Seasonal climate forecasts and pasture growth in northern Australia

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Abstract
In the semi-arid tropics of north-eastern Australia the ability to have a skilful forecast of the upcoming wet season and understand its effect on potential pasture growth would allow for more accurate cattle management decisions. Often forecasts of El Niño Southern Oscillation (ENSO) are used as a guide to the wet season and potential pasture growth. However this relationship doesn’t always hold as many other factors come into play – including other modes of climate variability. Ideally a seasonal climate model coupled with a pasture model would incorporate a range of likely climate scenarios with the initial conditions of pasture quality to develop a decision tool. However to date, dynamical seasonal climate models have been limited in their skill to forecast the upcoming year at the paddock scale. A case study is conducted in the Dalrymple Shire to explore how effective ENSO is as a pasture predictor, determine the climate features relevant to pasture growth and evaluate the current skill of a seasonal climate model to predict pasture growth.

Keywords
Grazing, cattle, El Niño.

Introduction
In the semi-arid tropics of north-eastern Australia, beef cattle enterprises use grazing management and adjustments to livestock numbers to optimise productivity and profit. Stocking rate decisions are often made in June taking into account the remaining available pasture over the dry winter and spring months, and the current pasture conditions. It would also be useful to know when the wet season is likely to break and how ‘good’ the wet season might be, allowing pastoralists to optimally increase their stock numbers in good years, and to reduce stock number to mitigate losses in potential drought years.

The dominant climate feature controlling the wet season in north-eastern Australia is the El Niño Southern Oscillation, typically bringing a drier-than-average wet season in the El Niño phase and wetter-than-average wet season in the La Niña phase (Stone and Auliciems 1992). Its effects on the pastoral industry in north-eastern Australia can be particularly severe in terms of reduced pasture and beef production (Ash et al. 2000). There are limits to using ENSO as a forecasting tool as the relationship doesn’t always hold, especially with the influence of other climate features such as the Interdecadal Pacific Oscillation and Climate Change, and each event can have a very different local rainfall signature (Brown et al. 2009). Further, the neutral phase of ENSO can also bring either wet or dry conditions.

In this paper we develop a case study in the Dalrymple Shire in north-eastern Australia. We first explore the role of ENSO in predicting wet season rainfall and the resulting pasture growth. We then explore how effective a seasonal climate forecasting model is at predicting wet season rainfall and pasture growth for the region as an alternative to using an ENSO forecast.

Methods
Estimating Pasture Growth
Plant-growth-days can be estimated using a calculation of Growth Index Days (GID) (Fitzpatrick and Nix 1970; Nix 1981; McDonald 1994). This index incorporates temperature, radiation and soil moisture availability. GID is a more powerful metric for forage growth than simply acting as a rainfall forecast. For example GID will distinguish a single heavy rainfall event falling on already wet soil from sustained modest rainfall that keeps soil moist in a typically dry period.

The Growth Index (GI) has a value of 0 to 1 for each day. If the value of the GI is greater than 0.2, the day is counted as a ‘green day’ and these are aggregated over the relevant period to give Growth Index Days (GID). The GI is calculated as

$$GI = RI \times TI \times MI \qquad (1)$$

Where RI is the radiation index, TI is the temperature index and MI is the moisture index (see McDonald 1994 for details). In this study the GID is the sum of the GI from the 1st July to the 31st March.

Climate data and study region

We explore the skill of the POAMA seasonal climate model (Alves et al. 2003), run at the Australian Bureau of Meteorology. The observational data used in calculating GID were obtained from daily climate records sourced from the SILO database (https://www.longpaddock.qld.gov.au/silo/) over 125 years. The required variables are rainfall, radiation, maximum daily temperature, minimum daily temperature and evaporation. The climate stations that were used in this study were Balfes Creek PO, Broadleigh Downs, Charters Towers Airport, Kangaroo Hills Station, Ravenswood PO, Spring Creek Station and Wando Vale Station.

Modelling live weight gain

The prospective production and economic value of a seasonal forecast to a beef enterprise is explored using the NABSA beef herd bio-economic simulation model (Ash et al. 2015). The model was calibrated to mimic the animal turnoff and net profitability of a hypothetical 30,000 ha beef enterprise assumed to be located in Dalrymple Shire. The model enterprise carries an average herd of 2900 adult equivalents comprised of a mixed age Zebu breeding cows and steers that are grown out to slaughter weight (av. 300 kg carcase at 42 months of age).

Results

Role of El Niño Southern Oscillation (ENSO)

There is a strong relationship between the total July to March rainfall (size of circles, Figure 1) and ENSO phase (colour of circles), with La Niñas (blue) corresponding to higher totals and El Niños (red) less. Neutral years (black) have a range of high to low rainfall totals. However, the total amount of rainfall is not a perfect predictor of the pasture growth. A higher July to March rainfall (size of circles) is only loosely related to the GID over the same period (x-axis).

The successes of statistical models that use ENSO projections to estimate GID highlight the importance of this particular climate driver in the region. Some 73% of La Niña years had a GID in the highest tercile and 67% of El Niño years resulted in a GID in lowest tercile. It is rare, but possible, to have a La Niña year with low GID (1947) or an El Niño year with high GID (1940 and 1953). The fact that all El Niños are not necessarily low growth nor are all La Niñas high growth, points to the role of other climate features, and the current condition and use of the pasture.

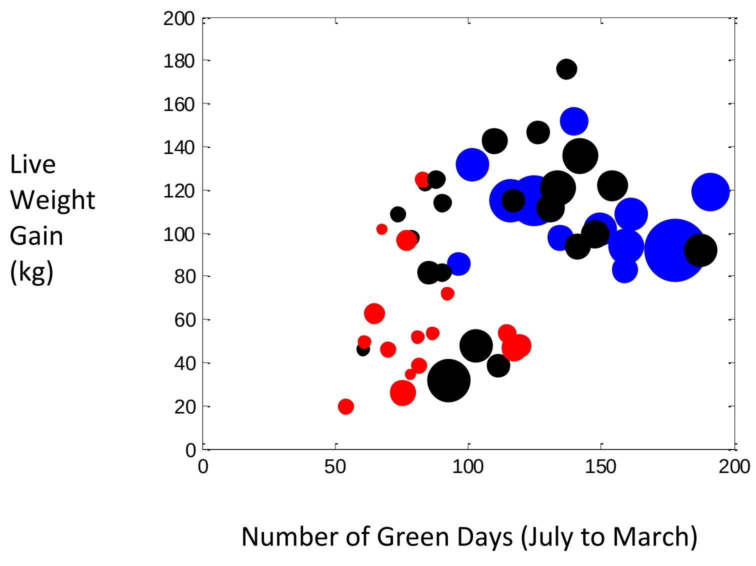

Figure 1. Summary of the relationships between the number of green days and the modelled live weight gain (kg) between July and March. ENSO phase is shown through blue circles - La Niña, red circles – El Niño, and black – neutral years. The size of the circle shows the relative amount of rainfall over the same period.

There also appears to be a relationship of live weight gain with GID and ENSO phase as would be expected. It is interesting that the highest live-weight gain occurred in a neutral ENSO year with low rainfall. This highlights the fact that live-weight gain is dependent on many factors some of these being the timing of the pasture growth (if early rain allows for growth in Spring), wet season onset date, and the initial cattle and pasture condition going into the season.

The onset date for the wet season is typically defined as the date of accumulation of 50 mm of rainfall commencing from 1st September. This metric is designed to capture the date at which the rainfall rate increases and remains high over the wet season. In this study, a late onset to the wet season occurred in 80% of El Nino years and an early onset occurred in only 40% of La Niña years. While none of the El Niño years experienced an early onset of the wet season, a late onset occurred in 3 La Niña years - 1908, 1955 and 2011.

The wet season onset is one of the contributors to the amount and timing of pasture growth and ultimately LWG, so the ability of a dynamical climate model to forecast wet season onset will be crucial to the skill of the forecasting system. This information is already being provided operationally from dynamical climate models at the Australian Bureau of Meteorology- http://www.bom.gov.au/climate/rainfall-onset/.

Predicting Pasture Growth

Total rainfall is a commonly used metric for evaluating the forecast skill of a climate model. The POAMA climate model has a low skill requirement for simulating the total seasonal rainfall in Dalrymple Shire over July to March compared to observed values (Figure 2a), even when the data is calibrated so that it is statistically similar to observed rainfall (thin blue line, McIntosh and Brown 2017). The model rainfall forecast predicts the observed tercile of rainfall for that same year only a third of the time, suggesting there is little or no skill. However, if the output of the POAMA model (temperature, radiation, and evaporation) is used to calculate the number of green days in a season (Figure 2b) the forecast skill improves dramatically. The POAMA multi-model ensemble average predicts the same tercile as the observations approximately 50% of the time.

The NABSA herd economic model (Ash et al. 2015) was run with the observed monthly GID values (Figure 2b - pink line). Ultimately the profitability of a beef enterprise is underpinned by the total live weight gain of the animals each year through either its effect on herd reproductive efficiency or the numbers and weights of turnoff animals. Total GID is not adequate as a sole predictor of LWG. This is primarily because GID is only a proxy measure for pasture growth, and there are many other factors that also contribute to weight gain including the quality of pasture in the previous year, animal condition, and breeder conception rates.

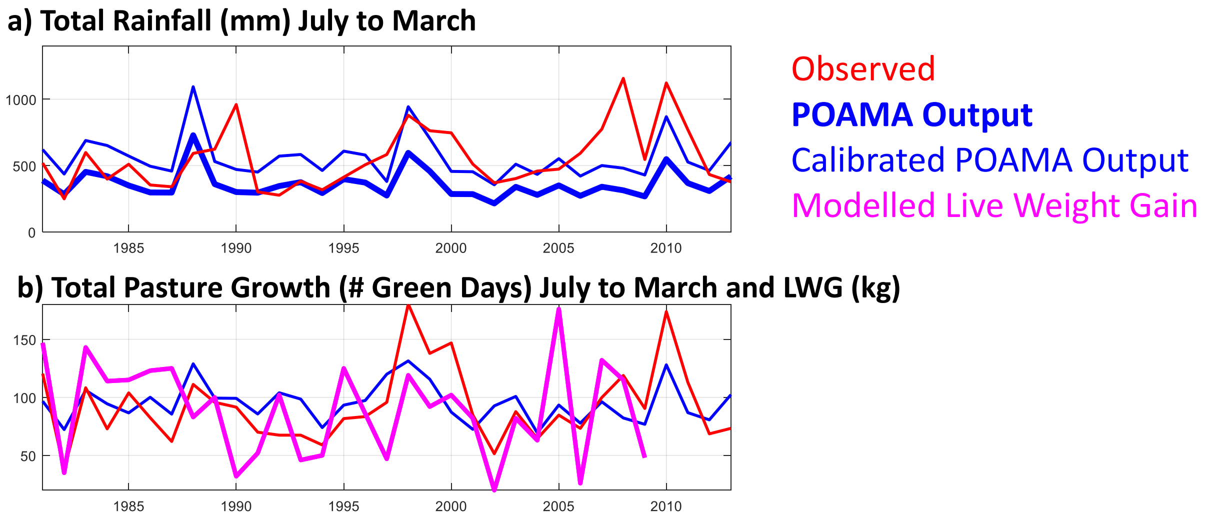

Figure 2. (a) Total observed rainfall from July to March compared to raw and calibrated POAMA outputs. (b) Total number of green days (July to March) calculated from observed climate and calibrated POAMA climate. Overlaid is the corresponding modelled live weight gain calculated from observed climate.

Conclusions

Knowing the potential live weight gain of stock on a property due to total pasture growth and timing of that growth, can aid in stocking rate and management decisions to optimise productivity. Advance knowledge of the pasture growth however relies on a skillful climate forecast.

A perfect knowledge of the upcoming ENSO phase would provide some indication of the pasture growth. However, ENSO phase is not a perfect prediction system, particularly for understanding the pasture growth in neutral years. Further, there are limitations on how well ENSO phase can be predicted in advance – for example the El Niño that failed to develop in 2014.

Seasonal climate forecasting models have the potential to advance upon the practice of using ENSO phase predictions to make stocking decisions. The advantage of these models is to provide information about the distribution of the rainfall ahead and the impact of other climatic influences beyond ENSO. At this stage the Australian POAMA model is limited in its ability to predict total wet season rainfall, but there is promise in its ability to predict pasture growth which is more desirable.

Ultimately the ideal modelling system would incorporate a range of leading seasonal climate forecast models with pasture growth and herd models to account for many sources of uncertainty and the initial conditions and practices of an individual property.

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