Can modelled soil moisture with the Southern Oscillation Index predict poor spring pasture production?

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Abstract
Better early predictions of low spring pasture production would be of great value to southern Australian broad acre grazing farmers. Three Victorian livestock farm case studies were used to investigate whether the use of modelled soil water, combined with the Southern Oscillation Index (SOI), could provide early and accurate prediction of poor spring pasture production. Case studies were located in Central Victoria at Woodend (W) and Baynton (B), and North East Victoria at Seymour (S). Climate data from the last 120 years (1890-2010), obtained from the closest meteorological station, were used for each farm to model total spring pasture production and total soil water (TSW) using the GrassGro™ model. A combination of TSW on the first day of September and the SOI for August were used to predict spring pasture production for all paddocks on each farm. TSW with the SOI accounted for 75.6 percent of the variance, where the previous year's spring pasture production was included. Eighty eight percent of years that had low decile TSW on September 1st and SOI at or below -8 were followed by very poor springs (pasture production in the lowest two deciles) and only 4% of years had above average springs. Providing farmers with localised up to date modelled soil water, together with the SOI, may provide acceptable accuracy in predicting most years of low spring pasture production, enabling early tactical decisions to reduce the impacts on the landscape and financial returns.

Keywords
Decision support system, GrassGro modelling, pasture production, tactical decisions.

Introduction
Australian farmers deal with some of the most variable climate in the world (Bureau of Meteorology BOM website) which has significant impact on farming profitability and sustainable grazing systems (Ash, 2007). The ability to reduce the impact of poor seasons relies on early and good information to make effective tactical decisions. Vizard and Anderson's (2009) analysis of seasonal predictions using the phases of the Southern Oscillation Index (SOI) reported that the use of the SOI as a forecasting tool was seldom high but had some value in predicting spring rainfall in eastern Australia. Cullen and Johnson (2012) modelled soil water content at Hamilton, SW Victoria, and concluded that modelled soil water had the potential to predict pasture growth at the most variable times of the year (autumn and spring). A combination therefore of modelled stored soil water at the end of winter and the SOI as a predictive rainfall for spring could be considered as a potential model for predicting spring pasture production, particularly in years of low pasture growth.

The aim of this study was to investigate whether modelled soil water at the end of winter in combination with the SOI could provide early and accurate prediction of low spring pasture production on case study farms in Central and North East Victoria. Low spring feed production was considered to be when spring pasture production was in the lowest two deciles over the 120 year period studied.

Method
Three case study farms were selected to represent areas with known high rainfall and land class variability, as well as farmers with reasonable records for validation of farm production. Farms were located in Central Victoria at Woodend (W) and Baynton (B), North East Victoria at Seymour (S) with average annual rainfalls (1970-2010) of 772mm, 661mm and 612mm respectively. Each farm had at least two distinct land classes, soil and pasture types. The pastures were improved perennial grasses (phalaris or ryegrass) and sub clover on the arable land and unimproved grasses (annual grasses and native perennial grasses) and sub clover on non arable country.

Farms were modelled using the GrassGro™ simulation program (Moore *et al.* 1997) using 120 years (1890 - 2010) SILO climate data (Jeffrey et al,.2001) from the closest weather recording station. Initially, farms were modelled with existing livestock enterprises and stocking rates for validation. Enterprises run on farms included superfine merinos (self replacing and wethers), fine wool self replacing merinos, Coopworths and composite self replacing ewes. The model was validated using historical production records. Whilst GrassGro™ could not fully mimic production performance as achieved on farm, (partly because stock numbers are kept constant across years in GrassGro™), the outputs were considered adequate in predicting the range and averages in values for wool cut (per head and per hectare), live weight or carcase sold for prime lamb enterprises, ewe fertility (as number of lambs weaned) and stocking rates.

Stocking rates were set to have a whole farm pasture utilisation rate of close to 40% to equal grazing pressure on each farm. Lambing times were between early July and August, reflecting farm management practices and optimal times estimated in gross margin analyses generated by GrassGro™. Grazing management of the different land classes was set to a flexible grazing of all livestock classes across all land classes, where stock were moved when weight gain could be improved by 10g/head/day. All farms were simulated to run Coopworth self replacing meat sheep as this was considered an enterprise that would be highly responsive to both good and poor seasons.

Estimates of total soil water (TSW) for each land class (as paddock) on each farm on the first day of spring (1st September) for each year between 1890 and 2010 were derived from GrassGro™. The TSW was modelled for each land class to test whether generic modelled soil water for a location or district would be robust enough to cover a range of soil and pasture types in predicting the season. Spring pasture production was estimated for each land class and farm for each year as kilograms of dry matter per hectare grown from 1st September to 30th November, inclusively.

GENSTAT was used to run a generalised least squares model and multiple linear regression analysis of the prediction of spring pasture production over the 120 years studied. Several mixed linear models were tested:

- TSW (1st Sep) and SOI (Aug)
- TSW (1st Sep) and SOI (Aug) plus spring pasture production in the previous year (Tonnage)
- TSW (1st Sep) and SOI (Aug) plus spring pasture production in the previous year (Tonnage) with
- different slope coefficients for TSW and SOI for each paddock
- TSW (1st Sep) and SOI (Aug) plus spring pasture production in the previous year s (Tonnage) plus soil parameters used in GrassGro™ (top and sub soil depth, saturated conductivity in the top and sub soil, root depth).

To further investigate the reliability of predicting poor springs, counts of years that had TSW on the first of spring (September) in the lowest 10 or 20 percentile combined with an August SOI of -8 or lower, were cross tabulated with spring pasture production with low deciles (0.1, 0.2 and 0.5).

Results and Discussion

Over the 120 year time period, using the TSW for the 1st September and the average SOI for August accounted for 71.9 of the percentage variance in predicting spring pasture production over all paddocks studied. Including both TSW and the SOI improved the prediction of spring pasture production over using each variable in isolation. The prediction was further improved to 75.6%, if the spring pasture growth from the previous year was included in the model. There was no improvement by including either paddock differences or soil parameters in the model.

Table 1 shows the accumulated analysis of variance with the TSW for September, SOI for August and the previous year's spring pasture growth (estimated within paddock). Figure 1 shows the observed versus the predicted values for spring pasture production (as pasture yield in Tonnes per hectare) using this model, over all paddocks.

Table1. Accumulated analysis of variance for predicting Spring Feed, including paddock, TSW (Sep), SOI (Aug) and previous spring feed (Tonnes).

Change	d.f.	s.s.	m.s.	v.r.
+ Paddock	6	2742.4	457.1	345.1
+ TSW Sep	1	563.1	563.0	425.1
+ SOI_ Aug	1	43.5	43.5	32.8
+ Prev_Spring feed	1	81.7	81.7	61.7
Residual	823	1090.1	1.3	
Total	832	4520.5	5.4	

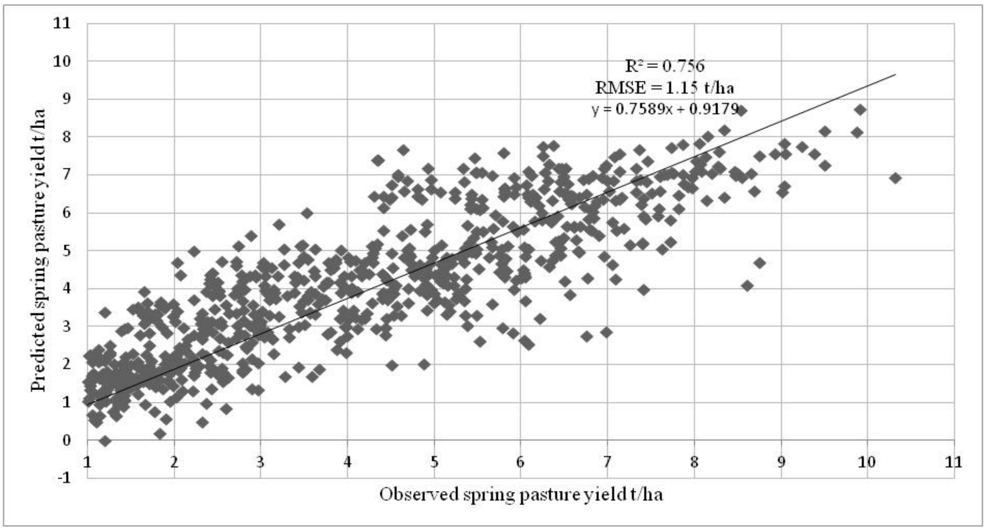

Figure 1. Predicted and observed values for spring pasture production on the 1st of September.

For these case study farms, the analysis showed that modelled soil water and the SOI provided a reasonable prediction of spring pasture production. As GrassGro uses TSW as one of the variables to estimate spring growth, the SOI has provided some predictive rainfall value.

To further investigate the reliability of using TSW and SOI to predict poor spring pasture production, only years that had low values for both TSW and SOI were considered. Years that had TSW on the first of spring (September) in the lowest 10 or 20 percentile combined with an August SOI of -8 or lower, were cross tabulated with spring pasture production with low deciles (0.1, 0.2 and 0.5) to provide counts of years that fell into each quadrant. This was used to consider the reliability of using these values as trigger points make a tactical decision to reduce the impact of low spring pasture production, without the risk of a good spring. For example, if one of the tactics was to sell 30% of stock in early September if there was to be a failed spring, what trigger points would provide adequate confidence that the spring would fail severely.

Over the 120 year period studied, if TSW was in the lowest decile on the 1st September and the SOI was – 8 or lower, there was an 88% probability that spring pasture production would be in the lowest two percentiles with only a 4% chance of being above the median growth.

Whilst the probability of a poor season is high and the chance of a good spring very low, not all failed seasons were predicted using these variables. For example the dry seasons of 2007 and 2008 (at these locations) would not have been identified as the SOI was positive in July and August for 2007 and only -4.3 in July and positive in August for 2008. However, using this trigger point criteria to make a tactical decision on the 1st September, to reduce the impact of a poor spring, may well provide acceptable probability with little risk of making a poor decision.

Conclusion

Including both modelled TSW and SOI improved the prediction of spring pasture growth in the areas studied, than either variable on its own. TSW on the 1st September and SOI for August provided reasonable predictors of spring pasture at the case study locations and with the pasture and soil types modelled.

Using trigger points of modelled TSW in the lowest decile on the 1st September with the SOI for the previous August at -8 or below, there was an 88% probability of a very poor spring, where a very poor spring was defined as spring growth in the lowest 20 percentile for the 120 years studied The chance of above average (median) spring growth was only 4 percent using these criteria. The use of modelled TSW and the SOI could be considered as potential reliable indicators of low spring pasture production to assist livestock farmers in making decisions to reduce the impacts, before the onset of spring. Further research is required to test the predictive relationship over a wider geographical area.

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