# PROCEEDINGS OF THE AUSTRALIAN RANGELAND SOCIETY BIENNIAL CONFERENCE

**Official publication of The Australian Rangeland Society**

## Copyright and Photocopying



## Form of Reference

The reference for this article should be in this general form;
Author family name, initials (year). Title. *In*: Proceedings of the nth Australian Rangeland Society Biennial Conference. Pages. (Australian Rangeland Society: Australia).
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 15$^{th}$ Australian Rangeland Society Biennial Conference'. (Ed. D. Orr) 4 pages. (Australian Rangeland Society: Australia).

## Disclaimer



The Australian Rangeland Society

# ADAPTING GRAZING MANAGEMENT TO CLIMATE CHANGE AND SEASONAL FORECASTING

*G.M. McKeon [1] and S.M. Howden[2]*

[1]Pasture Management Branch, Queensland Department of Primary Industries, GPO Box 46, Brisbane Q 4001.
[2]Bureau of Rural Resources, PO Box E11, Queen Victoria Terrace, ACT 2600.

**ABSTRACT**

Over the past 100 years, reactive methods have been developed to manage rangelands by adjusting herd/flock numbers and property size, and using better husbandry practices. However, reactive approaches to drought for example, have the risk of causing irreversible land and pasture degradation before management adjustments can be made. We now face the problem of adapting grazing management to cope with climate change where the direction and magnitude of the change is uncertain. We suggest that, in Queensland, seasonal forecasting has reached sufficient skill that it can contribute as a pro-active tool in adapting to climate change.

## INTRODUCTION

The likelihood of climate change as a result of increasing greenhouse gas concentrations (Pearman 1988) has important consequences for grazing management in terms of production and sustainable land use. The future management of rangelands requires an evaluation of the impact of climate change. In this paper we examine:

(1) current climatic effects on northern Australian rangelands;
(2) impact of past climatic variability and the estimation of safe stocking rates;
(3) adapting management decisions to cope with climate change.

## 1. Current climatic effects on northern Australian rangelands

The major land use of northern Australia is pastoralism based on beef cattle and sheep grazing in a variety of ecosystems. Both animal and economic production in pastoral systems are dependent on plant production, the two main effects on animal production being pasture growth (kg/ha/year) and the length of the pasture growing season (McCown 1980, Mott *et al.* 1985, McCaskill 1991). Pasture growth determines stocking rate (animals/ha) with pasture utilisation (proportion grown that is eaten) varying from 10-50% (Burrows *et al.* 1990). Animal growth (liveweight gain) requires levels of energy and protein usually only satisfied while the pasture is growing and hence climate, through its effect on the length of the growing season, has a strong effect on animal nutrition.

Both plant production and its seasonal distribution are determined by the interaction of climate and soils. Climate change will have direct effects on plant and animal production and hence prediction of these impacts requires an understanding of the current climatic effects on production. Geographic analyses of rangeland productivity has concentrated on the climate limitations (moisture and temperature) to plant growth. Changes to these limitations could occur by increasing $CO_2$ concentrations and/or global warming (Jones 1991, Plummer 1991), including possible increased rainfall in the summer rainfall regions of Australia (Whetton and Pittock 1991). The role of nutrients (nitrogen, phosphorus) limiting plant and animal production will become increasingly important if these changes occur. Because of the restricted growing season in rangeland environments, the quality of dry carry-over plant material is important for dry season/winter production. Changes in climate or $CO_2$, which cause increased plant growth but do not change the length of the growing season, are likely to result in dilution of limiting nutrients and hence lower quality feed.

Our capacity to predict the impact of future climate/atmospheric change on rangelands is limited by the lack of information on soil nutrients, their effects on plant growth, senescence and animal diet quality, and the impact of climate change on nutrient cycling. For Queensland's grazing lands we are just beginning to link the data banks of soil attributes to plant and animal models. When combined with climate change scenario's (e.g. Whetton and Pittock 1991) the likely changes in productivity and management can then be calculated. With these methods, the best management decisions can be derived from a wider and longer experience than is otherwise available to graziers or their advisers. However, the view that the best management decisions can be derived from past experience (whether in practice or from simulation with the last 100 years rainfall) is now being challenged because of the likelihood of climate change.

## 2. The impact of past climatic variability.

In Queensland, the pastoral areas are located in climatic zones with large differences between years in the duration and amount of rainfall. Variability of annual rainfall is high, with the co-efficient of variation ranging from 25% in south-east Queensland to 45% in western Queensland. A major meteorological cause of year-to-year variation is the Southern Oscillation with droughts usually associated with El Niño events and high rainfall with La Niña events (Nicholls 1990). Periods of well above and below average rainfall have occurred on a generation timescale (Russell 1981). For a range of stations in Queensland the period 1917-1946 had summer (November-April) rainfall 6% below the 100 year average in contrast to the period 1947-1976 when rainfall was 9% above average. These changes in average rainfall are similar to those simulated by global circulation models for a future doubling of $CO_2$ (Whetton and Pittock 1991).

The first wave of graziers in Queensland did not have rainfall records or any other way of estimating safe carrying capacity. It is only from a position of hindsight that it is possible to say that climatic conditions were above or below average. One hundred years later we can put past events in perspective, for example `in 1902 70% of Queensland had rainfall less than decile one'. We now may be in a similar position of `climatic ignorance' if some of the greenhouse climate scenarios actually occur in the next thirty years and beyond.

This short experience of pastoralism in northern Australia (less than 150 years) has also contributed to the problems of management. There have been combinations of climatic events (for example, droughts) and management (for example, high stocking rates), which have resulted in changes in pasture composition. These may occur only once in a manager's working lifetime. Examples of these type of events are the change from *Themeda triandra* to *Heteropogon contortus* in the 1870s and 1880s in South-east Queensland (Shaw 1957, Logan 1988) and the change from *Heteropogon contortus* to *Bothriochloa pertusa* in northern Queensland in the 1980s (Howden 1988, Gardener *et al.* 1990).

The above examples highlight the problems of pastoralism in a highly variable climate. In each case it was not possible to detect unfavourable changes in pasture composition and resource productivity until it was too late. The normal variability of drought and flood made it difficult to distinguish climate and man-made induced changes, so that poor or unsustainable management decisions could not be corrected in time. From the above studies, we conclude that pastoralism has been particularly susceptible to climatic variability when (1) a few years of high rainfall have biased expectations towards high stocking rates (e.g. the 1890s) or (2) high stocking rates have been forced on graziers by economic pressures such as reduced prices for stock (the mid 1970s).

The above examples of the interaction of climatic variability and management have shown the importance of historical ecological analysis. We have taken published explanations of these changes 'at face value'. However, as other authors have shown (e.g. Mitchell 1991) such historical analysis can be misleading because detailed scientific observations were not made. Current pasture ecologists have the opportunity to document changes as they occur (e.g. the invasion of *Acacia nilotica* in Queensland, Burrows *et al.* 1990, Carter *et al.* 1992). If managers are to avoid the mistakes of the past, they will require more immediate warnings of deleterious changes or provide opportunities for resource improvement. To provide these warnings, Queensland Department of Primary Industries has established a Drought Group to monitor the spatial distribution of drought and forecast regions at risk of land and pasture degradation.

**Estimating safe stocking rates**

The key issue in rangeland management is the choice of stocking policy. Recent advances in pasture ecophysiology and simulation modelling have led to a systems based approach to address the problem of estimating safe stocking rates (Gillard and Monypenny 1990, McKeon *et al.* 1990). Analyses of stocking rate experiments on native pastures indicate that perennial grasses decrease in basal cover when pasture consumption exceeds 30% of pasture growth in below average growing seasons (McKeon *et al.* 1990). Utilisation of less than 30% of growth is thus regarded as `safe stocking'. Heavy grazing during `dry' growing seasons substantially reduces perennial grass density and soil cover. Where graziers attempt to stock the same number of animals each year to maintain a breeding herd or flock, substantial damage to the resource productivity is most likely to occur during extended dry periods, for example, the 1960s or 1980s.

Simulation models of grazing systems allow stocking rate options to be examined and decision rules to be formulated. The model GRASSMAN (Clewett *et al.* 1991) simulates grass production, perennial grass density and beef production using historical (1880-1990) rainfall records. Simulation studies for northern Queensland (Charters Towers) show that the optimal stocking rate on a cleared pasture for beef production (kg LWG/ha) varied three fold between decades, e.g. 1900s compared to 1890s. The studies also indicated that over the 110 years simulated, the optimal constant stocking rate was one which was `safe' in 80% of years. A similar conclusion has been reached by Gillard and Monypenny (1990) after simulating the response of a beef cattle herd to variability in rainfall.

However, even the 100 years of accessible historical records may be misleading for estimating safe stocking rates. In northern Queensland, reconstruction of river flow from analysis of coral bands (Stewart *et al.* 1989) suggests that the last 100 years has had favourable rainfall compared with the period 1770 to 1880. The lower pasture production which would occur under these climatic conditions would increase (1) the difficulties of economic survival for existing enterprises and (2) the risk of land degradation. While stock numbers must eventually come into balance with pasture production the period of adjustment and re-evaluation of safe carrying capacity is one of increased risk of both over stocking and irreversible resource degradation due to soil erosion and woody weed invasion.

Current surveys of Queensland's grazing lands (Tothill and Gillies 1991) suggests that a proportion (20%) of the grazing resource was in a degraded condition and was not able to be economically restored. Similar trends appear to be occurring throughout the world's rangelands (Mabbutt 1984). Such studies show the difficulty that climate change and variability cause for pasture management decisions. The previous ten years experience of rainfall (e.g. the 1970s) has little relevance for the next ten years (e.g. the 1980s). Alternatively, the long-term view based on 100 years of rainfall records may be irrelevant given (1) the importance of episodic events producing irreversible resource damage (e.g. 1899-1902), (2) the doubtful stability of climate on a generation time scale (1917-1946 compared to 1947-1976) and (3) predicted climatic change.

## 3. Adapting management decisions with seasonal forecasting

The possible effects of climate and atmospheric change on extensive grazing industries have been speculated upon elsewhere (Graetz *et al.* 1988, McKeon *et al.* 1988, Russell 1991, McKeon and Howden, 1992). However such speculations may be of doubtful value given (1) the empirical basis of existing models of grazing systems (McKeon *et al.* 1990), and (2) the lack of knowledge of the interaction of climate and $CO_2$ on plant growth (Newton 1991). If agricultural scientists are to improve their ability to predict the consequences of climate change, then the existing models of grazing systems will require a better representation of the environmental interactions (e.g. climate, $CO_2$ and soil fertility) and further research to validate the predictions.

Given the uncertainty of future climate change, it is necessary to formulate both reactive and predictive management rules. For example, in western Queensland, where there is a high frequency of periods without pasture growth, grazing experiments have demonstrated the value of reactively adjusting stocking rates at the end of each growing season so as to use a safe (for example 30%) proportion of known feed supply (Beale *et al.* 1986, Orr *et al.* 1986).

Such an approach of reactive stocking rate management is likely to be successful in an environment where the probability of extended droughts (about 1 year) is high. Recent developments in seasonal forecasting have shown that the probability of drought varies from year-to-year depending on phases of El Niño/Southern Oscillation, (Pittock 1975, Nicholls 1990), sea surface temperature (Simmonds and Rocha 1991) and behaviour of the high pressure belt at mid latitudes (Pittock 1975). Thus it is likely that decisions on stock and pasture management can be improved by including the increasing knowledge of the causes of year-to-year variability. We are now at the stage of examining the biological and physical impacts of decisions using seasonal forecasts (McKeon *et al.* 1990, Willcocks *et al.* 1991, Hammer *et al.* 1991). The next stage is the economic evaluation of forecasts with whole property/herd models (Holmes 1990, Gillard and Monypenny 1990, Foran and Stafford Smith 1991).

However, where strategic stocking policies are adopted, for example a constant stocking rate which resulted in pasture utilisation being safe (less than 30%) in 80% of years, then there is only a small proportion of years (10-20%) where forecasts can be useful. Where resource damage is reversible then the value of unreliable forecasts is debatable and can be assessed only by sound economic models.

The calculation of strategic stocking policy requires assumptions about future climatic conditions on a 30-100 year time scale. For want of better knowledge the usual assumption has been to use a climatic record as long as possible i.e. usually back to 1880s. However, this assumption must now be questioned given the prospect of global warming and evidence from historical analyses of climate change (Stewart *et al.* 1989). The simulations of future climate provided by General Circulation Models are still classed as 'scenario's'. A major source of uncertainty is the future behaviour of ocean currents, especially El Niño, which are so important in determining rainfall in Australia's rangelands. Hence, the role of seasonal forecasting as a tool for revealing the future climate trends, albeit slowly, year-by-year, becomes more important than just the economic fine-tuning of existing management practices.

In Queensland, the demand for better seasonal forecasting has resulted in improvements of the current climate 'outlooks' based on simple correlations between rainfall and the Southern Oscillation Index. Stone and Auliciems (1991), and Nicholls (1985, 1992) have demonstrated the importance of the phase and trend in the SOI as a forecasting tool. Furthermore, Russell *et al.* (1992) have shown that combined predictors of SOI and sea surface temperature can substantially increase forecasting skill. Simulations with GCM models, using current sea surface temperatures, are providing more mechanistically based forecasts (N. Nicholls, personal communication; Folland *et al.* 1991; Simmonds and Rocha 1991; Hunt 1991).

Should climate change occur as a result of more frequent El Niño or La Niña events or other circulation changes (Folland *et al.* 1991), then linking management decisions to seasonal forecasts would allow managers to 'drift' in the correct direction. Such an approach, over the last hundred years, would have avoided the over-grazing and resource damage during the severe El Niño events that occurred in (1) the 1870s and 1880s, (2) 1899-1902, and (3) in the 1980s. Similarly, linking decisions such as pasture burning to the occurrence of La Niña's (1890s, 1950s, 1970s) would have allowed woody weed control in areas where burning has been regarded as a risky management tool (Willcocks *et al.* 1991).

## CONCLUSION

The calculation of the 'best' stocking rate remains the major issue for managers. Safe, constant stocking rates can only be derived in hindsight and hence are unlikely to be correct in a changing climate, resulting in either under-utilisation or over-grazing of the pasture. In contrast, strategies based upon seasonal forecasting will be able to adapt to a changing climate as forecasting skills improve in line with our understanding of climatic processes.

We expect that the future breakthroughs in land management will come if the skill in seasonal forecasting is improved to a level where managers can apply forecasts in their planning. Given the importance of seasonal forecasting both for current and future land management it is unfortunate that current funding has concentrated on scenarios related to the enhanced Greenhouse effect rather than the problems of seasonal forecasting. The latter problems will have to be resolved eventually for credible simulations of regional effects of global warming.

The challenge for research then is to find and demonstrate the land management, animal husbandry and financial practices which can take advantage of current and future forecasting skill.

## REFERENCES


Beale, I.F., Orr, D.M., Holmes, W.E., Palmer, N., Evenson, C.J. and Bowly, P.S. 1986. The effects of forage utilization levels on sheep production in the semi-arid south-west of Queensland. *Rangelands, a resource under siege*. (Eds. P.J. Joss, P.W. Lynch and O.B. Williams.) p.30, Australian Academy of Science, Canberra.

Burrows, W.H., Carter, J.O., Scanlan, J.C. and Anderson, E.R. 1990. Management of savannas for livestock production in north-east Australia: contrasts across the tree-grass continuum. *Journal of Biogeography*. **17**:503-512.

Carter, J.O., Jones, P. and Cowan, D.C. 1992. Control of woody weeds in western Queensland. Report to the Australian Wool Corporation. Queensland Department of Primary Industries, Brisbane. pp.74.

Clewett, J.F., Cavaye, J.M., McKeon, G.M., Partridge, I.J. and Scanlan, J.C. 1991. Decision support software as an aid to managing pasture. *Tropical Grasslands*. **25**:159-164.

Folland, C., Owen, J., Ward, M.N. and Colman, A. 1991. Prediction of seasonal rainfall in the Sahel region using empirical and dynamical methods. *Journal of Forestry*. **10**:21-56.

Foran, B.D. and Stafford Smith, D.M. 1991. Risk, biology and drought management strategies for cattle stations in Central Australia. *Journal of Environmental Management*. **33**:17-33.

Gardener, C.J., McIvor, J.G. and Williams, J. 1990. Dry tropical rangelands: solving one problem and creating another. *Proceedings of the Ecological Society of Australia*. **16**:279-286.

Gillard, P. and Monypenny, R. 1990. A decision-support model to evaluate the effects of drought and stocking rate on beef cattle properties in northern Australia. *Agricultural Systems*. **34**:37-52.

Graetz, R.D., Walker, B.H. and Walker, P.A. 1988. The consequences of climatic change for seventy per cent of Australia. *Greenhouse: Planning for Climate Change* (Ed. G.I. Pearman.) pp.399-420. CSIRO, Melbourne.

Hammer, G.L., McKeon, G.M., Clewett, J.F. and Woodruff, D.R. 1991. Usefulness of seasonal climate forecasts in crop and pasture management. In: `*Proceedings of Conference on Agricultural Meteorology*, Bureau of Meteorology, Melbourne. 17-19 July. pp.15-23

Holmes, W.E. 1990. Breedcow and Dynama. Herd Budgeting Spread-sheet Models, Queensland Department of Primary Industries.

Howden, S.M. 1988. Some aspects of the ecology of four tropical grasses with special emphasis on *Bothriochloa pertusa*. PhD thesis. Griffith University, Nathan. pp.224.

Hunt, B.G. 1991. The Simulation and prediction of drought. *Vegetatio* **91**:89-103.

Jones, P.A. 1991. Historical records of cloud cover and climate for Australia. *Australian Meteorological Magazine.* **39**:181-190.

Logan, D. 1988. *Where two rivers run: a history of Kilkivan Shire.* Kilkivan Shire Council, Kilkivan, Queensland. pp.483.

Mabbutt, J.A. 1984. A new global assessment of the status and trends of desertification. *Environmental Conservation.* **11**:103-113.

McCaskill, M.R. 1991. Prediction of cattle growth rates in northern Australia from climate information. In *Proceedings of Conference on Agricultural Meteorology,* Bureau of Meteorology, Melbourne. 17-19 July. pp. 85-88

McCown, R.L. 1980. The climate potential for beef cattle production in tropical Australia. Part 1. Simulating the annual cycle of liveweight change. *Agricultural Systems.* **6**:303-317.

McKeon, G.M., Howden, S.M., Silburn, D.M., Carter, J.O., Clewett, J.F., Hammer, G.L., Johnson, P.W., Lloyd, P.J., Mott, J.J., Walker, B., Weston, E.J. and Willcocks, J.R. 1988. The effect of climate change on crop and pastoral production in Queensland. In: *Greenhouse: planning for climate change.* Pearman, G.I. (Ed.) pp.546-563. CSIRO, Melbourne.

McKeon, G.M., Day, K.A., Howden, S.M., Mott, J.J., Orr, D.M., Scattini, W.J. and Weston, E.J. 1990. Management for pastoral production in northern Australian savannas. *Journal of Biogeography.* **17**:355-372.

McKeon, G.M. and Howden, S.M. 1992. Adapting the management of Queensland grazing systems to Climate Change in *"Climate Change: Implications for Natural Resource Conservation".* University of Western Sydney, Hawkesbury (in press).

Mitchell, P.B. 1991. Historical perspective on some vegetation and soil changes in semi-arid New South Wales *Vegetatio.* **91**:169-182.

Mott, J.J., Williams, J., Andrew, M.H. and Gillison, A.N. 1985. Australian savanna ecosystems. In: *Ecology and management of the world's savannas.* (Eds. by J.C. Tothill and J.J. Mott.) pp.56-82. Australian Academy of Science, Canberra.

Newton, P.C.D. 1991. Direct effects of increasing carbon dioxide on pasture plants and communities. *New Zealand Journal of Agricultural Research.* **34**:1-24.

Nicholls, N. 1985. Impact of the Southern Oscillation on Australian crops. *Journal of Climatology,* 5:553-560.

Nicholls, N. 1990. Predicting the El Niño-Southern Oscillation. *Search.* **21**:165-167.

Nicholls, N. 1992. Recent performance of a method for forecasting Australian seasonal tropical cyclone activity. *Australian Meteorological Magazine.* **40**:105-110.

Orr, D.M., Bowly, P.S., Evenson, C.J. 1986. Effects of grazing management on the basal area of perennial grasses in *Astrebla* grassland. *Rangelands: a resource under siege.* (Ed. by P.J. Joss, P.W. Lynch and O.B. Williams.) pp.56-57. Australian Academy of Science, Canberra.

Pearman, G.I. (Ed.) 1988. *Greenhouse; Planning for climatic change.* CSIRO, Melbourne. pp.752.

Pittock, A.B. 1975. Climate change and the patterns of variation in Australian rainfall. *Search.* **6**:498-504.

Plummer, N. 1991. Annual mean temperature anomalies over eastern Australia. *The Bulletin of the Australian Meteorological and Oceanographic Society.* **4**:42-44.

Russell, J.S. 1981. Geographic variation in seasonal rainfall in Australia - an analysis of the 80 year period 1895-1974. *Journal of the Australian Institute of Agricultural Science.* **47**:59-66.

Russell, J.S. 1991. Likely climatic changes and their impact on the northern pastoral industry. *Tropical Grasslands.* **25**:211-218.

Russell, J.S., McLeod and Dale, M.B. 1992. Combined southern oscillation index and sea surface temperatures as predictors of seasonal rainfall. *Proceedings of International COAD Workshop,* Boulder, Colorado (in press).

Shaw, W.H. 1957. Bunch spear grass dominance in burnt pastures in south eastern Queensland. *Australian Journal of Agricultural Research.* **8**:325-334.

Simmonds, I. and Rocha, A. 1991. Implications for Australian agriculture of winter Indian Ocean temperatures. In: *`Proceedings of conference on Agricultural Meteorology',* Bureau of Meteorology, Melbourne. 17-19 July. pp.32-35.

Stewart, B.J., Tickle, K.S. and Isdale, P.J. 1989. Reconstruction of Past Hydrological Data in the Burdekin River Basin. *Hydrology and Water Resources Symposium,* Christchurch, New Zealand. (in press).

Stone, R. and Auliciems, A. 1991. SOI phase relationships with rainfall in eastern Australia. *International Journal of Climatology.* (in press).

Tothill, J.C. and Gillies, C. 1991. Sustainability of the livestock production resources of the grazing lands of northern Australia. Report to Meat Research Corporation, Sydney. December 1991.

Whetton, P. and Pittock, A.B. 1991. Australian Region Intercomparison of the Results of some General Circulation Models used in Enhanced Greenhouse Experiments. CSIRO, Division of Atmospheric Research Technical Paper No. 21, pp.73.

Willcocks, J.R., McKeon, G.M. and Day, K.A. 1991. Using the Southern Oscillation Index to predict the growth of *Heteropogon contortus* pasture in south-east Queensland. In: *`Proceedings of Conference on Agricultural Meteorology',* Bureau of Meteorology, Melbourne. 17-19 July. pp.36-39.