts in land use and competition between land uses (e.g. biodiversity conservation, loss of land for carbon sequestration and renewable energy generation)	
Conflicts and synergies with other public and private policies and initiatives (especially drought, water, natural resource and GHG emission policies)	

Table 5.2 Options for adapting to climate change in the livestock industry

ADAPTATION OPTION
Grazing and pasture management
Introduce stocking rate strategies that are responsive to seasonal climate forecasts and track longer term climate change trends
Redefine safe stocking rates and pasture utilisation levels for climate change scenarios
Improve on-property water management, particularly security of supply and placement with regard to forage supply (i.e. distance to water)
Develop software to assist proactive decision making at the on-farm scale
Accept climate-induced changes in vegetation and modify management accordingly
Expand routine record keeping of weather, pests and diseases, weed invasions, inputs and outputs
Diversify on-farm production and consider alternate land uses



Managing pests, diseases and weeds
Improve predictive tools and indicators to monitor, model and control pests
Increase the use of biological controls (with caution)
Incorporate greater use of fire for controlling weeds and woody thickening
Livestock management
Select animal lines that are resistant to higher temperatures but maintain production
Adjust use of supplements to offset declines in diet quality
Modify timing of mating, weaning and supplementation based on seasonal conditions
Provide extra shade using trees and constructed shelters
Broad-scale adaptation (variously relevant to government, industry bodies and NRM regions)
'Mainstream' climate change considerations into existing government policies and initiatives (particularly those relating to drought, GHG emissions and natural resource management)
Encourage uptake of 'best practice' in livestock enterprises as a short-term strategy (e.g. 2030 planning). However, current best practice recommendations should be evaluated to ensure benefits will continue as climate change progresses towards the end of this century
Work with the livestock industry to evaluate potential adaptive responses to the system-wide impacts of a range of plausible climate change scenarios
Provide adequate buffering to dampen the unforeseen effects of possible adaptation failure undertaken by early adopters
Modify transport networks to support changes in agricultural production systems
Continuously monitor climate change impacts and adaptation responses, adjusting actions to support and ensure effective and appropriate adaptation

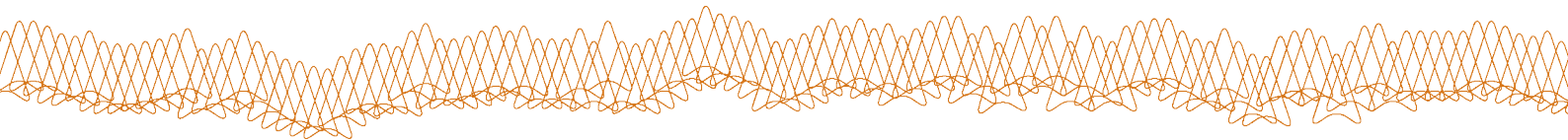
Such changes can have undesirable consequences for those continuing with wool growing (e.g. need to upgrade boundary fencing, increased predation because cattle producers place less emphasis on baiting dingoes and wild dogs), and there are advantages to regionally facilitating such change to better manage adverse and unexpected consequences.

Table 5.3 Plausible management responses to predicted climate change of a currently viable cattle breeding and opportunistic fattening property north of Alice Springs.

Climate change projections that are most likely to impact cattle enterprises in the NT Arid Lands NRM sub-region:

- Hotter summers and more frequent and longer heatwaves
- Continuing episodic rainfall – timing and amount uncertain
- More intense storms
- Recurrent drought – but timing and duration uncertain
- Increased fire danger resulting from hotter temperatures and reduced humidity.

CURRENT AND PROBABLE MORE IMMEDIATE VULNERABILITIES	PLAUSIBLE RESPONSES (EXAMPLES PROVIDED – NOT A COMPLETE LIST)
Reduced herd productivity	Consider introducing tropically adapted (i.e. <i>Bos indicus</i>) genetics to the herd (or increasing their component if already running hybrid cattle). Select for short-haired coats. Where coat colour is not a marketing issue, select for lighter colours that better reflect heat. Wean rigorously to reduce nutritional stress on breeders and improve re-conception. Increased awareness of animal welfare issues required when handling cattle during very hot weather and when stock are weakened by drought (particularly with regard to long-distance transport).
Reliable water supply, particularly in hotter months	Watersmart principles (reduce evaporation from dams, deeper dams with steep batters that store >1 year's water supply, telemetry for remote and continuous monitoring of water supply).
Year-to-year variation in forage supply	Use reliable sources of information for forward planning (e.g. climate forecasts). Close monitoring of useful pasture supply and its quality, with timely



CURRENT AND PROBABLE MORE IMMEDIATE VULNERABILITIES	PLAUSIBLE RESPONSES (EXAMPLES PROVIDED – NOT A COMPLETE LIST)
	<p>destocking as forage availability declines.</p> <p>Feed supplements (urea, phosphorus) to improve the nutritional value of poorer quality pasture.</p> <p>Manage existing buffel grass in the pasture (provided palatable varieties are present) and control its spread to areas with conservation value.</p> <p>Recognise that buffel grass poses a real threat to biodiversity. Where palatable species can be managed to contain their spread, they provide a passive and cheap opportunity for increasing the palatable perennial component of pastures.</p> <p>Remove unwanted herbivores (brumbies, camels).</p> <p>Additional water points so that water supply is closer to available forage.</p> <p>Drought preparedness – have a plan for appropriate destocking and act on it following failure of summer rainfall.</p>
High fire risk following successive wetter years (approximate decadal time scale)	<p>Identify key assets, have a plan (infrastructure, pasture resources, etc.) and seek to protect with suitable fire breaks, short-term heavy grazing, patch burning, etc. (let the rest burn if not able to safely manage wildfire).</p> <p>Where possible, learn from experience (what worked in the last major fire season and what would I do differently next time with regard to protecting life and assets – on property, working with neighbours and relevant government agencies).</p> <p>Not all fire is bad – intense wildfires might provide the ideal opportunity to control thickening scrub that threatens future pastoral</p>

CURRENT AND PROBABLE MORE IMMEDIATE VULNERABILITIES	PLAUSIBLE RESPONSES (EXAMPLES PROVIDED – NOT A COMPLETE LIST)
	<p>productivity. Recognise that further small-scale managed fire may be necessary to control woody regeneration following wildfire.</p>
Labour – particularly OH&S issues	<p>To the extent possible, confine stock work to the cooler months. Where summer mustering is required, start early and rest up during the hottest part of the day.</p> <p>Perhaps make greater use of contractors for infrastructure development and maintenance freeing up family labour for more concentrated periods of stock work. Alternatively, use a contractor for the main mustering round(s), again to concentrate this labour-intensive activity.</p>

Longer term climate change adaptations that could improve the resilience of the cattle enterprise:

- Increase drought robustness: re-assess long-term stocking rates according to land type; increase the native perennial (and palatable) component of pastures through more conservative stocking and regular paddock spelling; reclaim formerly productive, but now degraded, areas (e.g. ponding banks on better soil types to repair leaky landscapes); use fire following better seasonal conditions to control woody thickening, etc.
- Increase the security of stock water supply (examples in Appendix A): this may require a degree of over-engineering but is warranted in reducing management stress and potential animal welfare issues associated with water-point failure during extended heatwaves.
- Adopt a more risk-averse approach to protecting infrastructure (relevant to increased rainfall intensity): relocate fencing, main station roads/tracks, waterpoints (and associated pipelines), etc. away from flood-prone areas and highly erodible soil types; use graders minimally and

carefully; insure key infrastructure against flood damage (or increase premiums if currently insured).

- Diversify sources of income: off-farm investments or another business; a station somewhere else that spreads the drought risk (but is a logical extension of the existing enterprise).

6. Key adaptation strategies

Systemic and managed/facilitated change that achieves regionally stronger and more resilient pastoral businesses in the face of projected climate change is preferable to ad hoc, enterprise-level application of management tactics that address short-term vulnerabilities to climate variability and the more obvious components of climate change (mainly increasing temperature and heatwaves). This approach should not deny opportunities for innovative responses to climate change, provided such innovations also address the need for enhanced industry resilience to a more extreme climate.

Merino wool production in the southern rangelands

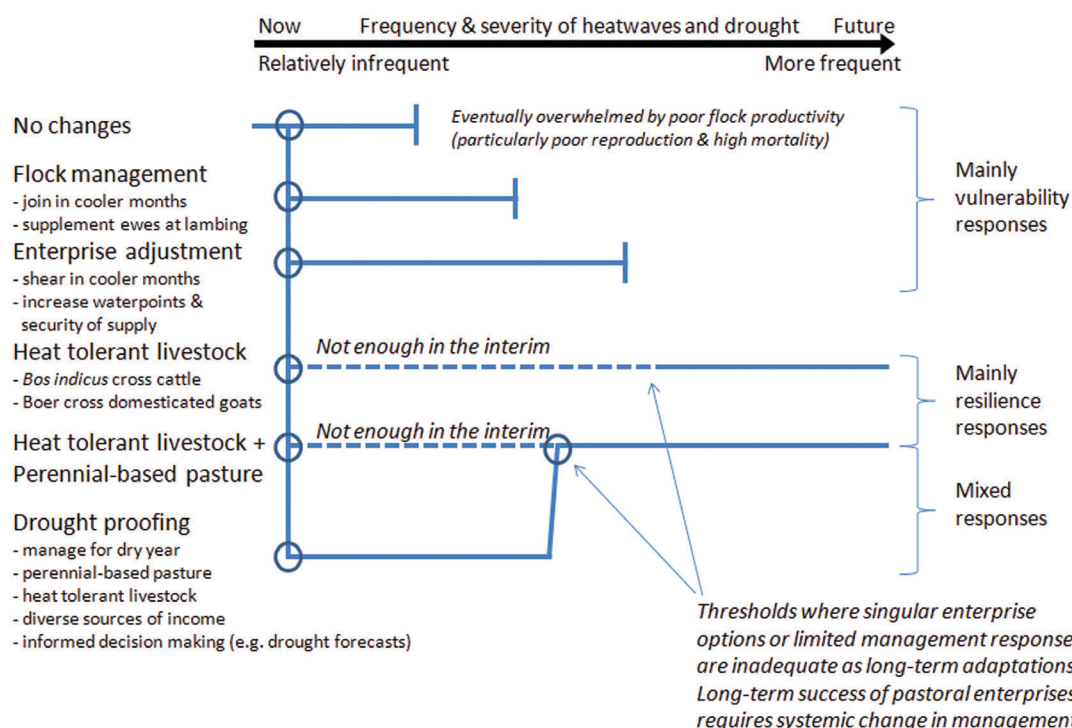
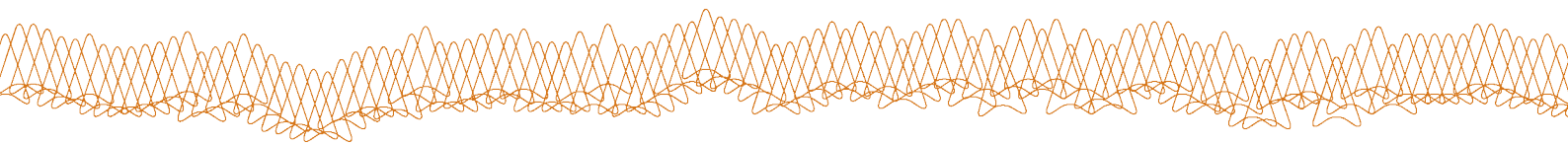


Figure 5.1 Potential adaptation pathways to address climate change impacts for merino wool producers in the southern rangelands.

Source: Figure adapted from Maru et al. (2014).



Issues associated with adaptation that are relevant to NRM planning include:

1. To what extent is gradual adaptive change relevant and when should appropriate transformational change be encouraged and facilitated? Broader uptake of regional best management practice by the pastoral sector may be appropriate for the next 15+ years (e.g. to 2030) but the utility of existing strategies and technology alone may have diminishing value as the effects of climate change intensify in the rangelands.

Appropriate transformational change is likely to require a shift in mindset towards more conservative use of natural resources (particularly stocking rate and safe utilisation levels of pasture) rather than simply rapid adoption of new technology as it becomes available.

The grazing industry and its advisers should be encouraged to think of, and implement, required transformational changes that will allow pastoralists to better manage livestock, people and the natural resource base in a hotter climate that has continuing highly variable rainfall and possibly more frequent and intense droughts.

2. Management of natural resources by the pastoral industry may become increasingly contested by other interest groups. Examples of current and likely emergent contestation include:
 - Continuing dissension among stakeholder groups of the value of buffel grass as a valuable forage species and its threat to biodiversity through direct competition, altered fire regime, etc.
 - Provision of additional waterpoints to reduce grazing distance in the hotter months and consequent negative impacts on parts of the native biota (i.e. the results from Biograzing research: James et al. 1999, Landsberg et al. 2003).
 - The extent to which feral goats continue to be harvested in the southern rangelands or, alternatively, domesticated, genetically improved and sustainably managed to provide an alternative income source to wool production. The feral versus managed value of

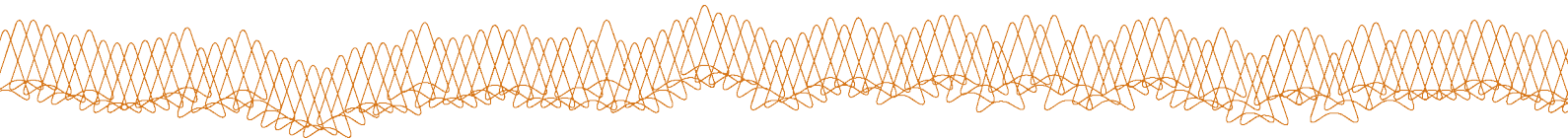
camels may also emerge as the climatic and nutritional challenges for continued grazing of sheep and cattle intensify. The long-term successful husbandry of both species will require the same attention to conservative management of natural resources as described above for sheep and cattle.



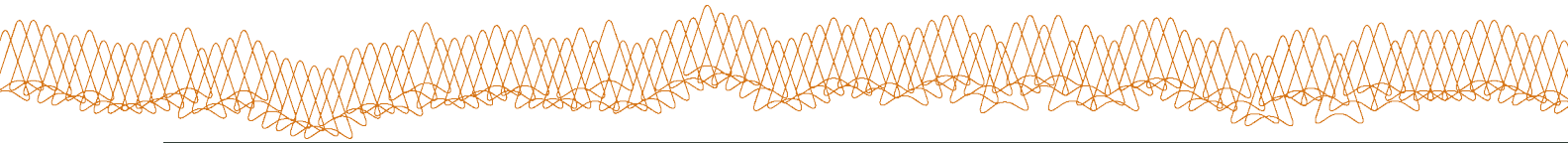
Appendix A Possible management responses by the pastoral industry to address climate change impacts in the Rangelands

The following table summarises those components of pastoral management in the Rangelands Cluster NRM regions which we understand are most likely to be impacted by projected climate change. It also describes probable required adaptation responses and suggests examples as to how these might be implemented. The list of responses and examples is not meant to be exhaustive. A key component of adaptation is innovation: pastoralists themselves are likely to implement novel ideas or combinations of tactics for addressing climate change.

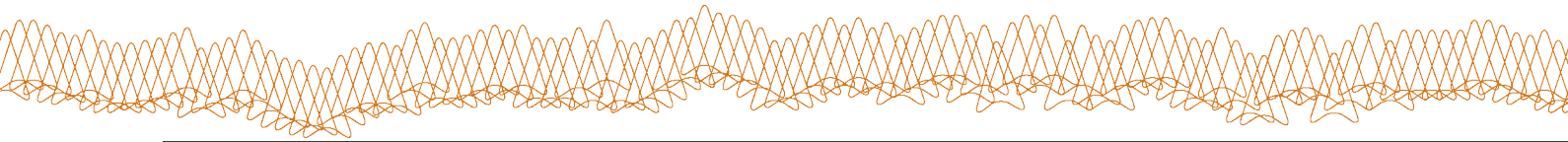
CLIMATE CHANGE ISSUE	COMPONENT OF PASTORAL MANAGEMENT	ELEMENT OF PASTORAL MANAGEMENT	LIKELY IMPACT	ADAPTATION RESPONSE	EXAMPLES
More frequent and extended heatwaves	Labour	Occupational health and safety (OH&S)	More difficult to find and keep suitable staff	Shift critical management practices (shearing, branding, etc.) from summer months	
			Acute: staff (including family members) are endangered while working outdoors (heat stress, etc.); Chronic: staff working under duress, including possible mental stress	Ensure that appropriate OH&S procedures are in place, training has occurred and practices are rigorously followed; ensure all staff (including the owner/manager) have time off in a cooler environment; build a swimming pool, etc.	
				Restrict activity to relatively cooler periods	Start early and rest during most intense heat



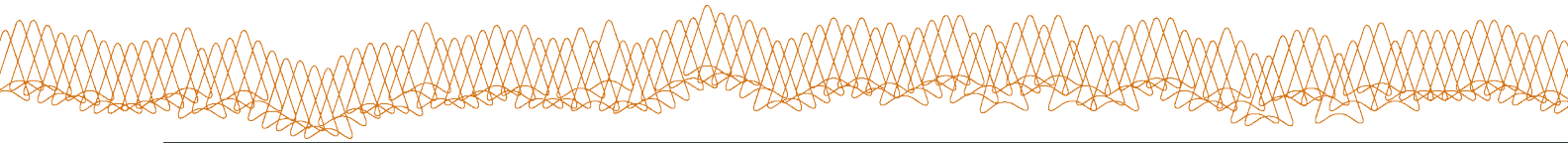
CLIMATE CHANGE ISSUE	COMPONENT OF PASTORAL MANAGEMENT	ELEMENT OF PASTORAL MANAGEMENT	LIKELY IMPACT	ADAPTATION RESPONSE	EXAMPLES
		Infrastructure	More frequent (and perhaps severe) crises (e.g. water supply issues)	Copper-plate water supplies for livestock (see relevant information from the DKCRC WaterSmart project, e.g. James and Bubb 2008)	Back-up and suitably equipped bores where continuous supply is problematic; provide additional storage volume; shift stock to areas with more secure supply, etc.
	Stock welfare	Infrastructure	Access to stock waters may need to be increased (walking distances reduced); shade structures over water troughs may be required; previously marginal stock waters may become unusable (salt levels or supply rates)	As above (i.e. increase security and quality of water supplies for livestock)	Shade structures; more water points (less walking distance)
		Land management – shade trees?	Stock may become stressed and seek increased shade – availability needs to match numbers	Manage land to ensure tree replacement (in open country) occurs regularly	
	Livestock production	Water points	Reduced grazing distance – stock seek shade and graze a shorter distance from water	Increase water supply	Pipe water closer to sources of useful forage (but don't increase total stock numbers)
Warmer in all seasons	Livestock water supply	Dams and earth tanks	Increased evaporation and less secure supply	Replace dams having limited catchments (i.e. poor supply) with piped water from reliable bores	



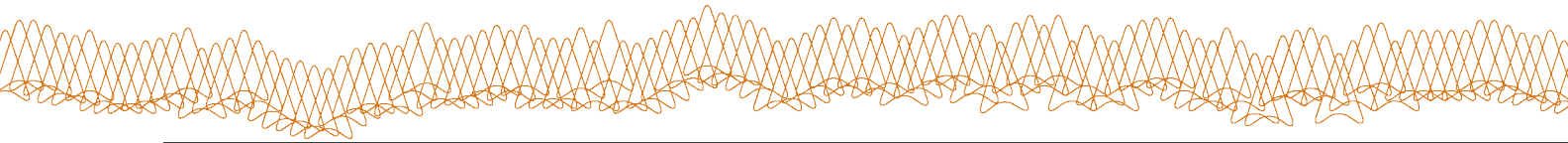
CLIMATE CHANGE ISSUE	COMPONENT OF PASTORAL MANAGEMENT	ELEMENT OF PASTORAL MANAGEMENT	LIKELY IMPACT	ADAPTATION RESPONSE	EXAMPLES
				Where catchments suitable, sink deeper dams with steep batters to extend supply and reduce evaporation	Useful information in the WA Department of Agriculture technical bulletin <i>Dam design for pastoral stock water supplies</i> (Addison et al. 2003)
				Cover water surface to reduce evaporation	Plastic film, tyres, etc. as per WaterSmart project
	Livestock production	Livestock nutrition – more grass and less herbage (C ₃ to C ₄ pasture compositional change)	Reduced palatability and nutritional value (lower digestibility and protein content)	Provide supplements to increase intake and forage value	Urea, non-protein nitrogen (cottonseed meal, etc.)
			Possible increased pasture biomass (albeit of lower quality)	Change livestock enterprise (different type and/or class of livestock)	From sheep to cattle or goats; from fattening to breeding, introduce <i>Bos indicus</i> genetics, etc.
				Possibly increase stocking rate to utilise increased forage supply (when available)	
				Maintain existing stocking rate and improve drought buffering	Carry-over of low-quality forage (mainly dry grasses) heading into drier years
		Nutrition of lactating cows and/or ewes	Reduced reproduction rate; increased mortality	Wean rigorously and regularly	



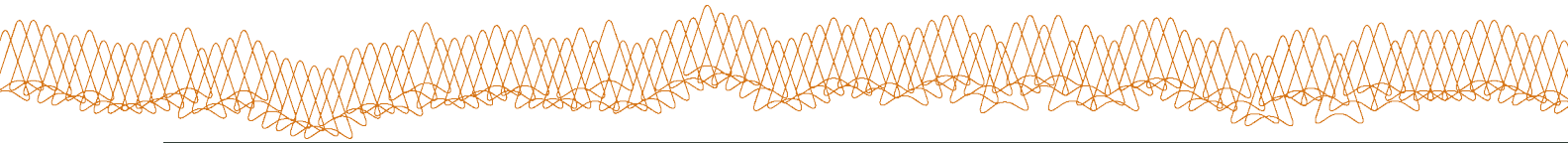
CLIMATE CHANGE ISSUE	COMPONENT OF PASTORAL MANAGEMENT	ELEMENT OF PASTORAL MANAGEMENT	LIKELY IMPACT	ADAPTATION RESPONSE	EXAMPLES
		Reproduction rate	Reduced fertility due to longer exposure to higher ambient temperatures	For merino sheep, join and lamb in cooler periods of year (success of this tactic will be related to adequate nutrition)	
				Alternatively, shear ewes prior to lambing?	
			Heat stress	Change livestock enterprise (different type and/or class of livestock)	Tropical adapted cattle breeds; short-haired, light-coloured coats; wooded/timbered paddocks for joining and calving (i.e. ample shade)
					Meat-sheep breeds that shed wool/hair rather than merinos; wooded/timbered paddocks for joining and lambing
				Actively develop markets for alternative, heat-tolerant species	Camels, goats??; this requires a long-term strategy and persistence
		Water supply	Tolerance for poor quality water reduced	Provide secure sources of clean water for livestock	Lids on tanks; pump out of dams to tanks and troughs; reduce reliance on salty bore water (where possible)



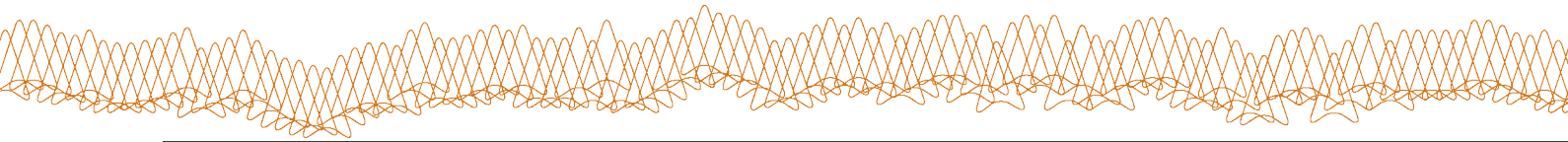
CLIMATE CHANGE ISSUE	COMPONENT OF PASTORAL MANAGEMENT	ELEMENT OF PASTORAL MANAGEMENT	LIKELY IMPACT	ADAPTATION RESPONSE	EXAMPLES
		Distance to water	More energy (and time) required for walking as forage supplies dwindle and livestock have to graze further from water	Take water to the feed (i.e. reduce grazing distance)	Additional waterpoints by piping; increase number of tanks and troughs, dams, etc.
Increased rainfall variability	Drought preparedness (drought likely to be more frequent and severe)	Stocking rate	More variable forage supply	Stock conservatively (manage for the next year being dry)	More conservative levels of safe pasture utilisation (e.g. 15% reduced to 10%); lower defoliation rates (increased grazing height) for palatable perennial grasses
				Recognise/accept deteriorating seasonal quality early and reduce livestock numbers accordingly	Trader approach to forage supply; use agistment to utilise additional forage following infrequent wetter periods
				Change enterprise to an agistment-based operation	
		Feral animal control	Increased grazing pressure	Ruthlessly control manageable feral herbivores (i.e. total grazing pressure)	
	Drought policies – State and Federal	Economic stability	Drought relief may become too expensive for Governments to continue	Landholders become dependent on their own management actions (a desirable outcome)	



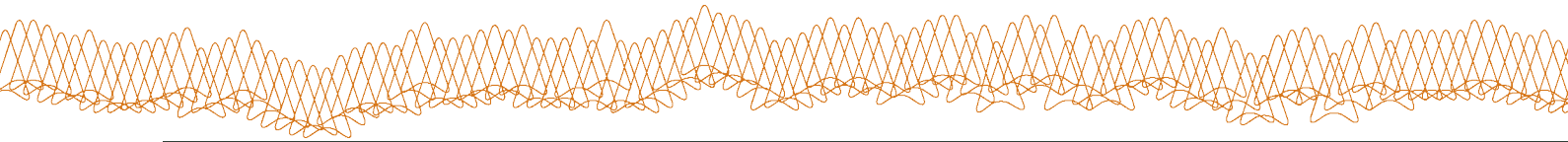
CLIMATE CHANGE ISSUE	COMPONENT OF PASTORAL MANAGEMENT	ELEMENT OF PASTORAL MANAGEMENT	LIKELY IMPACT	ADAPTATION RESPONSE	EXAMPLES
	Maximise rain use efficiency	Land condition	Land in poor condition has reduced opportunities for effective growth of productive pasture	Repair leaky landscapes	Ecosystem Management Understanding™ (EMU) principles; ponding banks and other land reclamation activities as appropriate; paddock rotation to allow pasture regeneration through resting, wet season spelling, etc.
				Where feasible, increase palatable perennial component of pasture (i.e. critical stock forage)	Apply grazing land management principles and related strategies and tactics as regionally appropriate
				Reduce competition from woody weeds (invasive native scrub)	Maximise opportunity for, and effectiveness of, managed fire following infrequent wetter periods; implement other cost-effective options for reducing woody density as regionally and legally appropriate
Lower winter rainfall	Opportunistic cereal cropping on eastern and southern margins of rangelands	Soil management	Reduced opportunities for a successful crop	Implement best practice from adjacent non-rangeland cropping areas	Seasonal forecasts as an integral part of cropping program; zero-till; maximise soil protection through stubble management



CLIMATE CHANGE ISSUE	COMPONENT OF PASTORAL MANAGEMENT	ELEMENT OF PASTORAL MANAGEMENT	LIKELY IMPACT	ADAPTATION RESPONSE	EXAMPLES
	'Abandoned' cropping lands too small to be run as pastoral enterprises, i.e. 'Goyder line' type areas move south	Vegetation and soil management	Cropping could carry on too long and soil loss accelerates and/or overgrazing of pastures results because properties are too small; difficult to re-establish rangeland species in long-term cropping country	Social restructuring may be required – adjoining pastoral properties may have opportunities to increase operational size	
	Livestock production	Livestock nutrition – more grass and less herbage (C ₃ to C ₄ pasture compositional change)	Reduced palatability and nutritional value (lower digestibility and protein content)	Provide supplements to increase intake and forage value	Urea, non-protein nitrogen (cottonseed meal, etc.)
		Drought resistant perennials (including woody species) advantaged in some instances or drought avoiding plants (annuals) become dominant	Reduced pasture supply for stock over the year.	Use available (and legal) land management and grazing strategies to minimise undesirable changes in vegetation composition (paddock spelling to regenerate desirable species, controlled burning, etc.)	
Increased evaporation (and evapo-	Livestock water supply	Dams and earth tanks	Increased evaporation and less secure supply	As above for climate change issue 'warmer in all seasons'	



CLIMATE CHANGE ISSUE	COMPONENT OF PASTORAL MANAGEMENT	ELEMENT OF PASTORAL MANAGEMENT	LIKELY IMPACT	ADAPTATION RESPONSE	EXAMPLES
transpiration)	Livestock production	Forage availability / budgeting	Shorter growing season following effective episodic rainfall in any season	Maximise rain-use efficiency by encouraging palatable perennials where possible; repair leaky landscapes; maintain optimal ground cover (including litter) to promote infiltration and reduce evaporation	
Generally lower humidity	Uncertain (lower humidity may actually be a bonus: e.g. reduced risk of fly strike in merino sheep)				
More intense rainfall	Infrastructure	Maintenance and repair	Increased requirement – both in amount and frequency (repeat maintenance)	Replace/relocate with more appropriate and robust infrastructure	Better sited fences, waterpoints, yards, roads, etc.; appropriately engineered crossings for watercourses and creeks; rapid response when key fences crossing creeks/ watercourses are lost; humps on roads, tracks and fence lines to divert water flow and minimise erosion; increased safety margins on dam walls and wings; silt traps in front of dams, etc.



CLIMATE CHANGE ISSUE	COMPONENT OF PASTORAL MANAGEMENT	ELEMENT OF PASTORAL MANAGEMENT	LIKELY IMPACT	ADAPTATION RESPONSE	EXAMPLES
		Insurance premiums	Either increased cost of existing premiums or insurance becomes essential (for assets not currently insured)	As for maintenance and repair (above) – on-ground action to reduce risk	
	Long-term productivity	Soil management	Increased risk of erosion (scalding and gullyng); productive landscapes that become progressively more leaky	Maintain critical levels of ground cover including plant basal cover; reduce and slow overland water flow and avoid channelling of such flows	Set minimum acceptable ground cover targets for each land type and manage appropriately to achieve these; appropriately sited and maintained infrastructure (particularly fence lines, roads and tracks); minimal and careful use of graders

Abbreviations

IN THIS REPORT

TERM	DEFINITION
DKCRC	Desert Knowledge Cooperative Research Centre
EMU	Ecosystem Management Understanding™
GHG	greenhouse gas
NRM	natural resource management
OH&S	occupational health and safety

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
BoM	Bureau of Meteorology
BS	bare soil
CMA	Catchment Management Authority
DSI	Dust Storm Index
EI	Ecoclimatic Index
ENSO	El Niño Southern Oscillation
FIFO	fly in, fly out
GAB	Great Artesian Basin
GCM	General Circulation Model
GDM	Generalised Dissimilarity Modelling
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

IN ALL REPORTS IN THE SERIES

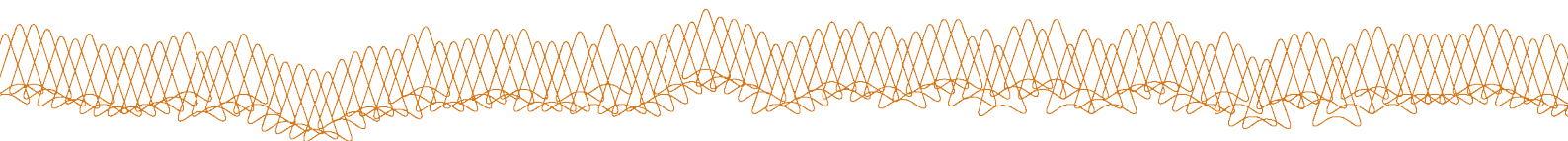
TERM	DEFINITION
NAFI	North Australian Fire Information
NCCARF	National Climate Change Adaptation Research Facility
NPV	non-photosynthetic vegetation: senescent pasture and litter
PV	photosynthetic vegetation: green
RCP	Representative Concentration Pathways
SAAL	South Australia Arid Lands
SDM	species 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
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



References

- Addison JS, Law RJ and Eliot GB (2003) Dam design for pastoral stock water supplies. WA Department of Agriculture Bulletin 4576. 35 pp. Available at http://archive.agric.wa.gov.au/objectwr/imported_assets/content/lwe/water/watstor/bull4576.pdf (accessed 23 October 2014).
- Bastin G (2014a) *Australian rangelands and climate change – rainfall variability and pasture growth*. Ninti One Limited and CSIRO, Alice Springs.
- Bastin G (2014b) *Australian rangelands and climate change – meteorological drought*. Ninti One Limited and CSIRO, Alice Springs.
- Bastin G (2014c) *Australian rangelands and climate change – heatwaves*. Ninti One Limited and CSIRO, Alice Springs.
- Bastin G (2014d) *Australian rangelands and climate change – remotely sensed ground cover*. Ninti One Limited and CSIRO, Alice Springs.
- Bastin G (2014e) *Australian rangelands and climate change – fire*. Ninti One Limited and CSIRO, Alice Springs.
- Bastin G (2014f) *Australian rangelands and climate change – dust*. Ninti One Limited and CSIRO, Alice Springs.
- James C and Bubb A (2008) *WaterSmart Pastoralism™ Handbook*. Desert Knowledge CRC. Alice Springs. <http://www.desertknowledgecrc.com.au/resource/WSHbook/index.html>.
- James CD, Landsberg J and Morton SR (1999) Provision of watering points in the Australian arid zone: a review of effects on biota. *Journal of Arid Environments* 41(1), 87–121.
- Landsberg J, James CD, Morton SR, Muller WJ and Stol J (2003). Abundance and composition of plant species along grazing gradients in Australian rangelands. *Journal of Applied Ecology* 40(6), 1008–1024.
- Landsberg RG, Ash AJ, Shepherd RK and McKeon GM (1998) Learning from history to survive in the future: management evolution on Trafalgar Station, north-east Queensland. *The Rangeland Journal* 20(1), 104–117.
- Lange RT, Nicolson AD and Nicolson DA (1984) Vegetation management of chenopod rangelands in South Australia. *Australian Rangeland Journal* 6(1), 46–54.
- Maru YT, Stafford Smith M, Sparrow A, Pinho PF and Dube OP (2014) A linked vulnerability and resilience framework for adaptation pathways in remote disadvantaged communities. *Global Environmental Change*. [online] <http://dx.doi.org/10.1016/j.gloenvcha.2013.12.007>
- McKeon GM, Stone GS, Syktus JI, Carter JO, Flood NR, Ahrens DG, Bruget DN, Chilcott CR, Cobon DH, Cowley RA, Crimp SJ, Fraser GW, Howden SM, Johnston PW, Ryan JG, Stokes CJ and Day KA (2009) Climate change impacts on northern Australian rangeland livestock carrying capacity: a review of issues. *The Rangeland Journal* 31(1), 1–29.
- Measham TG (2014) *Australian rangelands and climate change – guidance to support adaptation: Addressing climate adaptive capacity, resilience and vulnerability of people in remote and marginalised regions*. Ninti One Limited and CSIRO, Alice Springs.
- Purvis JR (1986) Nurture the land: my philosophies of pastoral management in central Australia. *Australian Rangeland Journal* 8(2), 110–117.
- Stokes C, Marshall N and Macleod N (2012) *Developing improved industry strategies and policies to assist beef enterprises across northern Australia adapt to a changing and more variable climate*. Final report to Meat and Livestock Australia B.NBP.0617. 91, Meat and Livestock Australia, North Sydney.



Further reading

Crimp SJ, Stokes CJ, Howden SM, Moore AD, Jacobs D, Brown PR, Ash AJ, Kokic P and Leith P (2010) Managing Murray–Darling Basin livestock systems in a variable and changing climate: challenges and opportunities. *The Rangeland Journal* 32(3), 293–304.

Stokes CJ, Ash AJ and Howden SM (2008) Climate change impacts on Australian rangelands. *Rangelands* 30(3), 40–45.

Stokes CJ, Crimp S, Gifford R, Ash AJ and Howden SM (2010) Broadacre grazing. In *Adapting agriculture to climate change: preparing Australian agriculture, forestry and fisheries for the future*. Eds. C Stokes and M Howden. pp. 153–170. CSIRO Publishing, Melbourne.

Vanguard Business Services, Grazing Bestprac, Global Composition, Wendy Davidson Enterprises and Rural Directions Pty Ltd (2009) *Climate change in the Australian pastoral zone; the impacts, issues and tools available*. Bestprac, Clare, South Australia.



Contact Details

Gary Bastin
CSIRO Land & Water, Alice Springs
+61 8 8950 7137
Gary.Bastin@csiro.au

<http://www.csiro.au/Organisation-Structure/Divisions/Ecosystem-Sciences/GaryBastin.aspx>