PROCEEDINGS OF THE AUSTRALIAN RANGELAND SOCIETY BIENNIAL CONFERENCE
Official publication of The Australian Rangeland Society

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For example:

Anderson, L., van Klinken, R. D., and Shepherd, D. (2008). Aerially surveying Mesquite *(Prosopis* spp.) in the Pilbara. *In*: 'A Climate of Change in the Rangelands. Proceedings of the 15th Australian Rangeland Society Biennial Conference'. (Ed. D. Orr) 4 pages. (Australian Rangeland Society: Australia).

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CLIMATE CHANGE IMPACTS ON RANGELAND LIVESTOCK CARRYING CAPACITY: MORE QUESTIONS THAN ANSWERS

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INTRODUCTION

Climate change has been identified as a major issue for Australia's rangelands. The *Garnaut Interim Climate Change Review* highlighted the risk that Australia, with an 'already hot, dry and variable' climate, faces under global warming. Large trends in rainfall and temperature have been occurring, particularly since the 1970s, with a general increase in rainfall in the north-western rangelands and a decrease in eastern Australia. The CSIRO and the Bureau of Meteorology have recently (CSIRO 2007) detailed climate change projections for regions of Australia, including changes in CO_2, temperature, rainfall, rainfall intensity, solar radiation, humidity, wind and potential evaporation at annual and seasonal timescales. These projections consider a range of greenhouse emission scenarios, time periods (2030, 2050, 2070) and sensitivities to global warming. The challenge for rangeland science is to assess these projections in terms of impacts on rangeland grazing systems and their management.

Livestock (mainly cattle and sheep) carrying capacity (LCC) is a major determinant of production ($/ha), resource condition and property viability. Many studies have indicated that spatial variation in LCC is strongly related to interactions of land-type attributes (e.g. soil properties and tree density) and climatic variation. Climate factors and CO_2 interact with land-type attributes to affect pasture and shrub growth. Similarly, land-type and climate factors affect potential pasture utilisation, animal production per head (liveweight gain and wool), choice of breed, enterprise type, animal husbandry and supplementation, calendar of operations, and the impact of grazing on resource components such as cover, soil erosion, fire frequency and pasture species composition.

A risk management framework is being developed by QCCCE (G. Stone and D. Cobon unpublished) to assess the potential impact of climate change on the grazing industry at a regional scale. Current work has identified the importance of quantifying the current and potential impacts of climate change projections. A difficulty in risk assessment is that climate factors such as increasing temperature can have opposing effects on both pasture growth and animal nutrition. For example, at locations where there is winter rainfall and/or occurrence of frosts, higher temperatures can increase the length of the growing season and improve pasture/diet quality. In contrast, increasing temperatures in the growing season can increase evaporative demand, reducing forage yield and decreasing pasture digestibility.

To address these complex issues, simulation models have been developed to estimate the effects of climate variability and projected climate change on pasture growth and other components of the grazing system. These models represent an important distillation of rangeland science conducted since the 1930s through pasture growth studies (e.g. Elderslie, north-western Queensland in 1935) and grazing trials (e.g. Gilruth Plains, south-western Queensland in the 1940s). A perceived strength of the models is their ability to explain much of the current spatial variation in key attributes, particularly LCC (Crimp *et al.* 2002). However, a weakness is that many of the climate change projections involve climate factors and CO_2 concentrations outside current experience leading to uncertainties in predicting how different species of plants and animals will respond to future unprecedented climate change. In this paper, we briefly review: 1) the grazing system from a climate impact perspective; 2) models of livestock carrying capacity; and 3) possible adaptation responses to climate change.

THE GRAZING SYSTEM FROM A CLIMATE IMPACT PERSPECTIVE

The grazing system is underpinned by flows of water, nutrients and carbon with different land-types and landscapes having large effects on hydrology, production, and risk of resource damage. Many of the components of the grazing system are, in turn, influenced by a range of climatic factors.

The components of the water cycle are rainfall, runoff, run-on, infiltration, through-drainage, transpiration from pasture, shrubs and trees, and soil evaporation. Infiltration is determined by rainfall amount and intensity interacting with surface cover and soil surface condition. Soil condition can be influenced by tussock basal area and soil fauna which are strong affected by soil moisture and temperature. Transpiration and soil evaporation are determined by (and in turn affect) soil water availability and evaporative demand (potential evaporation). Grazing management affects the water cycle, through surface cover, surface soil condition, fire frequency, and pasture and tree composition.

The flow of carbon (or dry matter) includes the processes of growth, senescence, detachment, trampling, litter decomposition and animal intake. Plant growth is determined by the interaction of CO_2, solar radiation, soil water availability, temperature, humidity and wind. Nutrients (e.g. nitrogen and phosphorus) are commonly limiting factors for pasture growth in natural systems. Senescence is determined by temperature (frosts or extreme high temperatures), soil water deficits and humidity (e.g. fungal attacks). Detachment and trampling are affected by rainfall, wind and photo-degradation. The type of plant tissue (leaf or stem) is determined by growth conditions with more stem produced at high temperatures. Litter decomposition, including consumption by soil fauna, is affected by moisture, temperature and photo-degradation. Diet quality (digestibility, nutrient concentration) which affects animal intake is determined by both growth and senescence processes with better pasture growing condition leading to lower pasture quality through nutrient dilution. Animal intake is also influenced by grazing behaviour in response to wind, shade and distance from water. Nutrient availability (e.g. nitrogen mineralisation) is influenced by temperature and soil moisture.

The importance of palatable perennial grasses and shrubs in natural grazing systems has long been recognised as a necessary component to provide: dry season and drought feed; fuel for fires where appropriate; and surface soil protection and infiltration capacity. Annual species have dormant seed banks capable of surviving the extremes of climate (e.g. high soil temperatures and long drought periods). In contrast, perennial grass and shrub species rely on the survival of buds and existing root systems. The capability of existing species to survive unprecedented extremes of temperature and desiccation needs to be monitored (e.g. Orr and Phelps 2006).

Simulation models have been developed over the last 50 years to quantify the relationships between climatic elements and flows of water, carbon and nutrients considering the interactions with land-type attributes and grazing management. These models have been developed incrementally based on detailed research of individual processes. The fact that these models explain to some extent the effects of spatial variation in climate suggests that they can be used to quantify the effects of climate change.

The AussieGRASS model (Carter *et al.* 2000) is a comprehensive parameterisation of pasture communities across Australia's grazing lands. Pasture parameters include temperature response, potential growth rates, transpiration efficiency, and minimum nitrogen concentration for plant growth. These parameters were derived by calibrating the model output with observed time series of green cover (measured by NDVI) and estimates of standing dry matter using the rapid mobile data collection method developed by Hassett *et al.* (2000). Crimp *et al.* (2002) found that some model parameters could be related to climatic elements. For example, the minimum temperature required for pasture growth was correlated with temperature of the wettest quarter of the year. These relationships have been used to predict likely changes in pasture composition response. However, major uncertainties exist regarding the effect of CO_2 on plant growth, diet quality, and tree-grass balance. Furthermore, the potential variation in plant species response in native grasslands provides a major challenge in predicting the impact of climate change, especially given the limited number of measurements on the effects of increased CO_2 (Stokes *et al*. 2005).

MODELS OF LIVESTOCK CARRYING CAPACITY

Livestock carrying capacity (LCC) is a major determinant of the gross value of production from livestock systems. Considerable progress has been in calculating LCC from land-type attributes and climatic components. Fundamental to these approaches is the high correlation between pasture growth and LCC. LCC has been assessed from individual benchmark properties, surveys, expert knowledge, regional estimates and shire statistics (e.g. McKeon *et al.* 2008). LCC integrates a wide range of factors such as management of climatic variability, land-type fragility and resilience, and animal nutrition.

LCC in northern Australia is strongly limited by the length of the pasture growing season. A measure of the length of the growing season has been developed from simulation models described in the previous section. A pasture growth index is calculated by multiplying indices of available soil water, temperature and solar radiation. A simulated variable 'percentage of days a pasture growth index exceeds a threshold' (%GI-days) has been correlated with cattle liveweight gain in the black speargrass (combining north-eastern, central coastal and south-eastern Queensland data). Similarly, %GI-days was correlated with wool production from grazing trials from north-western to south-western Queensland. Thus the index, %GI-days, provides an integration of climatic factors affecting availability of pasture material capable of supporting higher animal nutrition and thus livestock carrying capacity. In turn, the above studies emphasise the importance of seasonal distribution of rainfall for both animal nutrition and potential pasture utilisation. Climate change projections of reduced winter and spring rainfall are likely to reduce the length of the growing season and place greater emphasis on winter/dry season nutrition.

McKeon *et al.* (2008) have shown that the index, %GI-days, is highly correlated with LCC, at a Statistical Division scale, across all of Australia's grazing lands including Statistical Divisions with high inputs of sown pastures and fertiliser. Multiple regression analysis indicated that tree density was also a significant contributing factor, especially in south-eastern Australia. The study also indicated that year-to-year climate variability was highly correlated with LCC at a Statistical Division scale, essentially comparing the large Statistical Divisions of inland Australia with the less climatically variable coastal Statistical Divisions. Other studies have indicated that the use of a more conservative LCC is a likely adaptation response to environments with high year-to-year variability in rainfall.

ADAPTATION RESPONSES TO CLIMATE CHANGE AND RISKS OF DEGRADATION

The above and other studies show that relatively simple indices of climate can explain a high proportion of spatial variation in LCC and animal production. However, the current distribution of LCC and animal production represents the result of over 100 years of incremental genetic and husbandry improvement to find the best adapted breeds and practices. The results of these successful adaptation processes are implicit in the climate-based relationships described above. The application of these relationships with projected climate changes indicates the likely result of 'adaptation' (e.g. in changing LCC), but does not indicate how the adaptation process may occur. Nevertheless, the risk management process being developed by QCCCE provides an approach for formally considering the risks that may occur and the need for adaptation responses.

The stocking rates and associated grazing management practices used by graziers on a year-to-year basis are important determinants of the risk of degradation and the rate of resource recovery. The interactions of stocking rate (including grazing pressure from other herbivores), economic factors (prices, costs) and climatic variability have led to major degradation episodes in rangelands over the last 100 years. Thus, the evaluation of different stocking rate strategies in terms of resource degradation is an important component of calculating the impact of climate change and developing adaptation responses.

An analysis of historical degradation and recovery episodes in rangelands has indicated the importance of components of the climate system affecting rainfall at different timescales. Climate phenomena such as the El Niño Southern Oscillation, and quasi-decadal and inter-decadal variability in sea surface temperatures and atmospheric pressures have had major impacts on variability in rainfall driving the ‘cycle’ of degradation and (partial) recovery. However, there is still much uncertainty with regard to current and future drivers of climatic (rainfall) variability in the rangelands. To some extent, the observed LCC in different regions represent an ‘adaptation’ over the last 100 years to this high year-to-year climate variability. A sustainable LCC minimises the proportion of years with likely resource damage and maximises the opportunity for resource recovery. However, in eastern Australian rangelands, a component of the perceived resilience of the resource can actually be attributed to the combination of La Niña years and the cool phase of Inter-decadal Pacific Oscillation. Hence, the future (but uncertain) frequency of these events will have important implications for LCC in eastern Australia.

In the presentation, major issues being encountered in climate change impact studies in the rangelands will be reviewed, including the adequacy of biophysical models of grazing systems; the linkage of biophysical models with climate change projections; assessment of the importance of quasi-decadal and inter-decadal climatic variability, and human-induced forcings other than greenhouse emissions; and adaptation responses needed for uncertain climatic and economic futures.

ACKNOWLEDGEMENTS

We gratefully acknowledge the support and insights of C. Stokes, L. Pahl, G. Whish, N. Flood, D. Bruget, N. Toombs, D. Cobon, A. Peacock, K. Day, B. Zhang, N. Treloar and T. Van Bruggen. The senior author is funded by a Land & Water Australia Senior Research Fellowship.

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