Climate Tools for Northern Grassy Landscapes

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Introduction

The high year-to-year and decade-to-decade variability in climate and pasture production of Australia's grazing lands is a major source of risk in terms of herd or flock management, financial performance and resource degradation. The El Niño/Southern Oscillation (ENSO) phenomenon is a major source of year-to-year variability in rainfall across tropical northern Australia (e.g. McBride and Nicholls 1983). The Southern Oscillation Index (SOI) is a common measure of ENSO behaviour and forms the basis of an operational seasonal forecasting scheme currently in use in Queensland (Stone *et al*. 1996). Several modelling studies have applied SOI-based seasonal forecasts for pasture, animal and whole property management in northern Australia. Some key findings of these studies are outlined in this paper, particularly grazing management strategies. While the results indicate benefits of using seasonal forecasts, they also support the generally held view that improvements to the skill and lead-time of forecasts would make forecasts a more useful aid to management. To this end, new sea-surface temperature (SST) indices are described which provide longer lead-time and greater skill than the SOI in forecasting summer (November to March) rainfall in Queensland. These indices are being incorporated in an experimental forecasting scheme which is being built specifically for grazing management in native pastures of Queensland (Day, in prep.). The experimental forecasting scheme will be available on "The Long Paddock" website after the necessary protocols, listed later in this paper, have been met.

Indices of year-to-year climate variability

ENSO is a coupled ocean-atmosphere phenomenon and the SOI is a commonly used measure of the atmospheric component. Year-to-year variation in rainfall in northern Australia has been correlated with the SOI for extended periods in the last hundred years. Below-average rainfall is likely when the SOI is strongly negative, i.e. El Niño years, and above average rainfall is likely when the SOI is strongly positive, i.e. La Niña years. However there have been periods (e.g. 1930's and 1940's) when the relationship between the SOI and rainfall has tended to break down. The impact of ENSO also varies with time of year and location (Stone *et al*. 1996). The oceanic component of ENSO is indicated by variation in sea-surface temperature (SST) in the equatorial Pacific Ocean. SSTs from the Pacific and Indian Oceans are now being used for seasonal forecasting in Australia (Drosdowsky and Chambers 1998).

Indices of inter-decadal climate variability

Inter-decadal variation in rainfall is evident over the last 100 years in Australia (Power *et al*. 1998) and as far back as A.D. 1735 based on proxy rainfall derived from fluorescent bands in coral cores (Lough, 1992). Inter-decadal rainfall patterns in Australia are linked to inter-decadal SST oscillations in the Pacific Ocean (Power *et al*. 1998) and this "Inter-decadal Pacific Oscillation" (IPO) also influences the correlation between the SOI and Australian rainfall (Power *et al*. 1999). McKeon *et al*. (1999) has shown that the IPO can be used directly to modify current SOI-based forecasts with implications for the grazing industry in northern Australia.

Use of seasonal forecasts

Seasonal forecasts based on the SOI have been available in Queensland since 1991 through a telephone "Hotline" service, television (ABC weather, Wednesday evening), poll-fax and "The Long Paddock" website (www.dnr.qld.gov.au/longpdk/). The Australian Rainman computer package provides ready access to local historical rainfall records and allows statistical relationships between the SOI and rainfall to be explored. Although seasonal forecasting based on the SOI is relatively new, it is widely known and adopted by graziers in Queensland. Paull and Hall (1999) conducted a survey in 1998 of 65 Queensland graziers mostly (86%) involved with beef cattle. Of those who responded, 45% used seasonal climate forecasts and 38% said they would use seasonal climate forecasts in deciding stock numbers in periods of feed shortage. Respondents also indicated that inaccuracy of forecasts was a factor limiting adoption, a view also shared by Ash *et al.* (2000).

Relevance of forecasts for managing the grassy landscapes of northern Australia

Simulation models of grazing systems can be used to evaluate outcomes of grazing and pasture management strategies which incorporate seasonal forecasts. Grazing systems models transform historical climate records into physical, biological and financial variables such as runoff, plant growth and cash flow. The forecasting system and management strategies can be evaluated in terms of such simulated variables, allowing decision rules to be derived and tested over a long (approximately 100-year) period. Results can be expressed as time-series or as probability distributions to reflect the risk associated with specific outcomes. Examples of studies that demonstrate usefulness of SOI-based seasonal forecasts are outlined briefly below and are more fully reviewed in Johnston *et al.* (2000). Studies indicating the usefulness of SST-based forecasts are also emerging (e.g. McKeon *et al.* 1999, McIntosh *et al.* 2000) but are not considered here.

Example 1: Pasture burning for weed control and animal nutrition

Burning pasture in spring is a controversial practice in Queensland. Pastures are burnt to improve animal nutrition and for weed control. However low feed availability and poor surface soil protection may result if reasonable rainfall does not follow burning. Based on 119 years of simulated native pasture growth at Gayndah, south-east Queensland, Willcocks *et al.* (1991) found that avoiding burning when the winter SOI was extremely negative (< -5) would reduce the risks of overgrazing, low surface cover and soil erosion in the following spring.

Example 2: Sowing legumes into native pastures

Sowing legumes into native pastures is risky due to poor seedling establishment in dry years and unreliable establishment is a factor limiting adoption of this practice. A simulation study of *Stylosanthes* establishment (Menke *et al.* 1999) showed that substantial improvement in reliability of establishment could be achieved by limiting sowing to years when the SOI was “Consistently Positive” or “Rising” (Stone *et al.* 1996).

Example 3: Animal Production

Analysis of animal production data from grazing trials has shown that steer growth and wool cut per head are highly correlated to the length of the growing season which, in many regions, varies according to winter and spring temperature, moisture and in some locations, frost (Johnston *et al.* 2000). SOI-based forecasting systems have skill in forecasting length of the growing season so it is not surprising that the SOI can discriminate between years of high or low steer live-weight gain (LWG) (McKeon *et al.* 2000). Similarly, O’Rourke *et al.* (1991) found that the pregnancy rate of mature lactating cows in north-eastern Queensland measured in June-July was correlated with the previous August to October SOI. Such forecasts are likely to aid the planning of management options such as diet supplementation, drought feeding, disease and pest prevention and marketing.

Example 4: Drought and Pasture Condition Alerts

Analysis of grazing trials indicates that the consumption of more that 30% of pasture grown over summer results in large decreases in grass basal area of desirable perennial grasses (McKeon *et al.* 1990). A simulation of pasture growth over 105 years (1890 to 1995) at Charters Towers (north-east Queensland) was used to examine the risks of exceeding 30% utilisation of summer growth when stocking at a constant ‘safe’ stocking rate (McKeon *et al.* 1990). Over all years the probability of exceeding 30% utilisation was 23%, but this nearly doubled in El Niño years (SOI August to October <-5) and was zero in La Niña years

(SOI August to October >+5). Hence, an extremely low SOI (<-5) in spring can be a warning of likely pasture degradation, and a trigger for appropriate actions such as early destocking. However this SOI-based warning indicated only about half the years when there was a high risk of pasture degradation.

Example 5: Managing stock numbers

Of many management options facing graziers, the choice of target carrying capacity for the property, and the year-to-year management of stocking rates, greatly influence both financial performance and pasture and soil condition on a property. Stocking rate primarily affects pasture availability and composition. In turn, pasture availability influences surface soil cover and thus runoff and soil loss, frequency of burning, weed invasion, individual animal performance and the need for supplementary feeding.

McKeon *et al.* (2000) modified the grazing systems model GRASP to compare different grazing strategies including some involving seasonal forecasts, for Charters Towers. The Charters Towers simulations indicated that increasing stocking rate generally resulted in increased LWG/ha but decreased resource condition. However strategies involving flexible stock numbers offered certain advantages over constant stocking. For instance, adjusting stocking rate in November, based on the August-October SOI, increased LWG/ha (7%) and reduced the risk of running out of feed without increased risk of resource damage.

Adjusting stock numbers in November based on the average August-October SOI was marginally inferior to a flexible stocking strategy which involved adjusting stock numbers in June based on pasture available at that time. The Charters Towers simulation included long sequences of years with above average pasture growth (1953-60, 1970-1982) and long sequences of years with poor pasture growth (1991-96). As a consequence, the stocking rate change made in response to the previous year's production was often also appropriate for the following year as well. Even in the absence of seasonal forecasts, this responsive stocking strategy may be suitable for a climate with inter-decadal variability and/or climate change trends.

McKeon *et al.* (2000) considered a hypothetical case where the SOI information available in November was (through likely advances in climate science) available in June. In the example provided, stock numbers are adjusted based on pasture available in June and the SOI "year type" (spring SOI <-5, neutral or >5) that would have otherwise been known in November. This strategy proved superior to the stocking rate adjustment made solely on the basis of feed availability with increased LWG/ha, reduced risk of live-weight loss, reduced risk of low pasture yield but increased risk of soil loss (4%). Alternative strategies could be found that reduced soil loss while maintaining the same live-weight gain per hectare. Thus, as McKeon *et al.* (2000) concluded, "the development of long-lead forecasts has considerable potential to contribute to better management of climate variability in these grazing lands."

Developing a forecast system for Queensland grazing lands

With the aim of increasing skill and lead-time of existing forecasts, a new scheme for forecasting growing season (November to March) rainfall in Queensland grazing lands is being developed (Day, in prep.). The scheme incorporates three new indices:

1. Index 1 is based on the difference in March SST between a region north of New Zealand and a region to the east of Hawaii. From 1900-1996, Index 1 accounts for 25% of the annual variation in rainfall for the following November to March period averaged over the grazing lands of Queensland. Due to the Hawaiian SST component, Index 1 exhibits inter-decadal variability that follows closely the pattern of the IPO.

2. Index 2 is based on the difference in SSTs between a region north of New Zealand and a region in the central Pacific just south of the equator. Index 2 shows ENSO-like annual variability due mainly to the equatorial SST component. In early June, Index 2 accounts for 19% of the annual

variation in the following November to March rainfall. The percent variation in rainfall explained increases to 36% by early October but then decreases to 27% by early November.

3. Index 3 is based on the difference in October SSTs between a region north of New Zealand and a region just south of the equator in the western Pacific. Index 3 has similar properties to Index 2 but in most months is not as highly correlated to November to March rainfall. However in early November, Index 3 accounts for 38% of the annual variation in November to March rainfall which is higher than the 27% of variation accounted for by Index 2.

Annual variation in Index 1 is not highly correlated with annual variation in Index 2 or Index 3. For this reason higher correlation with rainfall is achieved by combining Index 1 with Index 2 from May through to September and combining Index 1 with Index 3 in October. By November the combined indices account for some 50% of the annual variation in November to March rainfall, a much higher percentage than accounted for by the October SOI (Figure 1). The scheme can be used before April by taking the January or February SST values of Index 1. By early March the scheme accounts for a similar proportion of the following November to March rainfall as the October SOI (Figure 1) thus providing eight months lead-time on the SOI for the same level of accuracy. Hence the new scheme meets accuracy and lead-time criteria for improved forecasts as indicated both by graziers and by the simulation studies outlined in this paper.

Certain protocols must be observed in developing new forecasting schemes. Firstly and most importantly, the forecast should be based on known mechanisms. Certain statistical protocols should be observed in developing, assessing and comparing forecast schemes. In particular, widely accepted statistics (e.g. LEPS or ROCS scores) should be used to evaluate forecast skill and cross-validation techniques used to remove “artificial” skill. However forecast skill should also be represented in meaningful terms for the end-user as demonstrated by the simulation studies outlined in this paper. Information on the historical “track record” of the forecast for individual years should accompany the forecast. The stability of these “hindcasts” should be shown both in time and space. The likely response of the forecast scheme to a warming world should also be indicated. These protocols are being observed in developing our new scheme (Day, in prep.).

Summary and conclusions

Seasonal forecasting is an exciting and rapidly evolving field of relevance to managing the grassy landscapes of northern Australia. In particular, increased lead-time has brought forecasts more closely in line with key decision points for grazing management. While increase in both skill and lead-time of forecasts is important, appropriate decision rules are needed to capture the benefits of seasonal forecasts. Simulation studies provide one means to derive strategies for managing climate variability on both annual and decadal scales.

Seasonal forecasts can be used for constructive or destructive purposes. Simulations show that the way to make money out of forecasts is to “stock up” when favourable conditions for animal production are likely to occur. However simulations also show that stocking up can accelerate resource damage or slow recovery of pasture and soil attributes. As scientists we have a “duty of care” to highlight such trade-offs both in the short and long term. It is for this reason that we are investing in improving our capability to predict changes in resource condition.

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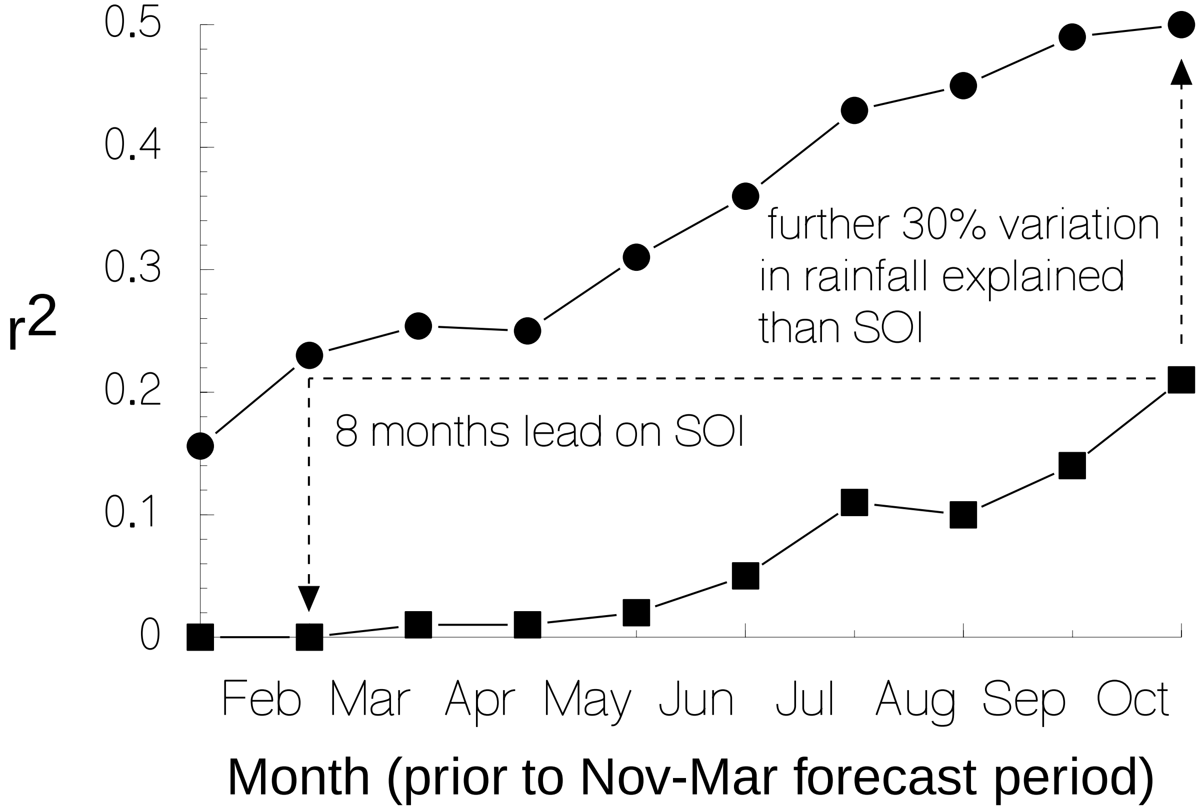
Figures

Figure 1: Correlation (r^2) between monthly value of the Southern Oscillation Index (SOI: ■) or forecast based on new indices (●) and rainfall across Queensland's grazing lands in the following summer (Nov-Mar) for the period 1901/2 to 1995/6.



Correlation (r^2) between summer (November to March) rainfall averaged across Queensland grazing lands (Figure 1) and two indices: 1) the Southern Oscillation Index (SOI: ■); and 2) the Queensland Rainfall Index (QRI: ●) from 1901/2 to 1995/6.

Figure 1