The use of climate information in sheep and beef cattle industries of Queensland

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1. Introduction

The sheep and beef cattle industries of Queensland are mainly based on native and sown grass pastures (Hall *et al*. 1998) and experience high year-to-year variability in rainfall and other climate elements (e.g. frost; McKeon *et al.* 1998). Climatic variation affects both feed availability and nutritional quality (Hall *et al.* 1998). A wide range of cattle and sheep production enterprises have evolved in response to spatial and temporal variation (O'Rourke *et al.* 1992; Hall *et al.* 1998).

Economically, meat and wool products from grazing lands contribute substantially to Queensland's production - $1.8 billion in meat and wool, representing 30% of the total value of agricultural production and 10% of total value of exports. However surveys of financial status of properties averaged across the state indicate that farms are only marginally profitable or are even running at a loss (ABARE 1999). Thus small changes in management can have substantial impact on profitability. Increases in stocking rate can have a short-term beneficial effect on cash flow but increase the impact of drought and risk of degradation (Gramshaw 1995, Stafford Smith *et al.* 2000). In particular episodic droughts in regions of Queensland during the 1960s, 1980s and early 1990s have resulted in increased financial stress (Miller 1973, Landsberg *et al.* 1998, Stehlik *et al*. 1999) and well documented deterioration and degradation of the grazing resource (e.g. Warrego Graziers Association 1988, Tothill and Gillies 1992).

In this paper we provide two examples of emerging technologies based mainly on the use of climate information and computer-based systems for the sheep and beef cattle grazing industries in Queensland. We describe (1) an on-property system for assessing 'safe' carrying capacity, and (2) a statewide drought/degradation alert system for policy and 'big picture' analysis.

2. Modelling ‘safe’ carrying capacity

Johnston *et al*. (2000) comprehensively reviewed the state-of-the-art in managing climate variability and their analysis is summarised here. The high year-to-year variability in climate and pasture growth of Queensland’s (and Australia’s) grazing lands has long been recognised as a major source of risk in terms of herd/flock management, financial performance and resource degradation (White 1978, Gardener *et al.* 1990, Stafford Smith and Foran 1992, Tothill and Gillies 1992). Some graziers have managed these risks by adopting conservative or ‘safe’ annual/seasonal stocking rates, or by managing around a ‘safe’ ‘long-term’ carrying capacity (Johnston 1996, Johnston *et al.* 1996a) resulting in long-term survival of their enterprises and reasonable resource condition (Johnston *et al.* 1996a, b).

The calculation of ‘safe’ long-term carrying capacity has been a major theme of recent work (McKeon *et al.* 1994, Scanlan *et al.* 1994, Johnston *et al.* 1996a, b, Day *et al.* 1997b). This follows the pioneering work of Condon (1968) and Condon *et al.* (1969) who developed quantitative systems for calculating ‘safe’ carrying capacities for both western NSW and central Australia (NT) respectively. The approach was based the relationship between average rainfall and the carrying capacities estimated from regional ratings or benchmark properties. In this way, both successful community experience and climatic and ecological knowledge were combined. The methodology also included the effects of varying tree density, land systems and resource condition.

This approach has been further developed in Queensland by simulating these biophysical effects on average pasture growth (Scanlan *et al.* 1994, Johnston *et al.* 1996a, b, Day *et al.* 1997b) with relationships developed from the GRASP model (Day *et al.* 1997a). For three regions of Queensland (south-west, south-east, north-east), similar relationships were found to occur between ‘safe’ carrying capacity and simulated average annual pasture growth. Analysis of the pooled data from these regions (Day *et al.* 1997b, Hall *et al.* 1998) showed that simulated pasture growth accounted for a high proportion of the variation (77%) in carrying capacity across a wide range of soil types, land systems, pasture communities, grazing enterprises and climatic zones. “When estimates of ‘safe’ carrying capacity were expressed as the ratio of animal intake per ha to average annual pasture growth, i.e. pasture utilisation, 47% of estimated ‘safe’ carrying capacities fell between 15 and 25% pasture utilisation, and 72% of estimated ‘safe’ carrying capacities were equivalent to less than 25% utilisation of average annual pasture growth” (Johnston *et al*. 2000).

Hall *et al*. (1998) applied this analysis to the 12 cattle producing regions of Queensland identified by O’Rourke *et al*. (1992). Regional carrying capacities were calculated from estimates of Tothill and Gillies (1992) and pasture growth calculated from spatial data on climate, soils, vegetation (including tree density, Carter *et al*. 2000). Calculated utilisation rates ranged from 6% in north Queensland to 30% in coastal areas and were strongly correlated with % gidays ($r^2 = 0.91$, $n = 12$) i.e. a climatic index of animal nutrition (Hall *et al*. 1998). Other indices were also examined and those representing aspects of animal nutrition were also correlated with utilisation rates supporting the above finding.

The above studies suggest that that wide variation in ‘safe’ stocking rates derived from successful grazier experience and expert opinion can be quantified in terms of climate, vegetation and soil resources, and hence successful experience in managing for climatic variability can be extrapolated to other properties. Thus the use of a range of technologies is contributing to reducing the complexity of the difficult issue of determining safe carrying capacity.

Application in south-west Queensland

P.W. Johnston and his colleagues have formally developed the methodology in south-west Queensland in response to grazier (Warrego Graziers Association 1988) and government initiatives towards a more sustainable grazing industry (Anon. 1993). A total of 217 properties participated in objective carrying capacity assessments from March 1994 to August 1998 representing 37% of the properties in the Murweh, Paroo, Quilpie, Bulloo and Barcoo shires covering a total of 137,439 km^2 (45% of the area of the above shires). At the time of writing (August 2000) 280 properties have been assessed, i.e. over 50% of the region.

The following evaluation is quoted directly from Johnston *et al.* 2000.

Properties ranged greatly in size from 2,376 ha to 866,949 ha. Estimated carrying capacities ranged from 9 DSE/km^2 to 305 DSE/km^2 reflecting the wide range in resource productivity. Where owner livestock figures were available, the range in owner carrying capacities was 9.4 DSE/km^2 to 334 DSE/km^2. On 165 properties the owner/manager provided their own estimates of long-term carrying capacities, either derived from their records or experience. On 66% of properties where owner figures were available, the assessed carrying capacity was within $\pm$ 10% of the owner-estimated carrying capacity.

On 23% of properties, the assessed carrying capacity was 10% or more below the owner nominated carrying capacity. Conversely, on 11% of properties the assessed carrying capacity was 10% or more above the owner nominated capacity. The ratio of owner carrying capacity to assessed carrying capacity (range 0.3 – 1.7) was not significantly related to property size, flock size or proportion of ‘downs’ country on the 165 properties where owner figures were available.

An evaluation of the above work was conducted from February to June 1998 to assess the impact of the project within the community and whether the work has brought about changes. To achieve this a telephone survey of 60 producers was conducted. One third of producers surveyed who had participated in the project indicated they had made some change to their management practices following assessment. Two thirds of those making changes believed they had seen some change in pasture condition since implementing the changes. Producers reported that where they agreed with the results, they used the information as a benchmark or reference for making stocking decisions or as a check of what they were presently doing.

Johnston *et al.* (2000) identified several major limitations to the adoption of ‘safe’ carrying capacities including the inability to control total grazing pressure and the marginal economic viability of some grazing enterprises. Nevertheless, where graziers have greatly reduced stock numbers (by 30-50%), substantial benefits in resource condition and cash flow have been reported (Landsberg *et al.* 1998, Fahey 1997, Anon. 1999). These graziers reported benefits in terms of reducing the impact of droughts on their production systems once they adopted lower stocking rates as well as more opportunities for pasture burning to control weeds.

Because of variation between properties in terms of land, vegetation and climate resources, it has been difficult to extrapolate actual stocking rates (beasts/ha) from property to property. The above approach of Johnston *et al.* (1996 a, b) provides a guide as to where an individual grazier may be operating relative to objective assessment of safe carrying capacity. The use of enterprise simulation models (Stafford Smith and Foran 1992, Holmes 1995) provides an approach whereby graziers can assess the financial impact of adopting lower stocking rates.

The future

Whilst the above approach shows that advances in science and technology can address issues as complex as ‘safe carrying capacity’, the best systems for year-to-year management of stock numbers are only just beginning to be publicly debated by graziers and the advisors (as will be described later). A major gap in addressing the issue in a scientific way is the lack of detailed property records to allow individual graziers to reconstruct their management history and then conduct “experiments” using alternative decisions. The “technology” is being developed and demonstrated (Buxton and Stafford Smith 1996) and could prove the next technological major advance in the complex field of property management.

3. Drought/Degradation Alert

Droughts have unleashed emotional and political forces (Daly 1994, West and Smith 1996) and early in the 1990s the need for objective assessment of drought conditions was recognised (O’Meagher *et al.* 1998, White *et al*. 1998). To address the two goals of (1) objectively assessing drought and (2) evaluating the risks of pasture degradation a computer-based system was developed by a science group led by K. Brook in 1991 and run operationally in Queensland throughout the 1991-1995 drought. With the collaboration of state agencies in NSW, SA, WA and NT and the external funding of LWRRDC the system was expanded to other rangeland regions (Carter *et al.* 2000).

The fundamental scientific basis of the system was that rainfall alone was a poor measurement of drought impacts on grazing industries and resource sustainability, and that the simulation of pasture growth was a superior approach to objectively assess drought and evaluate degradation risk (Day *et al.* 1997a).

The computer-based system has the following components:

(1) near real-time surfaces of climate variables;
(2) soil maps with linked parameter sets (e.g. available water range) derived from field collection and soil surveys;
(3) pasture community maps with linked parameters derived from pasture exclosure studies, grazing trials and extensive field assessment (described in detail later);
(4) estimates of tree density derived from time series of remotely-sensed green cover (NDVI, Danaher and Carter 1993);
(5) time series reported sheep and cattle numbers, and estimates of macropod and feral densities (Carter *et al.* 2000);
(6) the use of SOI-based forecasts to project forward 3-6 months (Stone *et al.* 1996);
(7) a pasture growth model GRASP which simulates soil water balance and dry matter flow in pastures/tree mixtures (Day *et al.* 1997a);
(8) a computing environment (CRAY ??) allowing data storage and simulation for 70,000 pixels in Queensland and 270,000 pixels in Australia (i.e. about 5km resolution);
(9) award-winning delivery systems including The Long Paddock web site (URL http://www.dnr.qld.gov.au/longpdk/.) and the "SOI hot-line" (07 3896 9602) (Paull and Peacock 1999, Paull and Hall 1999).

Thus the Drought/Degradation Alert system (Carter *et al*. 2000) represents a major technological advance in that the system integrates the many independent data sets collected over the last sixty years and hence provides a beneficial return on the past public investment in the many disciplines of science involved. Some major innovations in the system include the comprehensive parameterisation of pasture models using:

(1) remote sensing; and

(2) the combination of GPS, data capture and extensive vehicle-based survey. These innovations increased the availability of biomass data by several orders of magnitude.

Major applications of the Drought/Degradation Alert system include:

(1) use in objective assessment of drought for State and Federal governments. The system is credited by industry representatives (Acton 2000) as having "had a significant influence on determining drought status in the last decade";

(2) use by individual graziers in planning grazing management decisions (P.W. Johnston personal communication). Paull and Hall (1999) have surveyed 65 Queensland graziers (86% beef producers) who had reviewed the outputs from the system. There was strong support for the concept of Feed Shortage Alerts (72%) and moderate support for "warning of possible deterioration of pasture (54%) or soils (48%)".

Johnston et al. (2000) summarised the survey findings of Paull and Hall (1999) as follows:

1) the most important decisions were selling/agisting stock (83%), buying stock (44%), sowing crops/pastures (47%), burning pastures (34%) and weed/disease/pest control (34%);
2) judgement of future climatic condition was moderately (29%) to very (56%) important in decision making;
3) 58% agreed that climate forecasts are better expressed in terms of probabilities and that probability information was regarded as moderately (37%) to very (12%) useful;
4) 45% currently use seasonal climate forecasts; and
5) 38% said they would use seasonal climate forecasts to decide what number of stock to carry through period of feed shortages.

Individual comments highlighted the lack of accuracy of recent forecasts confirming that probabilistic forecasts such as those based on SOI, may not satisfy the needs of

40 to 50% of the grazing community. Given that graziers have only had access to this type of scientific seasonal forecasting information since 1991, the reported rate of adoption (35-45%) is relatively high.

The severity of the 1991-95 drought in Queensland was such that severe deterioration and degradation could have been expected where animal numbers had been maintained. The condition of native grasslands have been monitored by DPI and DNR through the QGRAZE network, which provided data on the state of native pastures from more than 400 monitoring sites. Preliminary Analysis of the data was reported in the State of Environment report for Queensland (EPA 1999, p3.40).

> "By July 1998, 375 sites had had the full array of data collected at least once, with a total of 526 data recordings made. Data collected include species composition, ground-cover, tree basal area, soil surface condition and pasture yield. In the *Aristida-Bothriochloa* pasture community, the largest of the Queensland pasture communities and one used extensively for grazing, monitoring between 1992 and 1997 at 43 representative sites found that the percentage composition of key perennial species and groundcover had declined. Undesirable perennial grasses declined between 1992 and 1994 but since 1994 have progressively increased. Rainfall was below average from 1992 to 1995, but was above average in 1996 and 1997. Continued monitoring is necessary to determine further changes in species composition (Cliffe, N.O. pers. comm.)."

The extent to which the outputs of the above system contributed to reduced deterioration/degradation in 1991-95 is not possible to determine given (1) the perceived over-riding impact of climatic variability, (2) the lack of extensive monitoring of the resource, and (3) changes in grazing pressure. Nevertheless the outputs of the system contributed to the emerging debate (Johnston *et al.* 2000, McCosker 2000) on grazing management which have allowed issues such as 'degradation', 'over-grazing', 'carrying capacity' to be publicly aired (Johnston *et al.* 2000). As such the system is part of the cultural change that is occurring towards better resource management.

The future

Operational systems require careful financial management to be maintained especially where state agencies are under funding pressure to reduce or reallocate expenditure. Bureaucracies and some graziers have shown a dysfunctional response to variability in the hydrological cycle. Planning for drought and alert systems have been abandoned during periods of favourable rainfall only to be reinvented during drought periods – a response which called the ‘hydro-illogical cycle’ (Wilhite 1993). For example, historical degradation episodes in Australia’s rangelands have usually followed periods of good years when stock numbers have increased and in some cases unconsciously promoted by government support for closer settlement (McKeon and Hall 2000). The return of normal and/or drought conditions has led to heavily utilisation and resource degradation. In eastern Australian rangelands these favourable rainfall periods have been associated with the combination of both ‘La Niña’ years and other SST anomalies in the Pacific Ocean which can last for several decades (the Inter-decadal Oscillation, Power *et al*. 1999, or Pacific Decadal Oscillation, Manuta *et al*. 1997).

The inclusion of this understanding of decadal variability in rainfall in the Drought/Degradation Alert System (K.A. Day personal communication, McKeon and Hall 2000) will for the first time provide a warning to counter the above dysfunctional ‘hydro-illogical’ responses.

Climate change

Implicit in the management of the grazing resource is the assumption of sustainable use of long time scales (thousands of years, e.g. Abel 1992). Simulations of the impact increasing greenhouse gas concentrations over the last and next hundred years suggest a warming of the eastern Pacific Ocean (e.g. Timmerman *et al.* 1997) and reduced rainfall in Queensland’s grazing lands (Walsh *et al*. 2000)

Simulations of future climatic conditions are regarded as ‘uncertain’. Nevertheless they suggest a plausible future risk to the management of the grazing lands. The Alert system may provide some forecast skill albeit year-by-year allowing adaptation to an uncertain future climate.

4. Other emerging technologies for policy and grazing management

During the 1990s there has been a rapid increase in the application of technological science to the issues of managing the natural resources of Queensland used for grazing. Operational examples include:

(1) the measurement of area of tree clearing with remote sensing;
(2) the use of GIS to support legislation on vegetation management;
(3) monitoring of vegetation burning as both an indicator of sustainable grazing practice (i.e. pasture burning to control woody vegetation) and as operation a fire alert system; and
(4) real-time climate data system (SILO, www.bom.gov.au/silo) allowing current and historical analysis;

Future potential applications being developed in CINRS include:

(1) use of carbon cycles to account for greenhouse gas emissions using whole property models;
(2) use of General Circulation Models and Regional Climate Models in long-lead climate forecasts and climate change assessment; and
(3) assessment of resource condition (bare ground) with remote sensing.

The large spatial and temporal variability of the Queensland’s natural grazing lands has in the past prevented comprehensive analysis. However, the recent technological integration of remote sensing, GIS, ground truthing, data capture systems, climate data bases, models of carbon and vegetation dynamics, and appropriate delivery systems has resulted in the potential for policy and individual grazier’s decision to be underpinned by the best available science.

The Science of Grazing Management Systems

During the 1990s there has been an increase in the public debate about grazing management systems (Johnston *et al*. 2000; McCosker 2000). In particular, individual graziers have documented their own experiences in implementing an monitoring managerial change (e.g. Fahey 1997, Landsberg *et al.* 1998, Lauder 1999). In climates such as Queensland with high year-to-year variability it is difficult to separate the effects of management change from rainfall/climatic variation. Thus it is encouraging that the debate on grazing management concentrates on the biological principles (Quirk 2000, McCosker, 2000, Lauder 2000) rather than the blind acceptance of management recipes. The transparent and objective evaluations are necessary to convert grazing management science and experience into a technology.

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