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A REVIEW OF EIGHT MAJOR DEGRADATION EPISODES IN THE HISTORY OF AUSTRALIA'S RANGELANDS - CAN WE PREVENT THE NINTH?

G.M. McKeon [1], W.B. Hall [2], B.K. Henry [1], S. Power [3], G.S. Stone [1], J.I. Syktus [1] and I. Watson [4]
in collaboration with K.A. Day [1] and J.O. Carter [1]

[1] NRM&E, 80 Meiers Road, Indooroopilly, Qld 4068[1]
[2] Meat and Livestock Australia, PO Box 3514, South Brisbane, Qld 4101
[3] Bureau of Meteorology Research Centre, GPO Box 1289K, Melbourne, VIC 3001
[4] Department of Agriculture Western Australia and Centre for Management of Arid Environments,
PO Box 483, Northam, WA 6401

ABSTRACT

The paper describes lessons learnt from historical degradation episodes in Australia's rangelands. We have recently reviewed eight well-documented episodes and the processes that led to degradation and partial recovery. The dominant features of the degradation episodes were: a) an over-expectation of carrying capacity which damaged the rangeland resource during periods of favourable rainfall and intermittent drought; and b) multi-year sequences of severe and extended drought which revealed and further amplified degradation. We discuss what information sources are required by graziers, their advisers and governments to prevent the recurrence of these historical episodes. A major deficiency is the inability to predict severe and multi-year drought periods, especially droughts not associated with El Niño

INTRODUCTION

During the 150 years that Australia's rangelands have been used for grazing there have been many episodes of resource degradation and partial recovery. In a recently completed report (McKeon *et al.* 2004) we reviewed eight of these episodes in detail. These episodes were well documented in government inquiries and reports, as well as by graziers and the media of the day. From this analysis, we discuss the commonalities and the information systems that are required to aid decision-making in grazing management. We focus on the dominant impact of climate variability, the need for better climate information, and the emerging understanding of the climate system. These episodes provide a challenge to governments, resource managers, graziers and their advisers to reduce the impact of further episodes of degradation.

EVIDENCE OF DEGRADATION

Since 1956, the rangelands of Australia have continued to carry 8-14 million cattle and 18-40 million sheep (National Land and Water Resources Audit 2001). There have been major improvements in water distribution, property infrastructure, livestock genetics and animal supplementation. These management improvements and climatic variability can mask the impact of land degradation on livestock production. Nevertheless, we found that associated with some episodes, there were examples of permanent losses in livestock carrying capacity: Gascoyne, Western Australia after the 1930s (Williams *et al.* 1980); Cobar/Byrock in western NSW after the 1950s (Anon 1969); and south-west Queensland after the 1960s (Warrego Graziers Association 1988). In other episodes there were also examples of irreversible resource damage from soil erosion (e.g. Beadle 1948, Rogers *et al.* 1999).

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[1] The views expressed herein are those of the authors and do not represent a policy position of the Queensland Government or the Department of Natural Resources, Mines and Energy or any other agency.

The eight historical episodes identified are briefly described in Table 1.

Table 1. Regional degradation episodes in Australia's rangelands (from McKeon *et al.* 2004)

The extended drought period (EDP) associated with each degradation episode was calculated using rainfall aggregated to regions. For consistency, a standard 12–month period (1 April to 31 March) was used. The first year of the extended drought period was the first year in which rainfall was below 70% of the mean. The drought was considered broken when average to well-above-average rainfall occurred. For Episode 5 which involved woody weed infestation in the 1950s, the impact was not revealed until a later drought period in the 1960s.

Episode 1: 1890s in western NSW involving soil erosion, woody weed impact, rabbit plagues, substantial financial losses and financial hardship, and resulting in the Royal Commission of 1901. EDP: 1898/99 – 1902/03.

Episode 2: 1920/30s in SA and western NSW involving substantial loss of perennial vegetation and soil erosion, resulting in government legislation for regulation of carrying capacity. EDP: 1925/26 – 1929/30.

Episode 3: 1930s in Gascoyne region of WA involving substantial loss of perennial shrubs, soil erosion and animal losses documented in the Royal Commission of 1940 and subsequent inquiries. EDP: 1935/36 – 1940/41.

Episode 4: 1940s in western NSW involving substantial dust storms and animal losses graphically portrayed in Drysdale's paintings and Newman's newspaper reports, and supporting the need for government action. EDP: 1941/42 – 1944/45.

Episode 5: 1950s in western NSW involving large increases in woody weeds resulting in reduced carrying capacity and income in the 1960s. EDP: 1964/65 – 1967/68.

Episode 6: 1960s in central Australia involving wind and water erosion resulting in extensive surveys and reassessment of carrying capacity. EDP: 1958/59 – 1965/66.

Episode 7: 1960/70s in south-west Queensland involving soil erosion and woody weed infestation, resulting in the government-sponsored South-West Strategy supporting review of recommended carrying capacities and property amalgamation. EDP: 1964/65 – 1967/68.

Episode 8: 1980s in north-east Queensland involving soil erosion and loss of desirable perennial grasses, resulting in extensive government-sponsored surveys and dramatic grazier response. EDP: 1984/85 – 1987/88.

Evidence of episodic degradation

Whilst the above episodes have some notoriety, the extent to which degradation is a continuous rather than an episodic process is debatable. Watson *et al.* (2004) developed simulation models of dynamics of edible shrubs to study the interaction of climate and grazing management for two episodes (Gascoyne region, Western Australia in the 1930s, and North East Soil District, South Australia in the 1920/30s). Their simulation results showed that the loss of shrubs was continuous under constant heavy utilisation, but was more episodic at lighter stocking rates. These results and the analysis by other researchers (e.g. Williams *et al.* 1980) suggest that the severe and extended drought periods: a) revealed previous resource degradation; and b) further amplified erosion and loss of desirable perennial grasses and shrubs. Models such as those of Watson *et al.* (2004) provide an experimental system (albeit simulation-based) for the testing of different grazing management options and their interaction with climate variability, and the relative importance of episodic and continuous degradation processes. Further research is underway to develop models for each of the episodes described above.

COMMONALITY OF DEGRADATION EPISODES

No two droughts or two degradation episodes have been the same, but some commonalities emerged from the eight episodes. It is this repetition of factors, common to events in different places and at different times, that provides the potential for anticipating and preventing future damage. Common factors were:

- A general over-expectation of safe carrying capacities by managers, investors and governments.
- Numbers of stock and other herbivores (e.g. rabbits, kangaroos and goats), and in some cases woody weed seedlings, had increased in response to a period of mainly above-average rainfall that preceded the drought/degradation episode.
- Intermittent dry seasons (or years) resulted in heavy utilisation damaging desirable perennial species and ultimately the grazing land resource. This led to a rapid collapse in the capability of the land to carry animals at the onset of drought.
- Very high utilisation in the early years of drought through retaining stock caused further loss of perennial species, exacerbating the effects of drought in subsequent years.
- Rapid decline in, or generally low, commodity prices resulted in some managers retaining stock in the hope of better prices or through fear of the high cost of restocking.
- Continued retention of stock through a long drought period compounded damage to the resource and delayed recovery.
- Recovery was mainly dependent on subsequent sequences of favourable years, sometimes decades after the drought episode.

IMPORTANCE OF CLIMATE VARIABILITY

Climate variability has played a major role in driving this 'cycle' of degradation and partial recovery. We have reviewed the emerging understanding of the global climate system and the major sources of variability (McKeon *et al.* 2004). A recent analysis of global sea surface temperatures (SSTs) and atmospheric pressures (Allan 2000) has shown that variability occurs at different time scales, e.g. quasi-biennial (e.g. 2.5 years), inter-annual (e.g. 3-7 years), quasi-decadal (e.g. 11-13 years) and inter-decadal (e.g. 15-20 years). Other natural factors include solar variability, volcanic emissions and the chaotic nature of the climate system itself. Human-induced factors affecting the climate system include the increasing concentration of greenhouse gases, depletion of stratospheric ozone, increasing aerosols from industrial development, and land cover change from agricultural and urban development.

Recent research has shown that interactions of fluctuations in Pacific Ocean SSTs, at different time scales, have been associated with sequences of above- or below-average rainfall in Australia's rangelands, in particular in eastern Australia (McKeon *et al.* 2004). The El Niño-Southern Oscillation (ENSO) phenomenon is a well-publicised inter-annual fluctuation which changes the probability of droughts and floods from year to year (McBride and Nicholls 1983). Research (Power *et al.* 1999, Mantua and Hare 2002) has also identified inter-decadal fluctuations in Pacific Ocean SSTs, and various indices have been proposed. Historical time series are available for the Inter-decadal Pacific Oscillation (IPO, Power *et al.* 1999) and Pacific Decadal Oscillation (PDO, Mantua and Hare 2002).

The possible interaction of ENSO and the IPO/PDO adds to the complexity of understanding rainfall variability. A major finding in our report was that in eastern Australia, the impact of La Niña years has been greatly enhanced when the inter-decadal component of the Pacific Ocean was in a mode characterised by a very large wedge-shaped body of cold water dominating not only the equatorial region of the eastern Pacific, but also extending into the extra-tropical regions of the northern and southern hemispheres (IPO/PDO *cool* phase). The above-average rainfall periods in eastern Australia coincided with the *cool* phase of the IPO/PDO (early 1890s, 1916-18, early 1920s, mid 1950s, early 1970s, and perhaps late 1990s). The effect on rainfall of the interaction of El Niño and phases of the

IPO/PDO has varied greatly with location in eastern Australia (Henry *et al.* 2004, this volume).

Indices of the IPO/PDO were *warm* for most of the period from 1925 to 1946 and *cool* for most of the period from 1947 to 1976, and hence provide supporting evidence for the shift in climate regimes that has been identified as a contributor to the recovery of vegetation, for example, in western New South Wales (Condon 2002) and South Australia. In eastern Australia, the major periods of woody weed establishment, increasing animal numbers, and also potential resource recovery have been associated with the *cool* phase of the IPO/PDO when sequences of above-average rainfall years have occurred (early 1890s, mid 1950s, early 1970s and perhaps late 1990s). Most of the degradation episodes occurred when the IPO/PDO indices were *warm* or neutral, and the chance of 'drought-breaking' (above-average) rainfall was not as high as in the *cool* phase of the IPO/PDO.

Frustratingly for scientists and graziers alike, the existence of mechanisms and predictability of inter-decadal fluctuations such as the IPO/PDO are still the subject of debate, and the capability to predict 'regime changes' is not yet available (Mantua and Hare 2002). Nevertheless, it is clear that the impact of ENSO on Australian rainfall has waxed and waned (Power *et al.* 1999). What is unclear is the extent to which the 'waxing and waning' can be predicted. There is hope that some aspects of this interaction of oscillations at different time scales can at least be represented in climate forecasting or risk assessment systems a year at a time (e.g. Day *et al.* 2000, White *et al.* 2003), though more research is needed.

Application of climate information

Current operational seasonal climate forecast systems (SCFs) have concentrated on 3-monthly seasonal outlooks using ENSO and in some cases Indian Ocean SSTs (e.g. Drosdowsky and Chambers 1998, Alemseged *et al.* this volume). A limitation of ENSO-based forecasts is that only a small (≈ 25%) proportion of the years in the extended drought periods were associated with El Niño. Hence the prediction of severe regional drought in non-El Niño years remains as a major challenge.

The perceived importance of annual rainfall variability in management has led to the proposal/development of various experimental systems with longer lead times which are currently being tested and/or documented (Day *et al.* 2000, Henry *et al.* this volume). However, many factors are contributing to difficulties of speeding adoption (Paull, Leith this volume): the plethora of systems, the danger of false skill, the long time required to gain confidence in new statistical systems, and the probabilistic nature of climate forecasts. Systems based on historical rainfall also have to address the issue of how to include climate change impacts from the various human-induced forcings.

An alternative is the use of forecasts derived from Global Climate Models (GCMs). GCMs are a numerical representation of the global climate system including ocean and atmospheric circulation, and are beginning to include both natural and human-induced climate forcings. Trial operational SCFs have been produced since 1997 (Syktus *et al.* 2003). However, as with statistical systems, widespread adoption of such forecasts will require further model development, and then time for public confidence to be gained. The Bureau of Meteorology has recently been providing routine forecasts with the Predictive Ocean Atmosphere Model for Australia (POAMA) based on a coupled atmosphere-ocean GCM. http://www.bom/gov.au/bmrc/ocean/JAFOOS/POAMA/

Using GCMs, J. Syktus (unpublished data) has carried out several simulation experiments to investigate possible causes of 'extreme' sequences of droughts (e.g. 1960s central Australia, 1990s coastal Queensland) and wet years (rangelands of Western Australia in the 1990s). Although the results are preliminary, we believe they have important implications for future research. The GCM experiments suggest that the observed decline in coastal rainfall, especially during the recent La Niña period was best simulated by the inclusion of human-induced forcings. In particular, the inclusion of the depletion of stratospheric ozone over the last 30 years was found to be important to represent the changes in rainfall across Australia and trends in atmospheric pressure in the Southern Hemisphere. A preliminary experiment was also carried out to investigate the causes of the severe drought in the late 1950s/early 1960s across central Australia. GCM simulations forced with observed SSTs did not represent the drought conditions during this period. However, when continental soil moisture was set to low values in 1957 (as suggested by soil moisture simulations from the AussieGRASS model, Carter *et al.* this volume) then rainfall deficits were simulated to occur in central Australia for up to three years (i.e. 1958/59 to 1960/61). The preliminary results support the need for further research using a GCM-based approach to understand and hopefully predict the extended drought periods described above.

A SYSTEMS APPROACH TO PREVENT DEGRADATION

The review of the historical degradation episodes has identified some major information gaps that need to be addressed to lead to more informed decisions in grazing management and support effective rangeland management.

Monitoring of resource condition

The episodes described above caught resource managers and governments unaware, with the media in some cases being the first to identify that 'all was not well'. By the time that degradation became apparent (soil erosion and dust storms, loss of carrying capacity in drought, woody weed infestation, economic hardship) it was too late to take action to protect the rangeland resource. However, there have been some improvements. Since the 1980s various resource monitoring systems have been in place in State agencies (e.g. Watson 1998) to measure long-term changes. Developments have also been occurring in the use of satellite data to measure (in near real-time) changes in ground cover, tree density and pasture biomass. However, the major drivers of the degradation, namely livestock and other herbivore numbers, are proving more difficult to monitor or interpret in some States.

Lack of understanding of climate variability and impact on safe carrying capacity

The over-expectation of carrying capacity was supported by periods of above-average rainfall. With the benefit of hindsight, and a hundred years of climate data, the rangeland community now has a better appreciation of the long-term climate that underpins successful grazier experience and the calculation of 'safe' carrying capacities (Johnston *et al.* 2000, Quirk and O'Reagain 2003). However, to some extent the community is now back in a state of 'climate ignorance' similar to that of our predecessors. Climate change scenarios (Pittock 2003) suggest that the impact of human-induced factors on regional rainfall may be as large as natural climate variability (calculated on a 30 year timescale). Prediction systems addressing natural decadal and longer timescale signals are also yet to be proven. Thus a major priority is the development of plausible climate scenarios for (at least) the next 30 years, for use in estimating safe carrying capacities, and anticipating the likely climate variations that have caused the devastating impact reported in previous degradation episodes.

Prediction of severe and multi-year drought

Each episode included periods of two or more years of extreme drought (e.g. annual rainfall less than 70% of mean). To our knowledge current SCFs are yet to be evaluated in terms of forecasts of extreme drought. Operational SCFs concentrate on the probability of above or below median rainfall or in some cases the chance of Tercile 1 rainfall. Preliminary studies with GCMs using ensembles of simulations to calculate probabilities are now addressing issues such as chaos, biospheric feedback and the role of human-induced forcings to estimate changing risks of extreme rainfall occurrence.

Drought and degradation alerts

Individual graziers monitor pasture and animal condition and combine this knowledge with hard-won experience and rainfall expectations to anticipate the devastating impacts of drought (Purvis 1986, Landsberg *et al.* 1998, Stone 2004). More formal approaches have also been suggested (Bartle 2003, Quirk and O'Reagain 2003). The approach in the AussieGRASS model developed by state agencies (Day *et al.* 2003, Carter *et al.* this volume) has been to formally calculate attributes of the grazing system such as soil moisture, pasture biomass, and grass basal cover. This approach has formed the basis for: a) identifying periods of feed deficit; b) ranking current conditions relative to simulations of historical pasture growth; and c) supporting assessment of drought for Exceptional Circumstances application. However, the conversion of drought alert systems into a degradation alert depends, to some extent, on estimates of livestock and other herbivore numbers as well as improved skill and lead-time in climate forecasting.

Understanding the major cause of resource resilience

Various studies have documented partial recovery from degradation. An important feature of this recovery has been sequences of above-average rainfall years, for example, in western New South Wales following the wet periods of the 1950s and 1970s (Condon 2002). In eastern Australia, these years have been associated with La Niña years and/or the *cool* phase of the IPO/PDO. Thus, to some extent the perceived resilience of the land appears to have resulted from the decadal/inter-decadal variation in the Pacific Ocean's SSTs. Given the apparent importance of these 'La Niña-like' periods to the recovery and resilience of rangeland ecosystems, evaluation of the likely impact of global warming on their future occurrence is a major criteria in terms of assessing climate change impacts. This is particularly important if current projections of the development an 'El Niño-like' mean state in the equatorial Pacific Ocean occur (Cai and Whetton 2000).

The role of year-by-year climate risk assessment

An important finding from surveys and observations conducted during the last two degradation episodes was that graziers who acted rapidly to reduce numbers came out of the drought episodes in a better financial position with higher livestock reproductive rates and better resource condition (i.e. surface cover) than those graziers who 'hung on'. This was supported in the recent (current) drought by anecdotal examples (Wahlquist 2003). Thus, a major role for SCFs is to provide the necessary climate risk assessment that would allow discrimination between a relatively short 'dry spell' and the conditions leading to a severe and prolonged drought period.

CURRENT RISK OF A DEGRADATION EPISODE

During the late 1990s, sequences of years with above-average rainfall have supported the increase in livestock and other herbivore numbers, increasing from the drought period of the early 1990s. For example, in Queensland, G.S. Stone (unpublished data) estimated that cattle and sheep numbers (expressed as adult beef equivalents) had increased from 10.3 million at the end of a drought period in 1995 to 11.7 million in 2000. In 2001, Queensland macropod numbers were estimated (A. Pople *pers. comm.*) to have increased to 24 million (≈ 1.5 million beef equivalents). Similarly, in the Gascoyne region of Western Australia, livestock equivalents in 2001 were over one and a half times as high as at the end of the drought in 1980, down somewhat after reaching a peak of almost double in the late 1990s.

Drier conditions commenced in several rangeland regions of Australia in 2001 with a widespread drought in 2002. The potential for high grazing pressure, resulting from livestock and other herbivores, was a major concern because of the possible increased risk of degradation. Prices for both sheep and cattle remained reasonable during this period, although volatile, allowing graziers to reduce numbers in many cases. For Queensland, we have monitored trends in resource condition, animal (livestock and macropods) numbers (where available), prices and climate indicators (ENSO, PDO). However, developing a capability to provide a comprehensive assessment at a regional scale remains a major challenge. We are using the report of the above episodes to raise awareness.

CONCLUSION

In summary, we suggest that information systems are evolving to support better management decision in the rangelands. Prevention of future degradation episodes will require: a) recognition of the impact of historical climate variability and over-expectation of carrying capacity (McKeon *et al.* 2004); b) monitoring of attributes of resource condition (cover, biomass, woody vegetation, fire regimes); c) near real-time assessment of pasture production and grazing pressure (e.g. Carter *et al.* this volume) for livestock and other herbivores; d) use of climate risk assessment tools to project consequences of maintaining current grazing pressure; e) extension and information delivery through industry-supported programs (e.g. MLA's EDGE*network* Grazing Land Management course, Quirk and O'Reagain 2003); and f) facilitation and recognition of appropriate action by graziers to reduce degradation risk.

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