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Living with climate change

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Abstract

The climate is changing and more change is in store. Projections of temperature change and CO_2 increase are robust whilst rainfall changes remain uncertain (and in many locations increasingly uncertain over time) even in terms of direction. The response to CO_2 increase in terms of plant growth and soil water relations is potentially large and positive but also uncertain. These changes will impact on almost all parts of rangeland systems including pasture and livestock production, feed budgeting and safe carrying capacity, fire, soil C, biomass C, heat stress and biodiversity. There is increasing focus on developing a practical and effective array of adaptation responses and these are the frontline approach to living with climate change. The evolution of science has been largely appropriate to help with this goal: moving from conceptual frameworks to quantitative analysis; from climate change impacts analyses to concrete adaptation and mitigation responses; from single-component studies to integrated responses.

Introduction

The evidence that the earth's climate is changing and that humans are the main reason for this change is accumulating day-by-day and year-by-year. The likelihood that humans are not the main contributor to global temperature rise through emissions of greenhouse gases such as carbon dioxide (CO_2) is now less than 1 in 100 000 (Kokic et al. 2014). The climate and atmospheric changes are having pervasive effects on sea level and acidification, on broadscale synoptic systems, on a large range of physical and biological systems and possibly on various climate extremes (IPCC 2013).

Climate means and variability are well-known to be fundamental drivers of the function of rangelands systems impacting on many different elements including choice of agricultural production system, production potential and variability, product quality, management systems and technologies, input costs and product prices, natural resource management (including water, soils, fire, biodiversity conservation, pests, diseases and weeds), human and animal health, businesses along value chains, regional economies and social fabric. Consequently, if the climate changes, these elements of rangeland systems will also be effected. This is not new. In 1987 the first major Australian conference on climate change and the subsequent book, painted out a picture of climate change impacts on Australian rangelands. In this paper, I will assess the trajectory of increased knowledge following this initial assessment (using three decadal periods viz. 1987-1996, 1997 to 2006 and 2007 to 2017) to explore how we can more effectively learn to adapt to and live with climate change.

Climate scenarios

A crucial part of adapting is understanding what to adapt to. The underlying temperature scenarios have been strongly consistent across the three decades spanning 1986 to the present, with 'business-as-usual' emissions scenarios giving 4 to 6^{o}C increases in temperature above baseline levels by the year 2070 when approximate doubling of CO_2 would occur (IPCC 2013). A 6^{o}C change in mean temperature is like placing the temperature of Longreach (in the middle of Queensland above the Tropic of Capricorn) over Dubbo in central NSW. Also consistent have been projections of increased intensity of rainfall (Gordon et al. 1992) which arise from a fundamental property of the atmosphere: that warmer air can hold more water – a relationship known for over 200 years. In contrast, scenarios of rainfall have changed significantly over these decades (Table 1). In particular, the extreme dry projections have become progressively and markedly more negative for all seasons with the wetter end of the spectrum also declining for all but Autumn and Winter in the north (i.e. the probability distribution of future rainfall has generally shifted towards on-average considerably drier conditions). Of particular note are the recent scenarios for the southern rangelands in Winter where there is no assessed likelihood of average increases in rainfall. These scenarios are not suggesting that there will not be wet years in the future just that they may become less frequent. Another important consideration is the progressive increase in the possible range of rainfall outcomes (i.e. the uncertainty in relation to rainfall change has increased). The scenarios also indicate an increase in inter-annual climate variability with harsher droughts and more flood risk (IPCC 2013).

Early scenarios (1987-1996)		
Summer	0 to +40%	
Winter	0 to -20%	
Mid-period scenarios (1997 to 2006)		
Summer	-20 to +20%	
Autumn	-20 to +40%	
Winter	-40 to +10%	
Spring	-40 to +40%	
Recent scenarios (2007 to 2017)		
	North	*South (including Murray Darling Basin)*
Summer	-15 to +20%	-20 to +20%
Autumn	-35 to +45%	-30 to +25%
Winter	-55 to +25%	-45 to 0%
Spring	-50 to +20%	-50 to +10%

Table 1. Rainfall changes (%) for the Australian rangelands for a year 2070/4°C increase scenario drawn from Whetton et al. (2016). The early period results are scaled to a 4°C increase, the more recent scenarios are for the year 2070 and 2090 respectively. Averaging across the rangelands was done visually from the various map products.

Climate impacts and adaptation

Climate changes of the degree of those above are likely to have pervasive but variable impacts on the key dynamics and functions of rangelands (a subset of these is presented in Table 2) particularly on grazing land uses. A range of assessments has translated changes in temperature, rainfall and CO_2 into plant production, livestock production, economic performance and net Greenhouse gas (GHG) emissions with increasing sophistication over time (e.g. McKeon et al. 2009). The impacts of course vary by location depending whether moisture, temperature or nutrients are limiting factors and on the choice of grazing system. Broadly, climate changes are likely to reduce 'safe' carrying capacity, reduce economic performance, drive changes towards more flexible, lower-risk, climate-robust systems and increase likelihood of degradation of the natural resource base. Importantly, climate change places a premium on effective, strategic systems management. Consequently, over time there has been an increasing focus on exploring with decision-makers, effective adaptation responses at farm, regional and sectoral level and integrating these with other issues (McKeon et al. 1993; Cobon et al. 2009; Stokes and Howden 2010).

The trajectory of knowledge about learning to live with climate change can be characterized broadly as: moving from conceptual frameworks to quantitative analysis; from climate change impacts analyses to concrete adaptation and mitigation responses; from single-component studies to integrated responses.

	Early (1987-1996)	**Mid-period (1997-2006)**	**Recent (2007 to 2017)**
Fire	Recognition that increased fire frequency and intensity may reduce tree and shrub cover. Fire identified as an important part of GHG budgets which can be manipulated to reduce anthropogenic emissions.	Moderate increases in Fire Danger Index, particularly increased frequency in the moderate to high danger ratings. Suppression of fire could be used to reduce net GHG emissions in Mulga lands (*Acacia aneura*) but at the cost of livestock production. Climate changes and CO_2 increase tend to increase the sensitivity of Mulga GHG balances to fire management decisions as well as grazing pressure.	Significant increases in days with high to extreme fire danger but this will depend on the interaction response between CO_2 and climate changes. Species changes (e.g. buffel grass) could significantly affect fire hazard. Fire management is now being used to reduce net GHG emissions from tropical systems.
CO_2 response	Elevated CO_2 will increase water and nitrogen use efficiency, likely increasing production especially in dry years but at the cost of reduced quality and palatability and this will be a particular issue in lower latitude rangelands. Woody plant response to CO_2 interacting with reduced fire regimes increasing woody vegetation.	Glasshouse trial responsiveness of C_4 grasses to elevated CO_2 likely a function of increased transpiration efficiency, quantified interactions of CO_2 response with differential water stress leading to farm-system level scenarios including evaluation of possible adaptations and biogeographic distributions as well as weed issues.	Field trial demonstration of impact of elevated CO_2 on enhancing shrub and grass growth and improving soil moisture status as well as influencing tree/shrub competition with grass components. Whilst there remains uncertainty around the transferability of these results, modelling studies consistently show that the CO_2 effect is likely to be large and somewhat counter to the impacts of climate change.
Soil C	Soil carbon is higher in well-managed pastures and reversing rangeland degradation could potentially store large amounts of carbon quite cheaply if a range of barriers are dealt with.	Quantification of soil C increases under specific management regimes and economic analyses of these.	Policy instruments and programs developed to pay for soil carbon storage.
Biomass C	Increased extreme events may result in woody vegetation die-off events, with possible C loss. Agroforestry options may generate win-win options.	Initial assessment of vegetation thickening cases and the interacting impacts of changes in climate, CO_2, and fire and grazing management.	Satellite analyses show biomass increases across rangelands due largely to response to elevated CO_2. Policy instruments and programs developed to pay for carbon storage.

	Early (1987-1996)	Mid-period (1997-2006)	Recent (2007 to 2017)
Heat stress	Recognition that increased heat loads may have implications for animal health, welfare and productivity.	National assessment of changes in heat stress risk under climate change which shows that under moderate temperature increases, every day will be a heat stress day for livestock across Australia's north.	Increases in heat stress quantified in terms of human and livestock mortality and morbidity. Industry-oriented operational heat stress warnings.
Biodiversity	Climate change likely to interact with existing pressures such as pests, weeds, fragmentation requiring a risk-management approach addressing comprehensiveness, adequacy and representativeness.	Recognition of the limitations of correlative models towards approaches using life history, intra- and interspecific competition and predation and the importance of considering other threatening processes. Documentation of climatic impacts on biodiversity.	Integration of climate change into conservation reserve planning. Development of biodiversity assessment frameworks for climate change planning and policy.

Table 2. Core climate change impacts (fire, CO_2 response, soil C, biomass C, heat stress, biodiversity) and the change in their understanding over the periods 1987-1996, 1997-2006 and 2007 to 2017 drawn from diverse literature sources.

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