AUSTRALIAN RANGELANDS: MANAGING THE RISKS OF CLIMATE CHANGE

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ABSTRACT

The IPCC Third Assessment Report confirms that the evidence for global climate change is now stronger than ever. While efforts to minimise climate change are critical, some degree of change is already inevitable. The key questions for rangelands are no longer whether climate change will occur, but how to adapt to it so as to mitigate its negative impacts and take advantage of any positive impacts. This paper briefly outlines the likely future changes, the likely impacts of those changes for Australian rangelands and the analysis of strategies at the farm scale and at the national scale which could help to make rangelands and rangeland livelihoods sustainable even in the presence of climate change.

INTRODUCTION

Human activities appear to be affecting the global climate. Global mean temperatures have risen approximately 0.7°C since the mid 1800s and changes in rainfall patterns, sea levels, rates of glacial retreat and biological responses have also been detected which are consistent with expectations of 'greenhouse' climate change. The most recent report of the Intergovernmental Panel on Climate Change (IPCC 2001) concluded that there is now stronger evidence of a human influence on global climate and that these trends will continue for the foreseeable future due to continued emissions of carbon dioxide (CO_2) and other greenhouse gases from fossil fuels and other sources. The most recent predictions are for an increase in global average temperatures of 1.4-5.8°C by the end of the present century. Intuitively, it is hard to conceive that such changes will not have implications for Australia's rangelands. Furthermore, temperature records such as those from the Vostok ice core (Petit *et al.* 2000) demonstrate that such high global temperatures have not been experienced before by the human species – we have no precedent for managing them. In addition to these projected temperature increases there will be increases in atmospheric carbon dioxide (CO_2), changes in mean rainfall with the prospect of substantial rainfall declines (up to 40%) across the southern half of Australia in particular, increases in rainfall intensity and the possibility of entering a more El-Niño-like mean climate condition. Consequently, the IPCC Third Assessment Report (IPCC 2001) concludes that rangelands in Australia have significant vulnerability to the changes projected over the next decades to 100 years, adding to the existing, substantial pressures on these regions.

HOW WILL GLOBAL CHANGE AFFECT RANGELANDS?

The higher atmospheric CO_2 concentrations that are inevitable in the future (ranging from 500 ppm to 900 ppm by 2100: IPCC 2001) are highly likely to increase the aboveground plant productivity in rangelands. Experiments show that increases of atmospheric CO_2 concentrations to 700 ppm significantly increase productivity of plants by 10-15% in mesic environments and 20 to 40% in water-limited situations (Wand *et al.* 1999) with doubling of above-ground production in dry seasons (Stokes *et al.* 2003). The main mechanism is an increase in water use efficiency arising from reduced stomatal apertures under elevated CO_2. There can also be some photosynthetic enhancement. The stimulatory effect on production levels off as the CO_2 concentration rises. The capacity to express this CO_2 'fertilisation' is affected by other factors such as species composition, temperature, soil nutrient availability and soil moisture leading to variable growth response. However, any increases in production may be offset by projected reductions in rainfall and increases in evaporation (Hall *et al.*

1998). For those rangelands where a large net drying is predicted (e.g. southern Australia), the effects may more than cancel each other out, resulting in reduced primary production.

Increased temperatures may increase pasture production in areas where low temperature limits the growing season, particularly in areas where C_4 grasses predominate, where soil nutrition is adequate and in years where soil moisture is not limiting (Hall *et al.* 1998). Conversely, in more southern regions where winter-growing pastures are more common, higher temperatures may reduce the length of the growing season, limiting forage accumulation and livestock performance.

The suggested increased competitive capacity of woody plants over grasses with higher CO_2 levels, based on differences in their photosynthetic mechanisms, remains speculative (Archer *et al.* 1995). More recent modelling work (Bond *et al.* 2003) suggests that the increase in CO_2 experienced in the last 120 years is large enough to explain increasing woodiness in savannas because regrowth of trees between fire events is fast enough that many can escape the damaging effects of the next fire. If, however, burning frequency is adjusted to higher grass biomass with increased CO_2 concentrations in the future, there may be increased opportunities to control woody plant establishment (Howden *et al.* 2001) provided that rainfall doesn't decrease too markedly.

Experiments have generally shown that elevated concentrations of CO_2 significantly decrease leaf nitrogen content (but not necessarily total plant nitrogen), increase easily-digested non-structural carbohydrates such as sugars and starch, but cause little change in digestibility in those species studied so far (Lilley *et al.* 2001). The implications of these changes differ between production systems. In production systems with high nitrogen forage (e.g. temperate pastures) the effects of CO_2 are likely to increase energy availability, increasing both nitrogen processing in the rumen and livestock productivity. In contrast, in chronically nitrogen deficient situation (many rangelands for part of the year), the effect of CO_2-induced nitrogen dilution may be to exacerbate the existing problems of low livestock productivity. This effect may be compounded if there is concurrent warming as warmer conditions tend to decrease digestibility and nitrogen content in tropical species (Wilson 1982). Such warming trends will also substantially increase the frequency of heat stress days, particularly in tropical climates, reducing productivity, decreasing reproductive rates, increasing mortality and increasing concerns about animal welfare in intensive livestock handling activities such as live sheep exports (Howden *et al.* 1999). The correlation of heat stress tolerance and lower productivity breed characteristics means that the search for effective adaptation to more heat stress will be challenging. In contrast, rising temperatures, in particular minimum temperatures, may result in a reduction in the frequency and severity of cold-stress events, such as conditions which foster high lamb mortality, although research to further understand this interaction has been limited.

Reductions in rainfall and increases in evaporation rates may combine to make surface water more scarce in many rangelands. Even where there is water available, higher temperatures are likely to increase water consumption by livestock, limiting the distance foraging takes place from watering points with consequent higher risks for sustainable management and reduced production.

During periods of decreased rainfall and plant-cover, rangelands become highly susceptible to soil erosion. This process serves to reduce pasture productivity through loss of valuable soil nutrients (Hall *et al.* 1998). In areas where climate models simulate increases in extreme daily rainfall, in conjunction with reductions in annual rainfall amounts, soil erosion may become an increasingly important management consideration.

The incidence and distribution of pests and diseases is likely to alter with climate change. Examples include the possible southward expansion of the insect vector of blue-tongue disease in Australia (*Culicoides wadia),* of bush ticks and of tropical parasites (Sutherst 1990, 2001).

There is a general expectation that there will be a loss of plant community integrity with climate change. This alteration in community composition may arise via expected changes in range of C_3 and C_4 species under global change, substantial differences in CO_2 responses by different species and change in the factors such as fire, which influence species survival and competition. In addition, there are predictions of accelerating invasion by 'alien' plants. For example, Prickly Acacia (*Acacia nilotica*) may expand southwards and into more arid lands than it currently occupies (Kriticos *et al.* 2003). The consequences for animal production from rangelands are generally negative, since highly palatable species are typically not among the successful invaders. The consequences for the conservation of rangeland biodiversity could be dire.

HOW CAN RANGE MANAGERS ADAPT TO CLIMATE CHANGES?

Even under the most optimistic scenarios of future greenhouse gas emissions reductions, the need for adaptation is now a given, since some processes of climate change are already underway, and the atmospheric concentrations of greenhouse gases will continue to rise even if emissions are substantially reduced. It is not a foregone conclusion that a warmer world will overall be worse for Australian rangelands, but in the process of transition, which is likely to last for centuries, significant changes in location and practice may be required. Gradual adaptations, such as a shift to breeds with greater temperature tolerance, and shifts in the mix of land use practices in given regions, are likely to take place with little policy intervention beyond support for research and extension, since they are not qualitatively different from the adaptations routinely faced by pastoralists in tracking market and technology trends and decadal shifts in climate. With increased rainfall variability and potentially more persistent El Niño like conditions under climate change, it would seem appropriate that rangeland managers be more proactive in managing current climate variability through tracking forage supply and forage budgeting or increased use of seasonal climate forecasts. However, more substantial and rapid climate changes may require more active policies so as to limit negative impacts. It is important to ensure that policy goals are periodically reviewed and re-set appropriately, for example, varying policies from industry support to industry restructuring (Scholes and Howden 2003).

The direct impacts of climate change on Australian agriculture will be the result of the combined effect of CO_2 increases, temperature increases, changes in evaporation and changes in the mean, variability and intensity of rainfall. It will be the integrated impacts of these changes that we will need to adapt to – either to counter negative impacts or take advantage of positive ones. These adaptations can be thought of as being applicable at different spatial scales, for example, national policy level or farm-level. Some of these adaptations are outlined below.

Table 1. National-scale climate change issues and suggested policy activities to enhance adaptation (Howden *et al.* 2003).

Issue	Action
Policy	Establish linkages to existing initiatives to enhance resilience
Managing transitions	Provide support during transitions to new systems
Communication	Develop industry-specific and region-specific information
R&D and training	Use a participatory approach to improve self-reliance and provide the knowledge base for adaptation
Model development and application	Develop systems modelling to integrate and extrapolate anticipated changes
Climate data and monitoring	Maintain data collection to link into ongoing evaluation and adaptation
Seasonal climate forecasting	Communicate to allow incremental adaptation when linked to other information
Breeding and selection	Support programs and ensure access to global gene pools
Pests, diseases and weeds	Enhance quarantine measures, sentinel monitoring and management
Water	Establish trading systems that allow for climate variability and climate change, improve distribution systems, develop water management tools and technologies
Landuse change and diversification	Undertake risk assessments and support rational changes

National and regional adaptation - developing more resilient systems

The high levels of uncertainty in future climate changes suggest that rather than try to manage for a particular climate regime, we need more resilient rangeland systems (including socio-economic and cultural/institutional structures) to more flexibly and rapidly cope with a broad range of possible changes, for example changes in global markets or a major new pest or weed may have far more impact on the rangelands than climate change. There is a substantial body of both theory and practice on resilient systems (e.g. Gunderson *et al.* 1995). However, enhanced resilience usually comes with various types of costs or overheads such as building in redundancy, increasing enterprise diversity and moving away from systems that maximise efficiency of production at the cost of broader sustainability goals. One approach to developing more resilient rangeland regions is to develop an adaptive management strategy where policy is structured as a series of experiments which have formal learning and review processes. However, this could provide a serious challenge to some rangeland institutions which are based on precedent (and hence only look 'backwards' not 'forward'), have a short-term focus only and which are risk averse (see Abel *et al.* 2002). Nevertheless, there is a large range of policy activities which could be undertaken which will enhance the capacity of Australian agriculture to deal with a changing climate (Table 1).

The options for biodiversity management in the rangelands of the future are currently mostly speculative. The optimal distribution of protected areas may have to be re-thought, with greater emphasis on their resilience in the face of climate change and exotic invasions, and greater emphasis on maintaining the existing conservation estate, particularly in 'refuge' areas. Existing conservation management activities may need reinforcement, with more consideration taken of climate vulnerability and increasing attention will be needed to manage for conservation on the 'matrix lands' between protected areas (van Jaarsveld *et al.* 2003). 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. *Ex situ* conservation is a strategy of last resort, but may be a necessary insurance policy for a few iconic species (Dunlop and Howden 2003).

Farm level adaptation – managing climate change risks

In addition to policy settings that could facilitate adaptation, there are many farm-level adaptations that could be undertaken (Table 2). Again, these are not markedly different from those strategies used to manage climate variability and fluctuating markets, although the emphasis can differ. As first noted by McKeon *et al.* (1993), one strategy to incrementally adapt to climate changes may be achieved by altering management according to seasonal climate forecasts.

In order for adaptation to climate change to be successful, it will need to incorporate both pre-emptive and reactive adaptive strategies and will need to occur in conjunction with already changing social, economic and institutional pressures. With this in mind, adaptation measures aimed at mitigating the negative impacts of climate change will have to reflect and enhance current 'best-practices' designed to cope with adverse conditions such as drought. Whilst a range of technological and managerial options may exist as indicated in Table 2, the adoption of these new practices will require: 1) confidence that climate changes several years or decades into the future can be effectively predicted against a naturally high year to year variability in rainfall that characterises these systems, 2) the motivation to change to avoid risks or to use opportunities, 3) development of new technologies and demonstration of their benefits, 4) protection against establishment failure of new practices during less favourable climate periods; and 5) alteration of transport and market infrastructure to support altered production (McKeon *et al.* 1993). 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.

One pathway forward is to develop knowledge via participatory processes at both farm and institutional levels (e.g. Abel *et al.* 2002). Participatory approaches are useful as they deal directly with the key concerns of the owners of the problems, draw on their valuable expertise and also contribute to enhanced knowledge in the rangeland community. In terms of assessing the future productivity and sustainability of rangelands as part of such participatory research processes, rainfall and its variability are the most important climate variables. Reduction in the uncertainty surrounding their future state is a high priority but there will remain high uncertainty for rainfall projections because of the irreducibly chaotic nature of some of the processes. Hence, a probabilistic approach based on risk assessment is likely to be necessary for the foreseeable future. For policy analyses, such risk-based approaches need to be extended to include key driving factors such as population growth and projected increasing demand for meat, milk and other livestock products.

Table 2. Farm level adaptations to manage risks of climate change (from Howden *et al.* 2003).

Managing climate change risks –pasture productivity and grazing pressure
Selection of sown pastures better adapted to higher temperatures and water constraints
Provision of additional nitrogen through sown legumes
Provision of urea and phosphates directly to stock via reticulation or blocks
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
Managing climate change risks – managing pests, disease and weeds
Improve pest predictive tools and indicators
Improve quantitative modelling of 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
Managing climate change risks – animal husbandry and managing health
Selection of animal lines that are resistant to higher temperatures
Modify timing of mating based on seasonal conditions
Modify timing of supplementation and weaning
Increase use of trees as shading and reducing wind erosion

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