

Climate change impacts on Australian Rangelands

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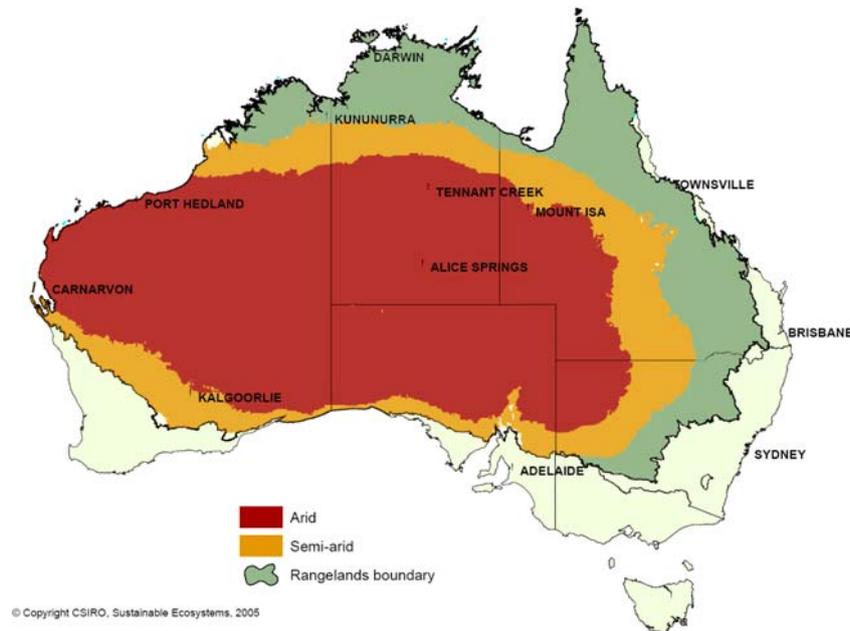
Introduction – Australian rangeland resources and their use

The recent IPCC Fourth Assessment report concluded that Australia has significant vulnerability to the changes in temperature and rainfall projected under climate change (Hennessy *et al.* 2007). Agriculture and natural resources were two of the key sectors identified as likely to be affected strongly. Extensive grazing is by far the most widespread agricultural land use in Australia. Most of the country is unsuitable for intensive agricultural production and is used instead for low intensity production of beef and sheep (meat and wool). The grazing industry has been an important contributor to the overall economic growth of Australia, but has also been vulnerable to the impacts of a variable climate (Campbell 1958; Anderson 1991). Climate change will likely add to and exacerbate existing pastoral management challenges such as declines in pasture productivity, reduced forage quality, livestock heat stress, greater problems with some pests and weeds, more frequent droughts, more intense rainfall events, and greater risks of soil erosion (Hennessy *et al.* 2007).

The native and improved pastures that form Australia's rangelands cover over three quarters of the continent (Figure 1). For the purposes of this discussion we use a simple three-category classification of Australian rangelands: 1) the arid rangelands and deserts of the centre, 2) the adjacent semi-arid region, which includes the productive Mitchell grass downs to the northeast, and 3) the remaining more mesic rangelands consisting of the tropical savannas to the north and productive highly-modified pastures to the east. The most intensive cattle production systems are situated in the productive eastern rangelands, and generally use European cattle breeds (*Bos taurus*), while hardier breeds incorporating *Bos indicus* bloodlines tend to be used in the harsher tropical climates. Sheep grazing is largely restricted to the cooler southern rangelands. The diversity in the rangelands means that there are likely to be regional and local differences in the effects of climate change.

In the following discussion, we summarise the range of likely impacts that climate change will have on Australia's rangelands and some of the implications of these changes.

Figure 1: Classification of Australian rangelands based on a moisture index: Arid (rainfall < 20% of potential evaporation [$\approx 250 \text{ mm yr}^{-1}$]), Semi-arid (rainfall = 20 to 40% of potential evaporation [$\approx 250\text{-}350 \text{ mm yr}^{-1}$]), remainder (rainfall > 40% potential evaporation [$\approx 350 \text{ mm yr}^{-1}$]).



Climate change projections

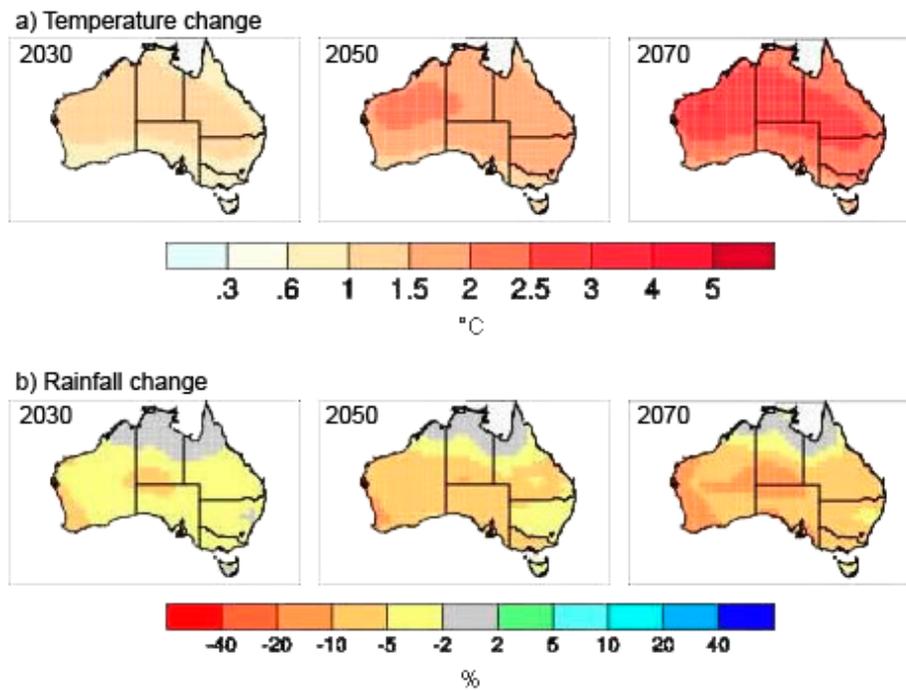
There is growing confidence that the Earth is warming and that future temperature increases and other climate changes at the global scale are highly likely. However, projections at regional and local scales, which are required for policy and land management planning, are more complicated and far less robust.

Temperatures in Australia are projected to increase by 1 to 5°C, depending on location and the emissions scenarios (CSIRO 2007). The greatest warming is expected in the interior of the continent, particularly towards the northwest of the country (Figure 2a). Associated with these temperature increases will be marked increase in the frequency of hot days and warm nights, but a less-marked decrease in the frequency of frosts (CSIRO 2007).

Regional rainfall projections are less robust than temperature, and the range of uncertainty (10th – 90th percentile) spans both drying and wetting trends at most locations in Australia (CSIRO 2007). Median rainfall projections show a general pattern of drying across the continent that is strongest in the southwest. Drying trends are weaker in the east of the country, and the northern tropics are the least likely to experience declines in rainfall (Figure 2b). Aside from changes in the amount of rainfall, there are also projected to be changes in seasonal rainfall distribution with reductions in winter and spring rainfall in the south. The intensity of rainfall is projected to increase in most parts of the country, particularly in the north, while the number of dry days will increase in many locations. Changes in the amount and distribution of rainfall and increases in evapotranspirational demand are projected to increase the incidence of drought with up to 40% more droughts in eastern Australia and 80% more in the south west by 2070 (Mpelasoka *et al.* 2007). El Niño events may become drier in

southeast Australia and La Niña events may become wetter, while changes in the Southern Annular Mode are projected to reduce rain across southwest Australia (CSIRO 2007).

Figure 2: a) Median projections for changes in temperature in 2030, 2050 and 2070 relative to the period 1980-1999. b) Median projections for changes in rainfall in 2030, 2050 and 2070 relative to the period 1980-1999. Based on A1B emissions scenario from the IPCC Special Report on Emission Scenarios. (<http://www.climatechangeinaustralia.gov.au>) (CSIRO 2007).



Climate change impacts

The most important impacts of climate change on rangelands will likely be through changes in both pasture productivity and forage quality. However, there are several other impacts on rangelands that managers will have to address including: botanical changes in vegetation composition; pests, diseases and weeds; soil erosion; and animal husbandry and health (Hall *et al.* 1998). We therefore consider how climate change will affect each of these components of rangeland management.

Pasture productivity: The dominant influence of climate change on pasture growth is expected to be changes in the amount of rainfall (Hall *et al.* 1998; Crimp *et al.* 2002). Furthermore, changes in the temporal distribution of rainfall may reduce the effectiveness of rainfall through projected increased variation within seasons (fewer, more intense rainfall events) and from year to year (more frequent droughts). Changes in river flow regimes and beneficial flooding may alter the production of locally-important ephemeral pastures on floodplains (Edmondston 2001; White 2001; Cobon and Toombs 2007b). Rising temperatures could benefit pastures in cooler, southern climates by increasing the length of the growing season and reducing frost damage. However, increased plant growth in the cooler months could deplete soil moisture at the expense of subsequent pasture growth in the spring. Changes in seasonal patterns of forage availability could pose additional challenges for grazing

management. In warmer climates, increased heat stress, and increased evaporative demand would likely have negative effects on pastures.

The most certain aspect of climate change is that atmospheric concentrations of carbon dioxide (CO₂) will increase and this will affect rangeland functioning even in the absence of climate changes. In water-limited rangelands, the dominant means by which CO₂ will affect plant growth will be through changing patterns of plant water use. Indeed, experiments that have separated the components of C₃ pasture responses to CO₂ have demonstrated that stimulated plant production was almost entirely attributable to indirect effects of moisture savings, rather than directly stimulated photosynthesis (Niklaus *et al.* 1998; Volk *et al.* 2000). Correspondingly there is growing evidence that C₄ rangeland grasses may not be substantially less responsive to CO₂ than C₃ grasses, particularly under field conditions (Owensby *et al.* 1993; Morgan *et al.* 2004). The effect of CO₂ in stimulating pasture growth may be greatest in ecosystems receiving intermediate amounts of rainfall (about 500 – 1000 mm yr⁻¹, depending on latitude) (Nowak *et al.* 2004; Stokes and Ash 2006) where water is limiting during most periods of active plant growth.

There are strong interactions of pasture responses to CO₂ with other variables such as temperature, soil nutrients and altered species interactions (Fischer *et al.* 1997; Smith *et al.* 2000; Edwards *et al.* 2001; Suter *et al.* 2002), so realised growth responses to CO₂ under future climate change may be variable (Campbell *et al.* 1997; Smith *et al.* 2000; Nowak *et al.* 2004). Modelling studies that have calculated 'safe' livestock carrying capacity from resource attributes and climate data (Scanlan *et al.* 1994; Day *et al.* 1997) have indicated that pasture growth is sensitive to small variations in climate and that responses to rainfall are non-linear (Wilson and Harrington 1984). For example, a study of Queensland native pastures (Hall *et al.* 1998) found that the combined effects of warmer temperature, doubling CO₂ and ±10% changes in rainfall altered 'safe' carrying capacity by +3 to +45% depending on rainfall scenario. Importantly this sensitivity study showed that CO₂ has the potential to mitigate or amplify the effects of warmer temperatures and changes in rainfall.

The more productive northern and eastern rangelands are the most likely to provide opportunities for slight increases in productivity in future (Crimp *et al.* 2002; Heyhoe *et al.* 2007). The northern rangelands are the only area of the country where median rainfall is not projected to decline with climate change, and the proximity to the coast should moderate increases in temperature slightly (Figure 2). In the eastern rangelands there is projected to be some drying and increase in the frequency of droughts (Cai 2003; Nicholls 2003; Whetton and Suppiah 2003) but moderate amounts of warming may benefit pasture growth by extending the growing season, so that there is projected to be a slight net increase in pasture productivity (Howden *et al.* 1999c; Crimp *et al.* 2002). In contrast, changes in rainfall and temperature are both projected to have their greatest negative impacts in the central arid rangelands (Figure 2), where already-marginal enterprises may be at most risk of becoming non-viable under climate change.

Forage quality: Stimulation of forage production by CO₂ is associated with changes in forage quality through declines in forage protein content (Wand *et al.* 1999), and increased forage non-structural carbohydrates in C₃ species (Wand *et al.* 1999; Lilley *et al.* 2001) but not C₄ (Wand and Midgley 2004) and decreased digestibility of tropical grasses, although there may be little change in digestibility of other species (Lilley *et al.* 2001). Warmer conditions tend to significantly decrease non-structural carbohydrate concentrations (and digestibility in tropical species) while also slightly reducing leaf N-content (Wilson 1982). However, counteracting this general overall tendency to reduced forage quality, there may be seasonal improvements in forage quality where growth seasons are extended either by earlier onset of winter growth (Cobon and Toombs 2007a) or prolonged availability of soil moisture (and delayed grass senescence) as a result of CO₂-induced conservation of

water by grasses. The combined effects of rising CO₂ and temperature will modify seasonal patterns of variation in forage protein and utilisable energy with likely consequences for ruminant nutrition, but these effects have yet to be investigated.

Botanical change in vegetation composition: The likelihood of climate change affecting the botanical composition of pastures is demonstrated by the past role weather events have played in effecting species changes (Bisset 1962; McKeon *et al.* 2004). Where climates become hotter and drier, pasture composition is likely to shift to more xeric species that may be less suitable for grazing. Grazing management practices may have to change to match the new vegetation and climate. Further changes in rangeland vegetation are expected in response to rising atmospheric CO₂ concentration (Warwick *et al.* 1998; Howden *et al.* 1999b). Rising CO₂ will affect pastures by changing the temporal and spatial patterns of soil moisture availability: higher levels of CO₂ delay soil moisture depletion following rainfall events (Gifford *et al.* 1996) thereby increasing the availability of moisture deeper in the soil profile. Differences in species responses to CO₂ are therefore likely to be strongly influenced by differences in rooting patterns and the ability of plants to rapidly exploit conserved soil moisture from reduced transpiration of other plants. Deep-rooted woody plants and legumes are likely to be advantaged over grasses at higher CO₂ levels, both because of higher CO₂-sensitivity of growth (Ainsworth and Long 2005) and because of the ability to tap deep water while still competing with grasses for moisture in shallow soil layers.

Pests, diseases and weeds: A major risk to the grazing industry from climate change relates to the potential change in the distribution of pests, feral animals, diseases and weeds, particularly a southward range shift of tropical pests following warming conditions.

Soil erosion: Projected increases in rainfall intensity (Tebaldi *et al.* 2006; CSIRO 2007) are likely to increase the risks of soil erosion. This will likely be exacerbated by increased year-to-year variability in rainfall, with more droughts and more floods, and therefore a greater chance of erosion events where a wet year follows a drought (when protective plant cover is low).

Animal husbandry and health: Climate change will substantially increase the frequency of heat stress days, particularly in northern Australia (Howden and Turnpenny 1997; Howden *et al.* 1999a) reducing productivity, decreasing reproductive rates and increasing concerns about animal welfare in locations where grazing populations are concentrated, such as feedlots. The upward trend in animal numbers in Australia has been made possible by continued breeding improvement in livestock, especially drought resistance in sheep and cattle, resistance to pests and diseases (Lloyd and Burrows 1988). As conditions in southern regions become harsher, pastoralists will have to rely on hardier northern breeds (and crosses), but this will likely come at the cost of lower productivity, fecundity and meat quality.

Management and Policy Implications

Climate change will involve not only negative impacts for Australian rangelands, but also some benefits. While some regions will be worse off, there will opportunities for improved production in others. However, minimizing the negative impacts and maximizing the benefits will require responses at both policy/industry level (Table 1) and the individual property scale (Table 2). Engaging pastoralists and policy makers during the evaluation of climate change impacts and development of adaptation options will assist in directing efforts that are most likely to be appropriate, effective and adopted.

Given the uncertainty in regional and property-scale impacts of climate change, adaptation strategies will need to take a flexible, risk-based approach that develops options and capacity to cope with a range of possible local climate changes, and continually monitor responses to ensure that they are appropriate and remain effective (Howden *et al.* 2007). For example, one important recommendation will be increased adoption of climate forecasting strategies (McKeon and Howden 1992). Adjusting stocking rates to seasonal variation in forage production will build in some automatic tracking of trends in climate change. Many of the options that provide gradual adaptations are similar to management adjustments that pastoralists routinely make in tracking market and technology trends and are likely to occur with little intervention beyond support for research and extension. However it will also be important to determine where such gradual, incremental changes will be insufficient. Where either the magnitude or rate of change imposed exceeds the adaptive capacity of pastoralists, more intensive policy intervention or industry change may be required.

Biodiversity in rangelands will also have to be managed under climate change, but adaptation options are currently mostly speculative (Scholes and Howden 2003). Protected areas may have to be re-configured, with greater emphasis on facilitating shifts in native species distributions, restricting exotic invasions and maintaining refuges. Conservation management activities may need to include 'matrix lands' between protected areas. Even if a landscape can be designed to be 'permeable' to migrating species, the rate of climate change is likely to exceed the dispersal rate of all but the most mobile organisms (e.g. leading to the likelihood of more weeds). Some form of assisted dispersal is likely to be necessary but this raises various issues of ethics, management and cost-effectiveness.

In developing sound climate change adaptation strategies it will be important to continually ensure that responses are effective in achieving their intended benefits while minimizing unintended consequences. There are several foreseeable risks of maladaptation, where trade-offs will need to be carefully evaluated. For example, introducing legumes into native pastures may offset declines in forage quality, but incurs the risks of soil acidification and impacts on biodiversity. Likewise, carbon trading schemes may create short-term opportunities for earning carbon credits from increases in woody plant biomass, but this would have to be weighed against the ongoing costs of possible losses in pasture production or reduced water yields from catchments. At the government and institutional level, it will be important to incorporate considerations of climate change adaptation into new and existing policies and initiatives to ensure complementarities and reduce conflicts in policy goals.

Successful adaptation will require a mix of pre-emptive and reactive adaptive strategies that respond to the combined changing challenges and opportunities posed by climate change and other social, economic and institutional pressures. Adoption of new property management practices will require: (1) confidence that climate change can be separated from the naturally high year-to-year climate variability inherent in these production systems; (2) the motivation to change based on the perceived risk and opportunities of climate change, (3) establishment and implementation of applicable new technologies and demonstration of their benefits; (4) buffering against establishment failure of new practices during less favourable climate periods; (5) alteration of transport and market infrastructure to support altered production (McKeon *et al.* 1993; Howden *et al.* 2007), and (6) development and modification of government policies and institutions to support adoption and implementation of the required changes. Adaptation strategies that incorporate the above considerations are more likely to be of value, as they will be more readily incorporated into existing on-farm management strategies.

Table 1: Industry and policy-level activities for adapting rangelands to global change (from Howden *et al.* 2003).

<i>Industry and policy-level adaptation options</i>
Policy: Develop linkages to existing government policies and initiatives (e.g. policies on greenhouse sinks, natural resource management, water resource allocation, rural development, poverty alleviation) and into integrated catchment management so as to enhance resilience to climate change.
Managing transitions: Policies and mechanisms to provide technical and financial support during transitions to new systems that are more adapted to the emerging climate.
Communication: Ensure communication of broader climate change information as well as industry-specific and region-specific information as it becomes available.
Climate data and monitoring: Maintenance of effective climate data collection, distribution and analysis systems to link into ongoing evaluation and adaptation. Monitor climate conditions and relate these to forage yield and quality aspects to support/facilitate adaptive management. Develop climate projections that can be downscaled so as to be relevant to farm and catchment scale.
R&D and training: Undertake further adaptation studies that include broad-based costs and benefits to inform policy decisions. Maintain the research and development base (people, skills, institutions) to enable ongoing evaluation of climate/CO ₂ /(species or landuse)/management relationships, and to streamline rapid R&D responses (for example, to evaluate new adaptations or new climate change scenarios). This R&D needs to be developed in a participatory way so that it can contribute to training to improve self-reliance in the agricultural sector and to provide the knowledge base for farm-scale adaptation.
Breeding and selection: Maintain public sector support for agricultural biotechnology and conventional breeding with access to global gene pools so as to have suitable options for higher temperature regimes and changed moisture availability and possible more climate variability.
Model development and application: Develop further grazing systems modelling capabilities that link with meteorological data distribution services, and can use projections of climate and CO ₂ levels, natural resource status and management options to provide quantitative approaches to risk management for use in several of these cross-industry adaptation issues (e.g. AussieGrass: Hall <i>et al.</i> 1999). These models have been the basis for successful development of participatory research approaches that enable access to climate data and interpretation of the data in relation to farmers own records and to analyse alternative management options. Such models can assist pro-active decision making on-farm and inform policy and can extend findings from individual sites to large areas.
Seasonal forecasting: Facilitate the adoption of seasonal climate forecasts (e.g. those based on El Niño and La Niña, sea-surface temperatures, etc) to help farmers, industry and policy incrementally adapt to climate change whilst managing for climate variability. Maximise the usefulness of forecasts by combining them with on-ground measurements (i.e. soil moisture, standing forage), market information and systems modelling.
Pests, diseases and weeds: Maintain or improve quarantine capabilities, sentinel monitoring programs and commitment to identification and management of pests, diseases and weed threats. Improve the effectiveness of pest, disease and weed management practices through predictive tools such as quantitative models, integrated pest management, area-wide pest management, routine record keeping of climate and pest/disease/weed threat, and through development of resistant species and improved management practices.
Water: Increase water use efficiency by 1) a combination of policy settings that encourage development of effective water-trading systems that allow for climate variability and climate change and that support development of related information networks, 2) improve water distribution systems to reduce leakage and evaporation, 3) developing farmer expertise in water management tools and enhancing adoption of appropriate water-saving technologies.
Landuse change and diversification: Undertake risk assessments to evaluate needs and opportunities for changing species, management or landuse/location in response to climate trends or climate projections. Support assessments of the benefits (and costs) of diversifying farm enterprises.
Natural resource base: Determine the impact of climate change (interacting with land management) on natural resource degradation issues such as erosion and salinisation risks and inform policymakers.

Table 2: Farm level adaptations to global change (from Howden *et al.* 2003).

<i>Managing pasture productivity and grazing pressure</i>
Selection of sown pastures better adapted to higher temperatures and water constraints
Provision of additional nitrogen through sown legumes
Provision of phosphates to both improved and unimproved pasture
Provision of urea and phosphates directly to stock via reticulation
Greater utilisation of strategic spelling
Introduction of responsive stocking rate strategies based on seasonal climate forecasting
Development of regional safe carrying capacities i.e. constant conservative stocking rate
Where appropriate, development of software to assist pro-active decision making at the on-farm scale
<i>Managing pests, disease and weeds</i>
Improve pest predictive tools and indicators
Improve quantitative modeling of individual pests to identify most appropriate time to introduce controls
Increased (but cautious) use of biological and other controls
Increased use of insect traps for sentinel monitoring and for population control
Incorporation of alternative chemical and mechanical methods for reducing woody weeds
Acceptance that the biota may change
<i>Animal husbandry and managing health</i>
Selection of animal lines that are resistant to higher temperatures
Modify timing of mating based on seasonal conditions
Modify timing of supplementation and weaning
Construction of shading and spraying facilities
Increase use of trees as shading and reducing wind erosion

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