Variability in weather: what are the consequences for grazing enterprises?

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Abstract
Evaluation of trends in rainfall and maximum and minimum temperature data over 117 years from 1890 to 2006 at Yass, NSW, suggest that both increases and decreases have occurred and there are consistently high levels of year-to-year variability. The impact of this on pasture and livestock production and financial outcomes was assessed using simulation of a finewool Merino enterprise with the decision support tool GrassGro®. The simulation was based on a wether flock grazing mixed perennial-annual pastures at 2 stocking rates. It showed an increase over the century in annual pasture yields stocked at 12 wethers/ha of about 3t DM/ha and in gross margins (GM) of $20/ha. There was a high level of variability in these values between years. At 15 wethers/ha the corresponding increase in GM was about $70/ha. Over the historical sequence of seasons (1890-2006) the effect on cash flow was examined in a simple balance sheet, assuming current prices throughout with the exception of higher supplement costs in drought years. Losses sustained in severe droughts in the first half of the century were not recovered until the second half, but the rate of recovery was greater at the higher stocking rate (15/ha).

The key feature of this analysis is the high year-to-year variability in weather and its effect on grazing enterprise outcomes. Throughout the 117 years, this year-to-year variability exceeds the magnitude of any shifts in average values for weather variables or production outcomes. It is not possible to predict the future direction of changes to the weather from this investigation. However, it is clear that livestock producers in southern Australia have dealt with high levels of variability in the past and should expect to manage similar levels of uncertainty in the future.

Key words
weather, climate variability, grazing systems, sheep enterprise, decision support, computer simulation, GrassGro

Introduction

The recent series of years with low rainfall in Southern Australia presents severe challenges to beef and sheep producers. Coupled with evidence for increasing global temperatures, these shifts in the weather pattern are a major cause of concern. However, it is not clear whether these shifts are temporary or represent systematic climate change. What confidence can graziers have in these trends as forecasts for future weather? What impact might the trends have on pasture growth and the profitability of grazing enterprises? This paper evaluates a long-term set of weather data for Yass, NSW and examines its likely effect on pasture and animal production using the computer decision support tool GrassGro® (Moore *et al* 1997).

Computer simulation provides a powerful and convenient way to assess the impact of historical weather patterns on grazing enterprises. Importantly, a simulation analysis removes the confounding effects of other changes over time that influence production, such as soil loss, changes to management, technology, pasture species composition, the genetic merit of livestock, costs and commodity prices. Simulation of a consistent managerial environment for a grazing enterprise over a long period of time can provide a structured way to answer important questions and guide management decisions. In particular it can show how recent weather, pasture production and enterprise profitability differ from those of the past. Such an understanding of past conditions can provide a guide to management for the future.

Methods

Daily weather data from 1 January 1890 to 31 December 2006 for rainfall, maximum and minimum air temperature, evaporation and radiation at Yass, on the southern tablelands of NSW, were obtained from the SILO Data Drill (Jeffrey *et al*, 2001). These data, based on Bureau of Meteorology records, provided an unbroken set of daily values suitable for inputs to GrassGro version 3 (Horizon Agriculture Pty Ltd) to simulate a mixed perennial-annual pasture at Yass, NSW, grazed continuously by finewool Merino wethers at stocking rates of 12 and 15 sheep/ha. These stocking rates were based on a study of land capability in the Yass district undertaken with producers of the Bookham Agricultural Bureau (Simpson *et al*, 2005). The sheep were supplemented with wheat whenever their body condition fell below score 1.0. Simulated fleece fibre diameter varied from year-to-year and was priced using median values from 2002-2007 for 16.0-20.0 micron fibre diameter categories (Independent Commodity Services Pty Ltd). The cost of supplement was $195/t. In years in which gross margins were less than $100/ha (droughts), gross margins were re-calculated using supplement costs of $300/t. Stocking rates were maintained in droughts and sheep were supplemented at pasture.

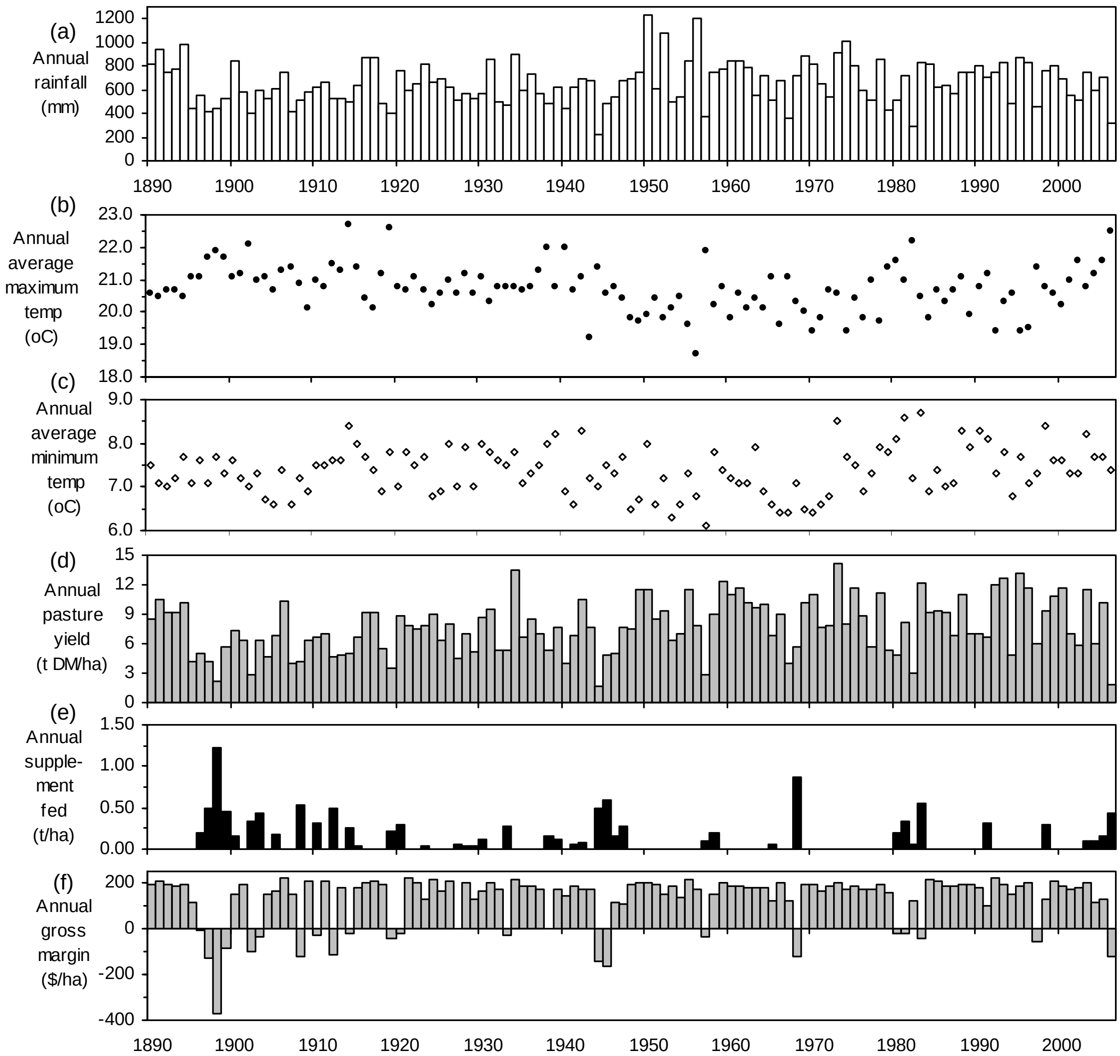

Figure 1. Annual rainfall (a), average maximum (b) and minimum temperatures (c) obtained from SILO Data Drill and annual pasture yield (d), supplement fed (e) and gross margins (f) obtained from GrassGro simulations of a finewool wether flock at Yass NSW from 1890 to 2006.

Weather data and the GrassGro outputs for 117 years of annual pasture growth, fleece weight, supplement fed and gross margins were examined for shifts over time. Results are presented as boxplots for each decade starting in 1890. The box labelled 2000 in each graph contains data for only seven years.

To examine the effect of sequences of good and bad seasons on financial stability for a 1000 ha property, annual cash flows were calculated using current dollar values by subtracting from the simulated gross margin fixed costs of $100 /ha and an operator allowance of $30,000 per annum. Profits were taxed at 33 cents in the dollar and interest of 5% was charged on negative balances.

Results and discussion

Rainfall

The meteorological data for the 117 years show that annual rainfall was highly variable (mean 657 +/- 179.9 mm) (Fig. 1a). Boxplots show that the level of variability was broadly consistent throughout this period (Fig. 2a); annual rainfall ranged from 220 mm to 1227 mm.

The rainfall data suggest that a small increase in annual rainfall has occurred between 1890 and 2006. The median rainfall in the 20 years from 1890 was 586 mm and the value from 1990 to 2006 was 697 mm. There is some evidence that the annual rainfall in the period 1950-2000 was somewhat higher, but with greater year-to-year variability, than rainfall in the period from 1890 to 1949 (Fig. 2a).

Evaluation of monthly data showed that autumn rainfall was consistently more variable throughout the 117 years than that for summer, winter or spring. However, the level of variability is such that it is not possible to state conclusively that autumns since 2000 have been consistently drier than those of earlier decades (Fig. 2b).

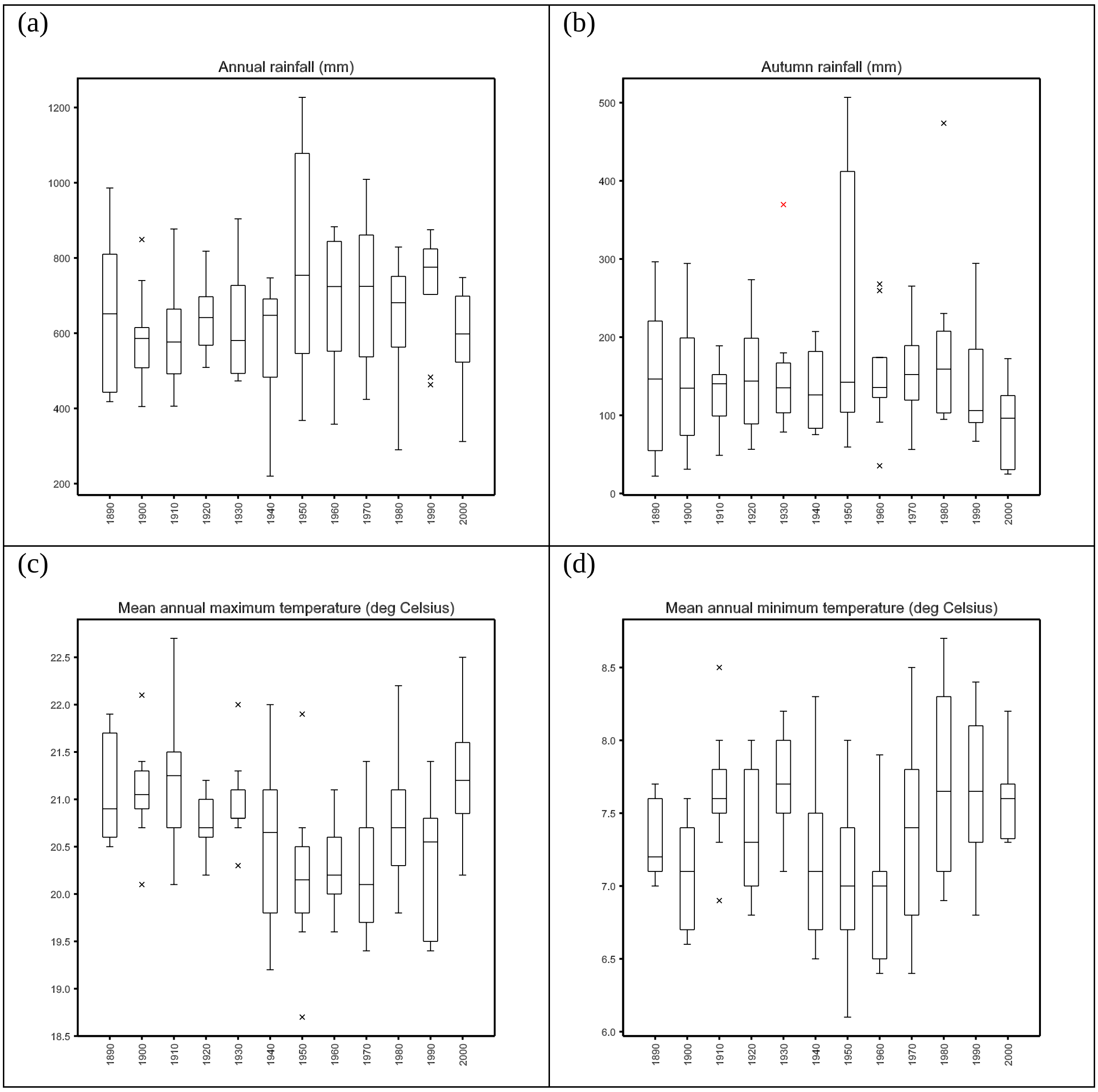

Figure 2. Boxplots showing the distribution over each decade from 1890 of weather data obtained from SILO Data Drill for Yass, NSW, for (a) annual rainfall, (b) autumn rainfall (1 Mar-31 May), (c) annual average maximum and (d) minimum temperatures. The boxes show the middle 50% of values, the lines extending above and below the boxes show the upper and lower 25% of values. Extreme values (outliers) are shown by symbols. The line inside each box shows the median (middle) value.

Temperature
There is evidence for increases in maximum and particularly minimum temperature since 1970 of about 0.5 ^{o}C. However, these increases in the minimum temperature follow a period of 4 decades from 1930 of generally declining temperatures with a change of similar magnitude (Fig.s 2c and d). Examination of monthly data for minimum temperature showed that these increases were largely because of higher values in summer and winter.

Pasture production
What do these shifts in weather patterns mean for pasture supply? Annual pasture yields and gross margins (Fig. 3) reflect the observed shifts in rainfall and temperature; from 1890 to 2006 pasture yields increased from about 6 to about 9 t DM/ha for pasture grazed by 12 wethers/ha (Fig. 3a). The increase was somewhat less at 15 wethers/ha (Fig 3b). At this location, where pasture growth in winter is limited by low temperatures, the simulated increase in pasture production due to higher temperatures contributed to increased wool production and income.

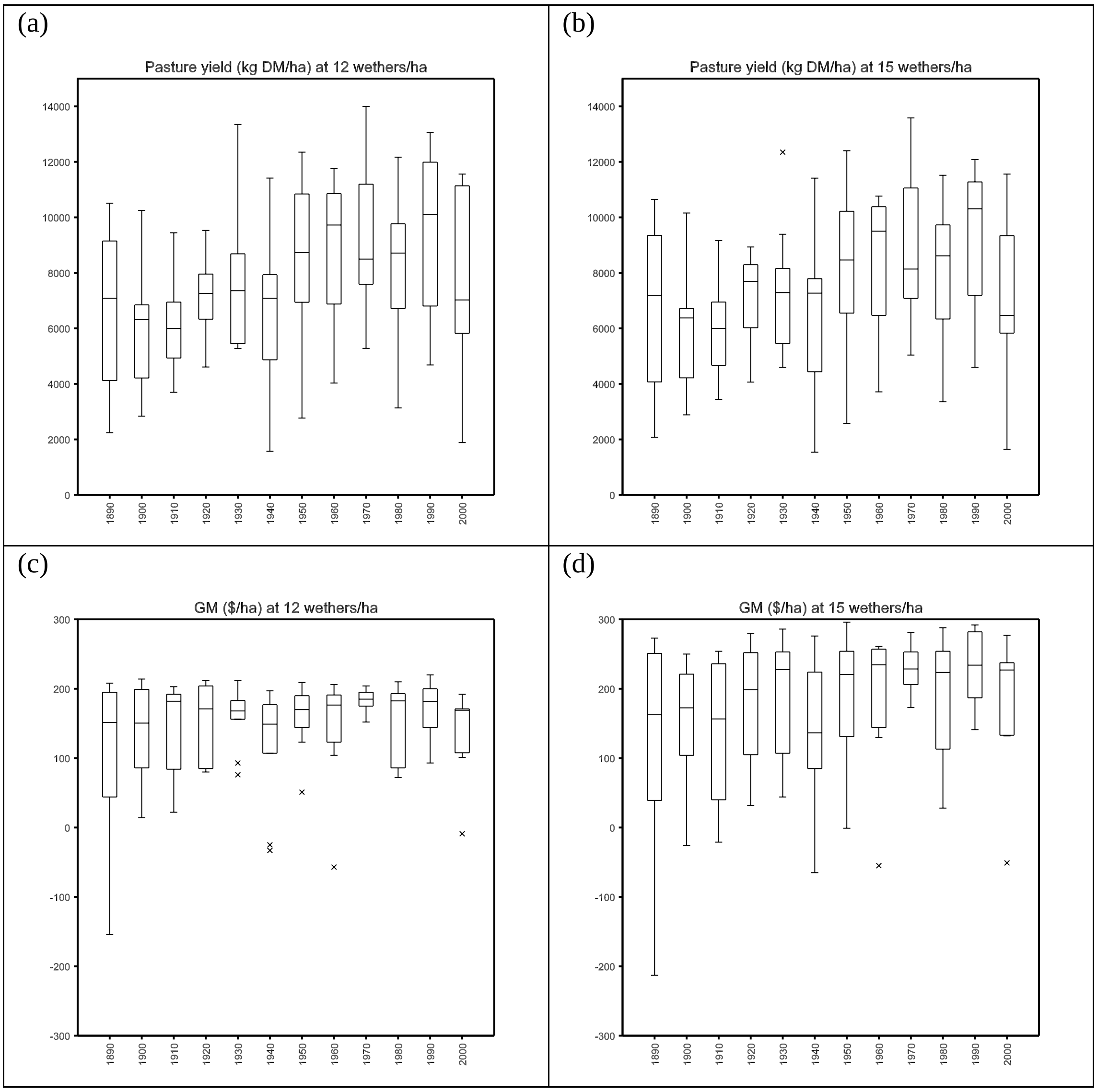

Figure 3. Boxplots showing the distribution over each decade from 1890 of annual pasture yield and annual gross margin (GM) from simulations of a finewool wether flock stocked at either (a and c) 12 or (b and d) 15 wethers/ha. The boxes show the middle 50% of values, the lines extending above and below the boxes show the upper and lower 25% of values. Extreme values (outliers) are shown by symbols. The line inside each box shows the median (middle) value.

These results are specific for the soil, pasture and finewool wether flock simulated at Yass, and assume constant soil fertility, no plant or animal disease or soil losses from erosion. The possible fertilizing effect on plant growth of increased atmospheric carbon dioxide that accompanies climate change has not been modelled in this version of GrassGro.

Gross margins

At a stocking rate of 12 wethers/ha, wool fibre diameter ranged from 16.2-18.6 micron (mean 17.9 micron). Gross margins increased from $138 to $162 /ha over 1889-2006, with an upper limit of $220 /ha in the best years. Increasing stocking rate to 15 /ha lifted gross margins from $140 to $214 /ha over this period. Stocking rate imposed an upper limit on the amount of income that could be generated even in the best seasons, but this 'ceiling' was higher for the higher stocking rate (Fig 3c and d). The range of gross margins also increased as stocking rate increased: from -$154 to $220 /ha at 12 /ha, and from -$213 to $300 /ha at 15 wethers/ha.

Cash flow

Analysis of individual years does not indicate the financial impact of sequences of dry years (Fig. 4). An artificial cash balance sheet created for 1890-2006 using current dollar values, and allocating high feed costs in years in which gross margins were less than $100 /ha (24 of the 117 years simulated), showed that cash flows were positive until the "Federation drought" of 1896-99. Several droughts during the following 20 years prevented financial recovery. Gains made during the 1920s were reversed in the severe droughts of the early 1940s. However, since the 1950s, longer runs of good seasons resulted in consolidated gains, with losses in the major but comparatively brief droughts of 1967, 1980-82 and 2002-06. These "balances" are not real historical values but indicate some of the effects of production risks from seasonal variability on cash flows. Some of the years with poor rainfall do not show up as major economic setbacks because of more favourable distribution and effectiveness of rainfall in those years. In addition, a fine wool enterprise is to some extent "buffered" in droughts by the increased value of the finer wool which is grown when feed intake is limited. Both of these effects are modelled in GrassGro.

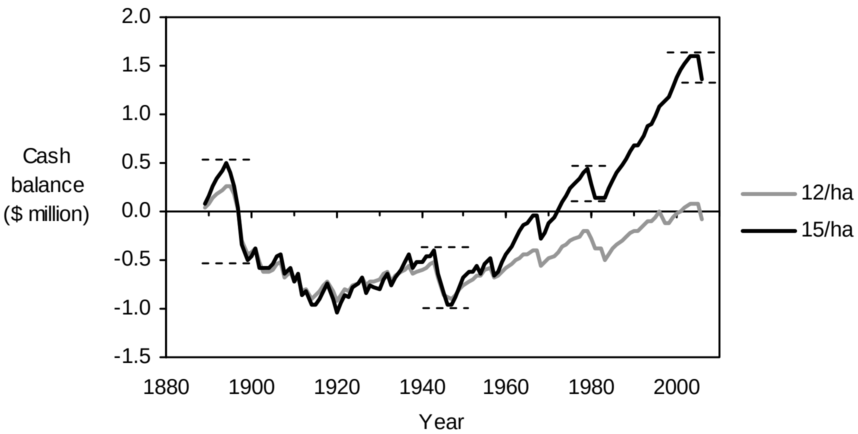

Figure 4. Hypothetical cash flows from 1890 to 2006 calculated from gross margins obtained from GrassGro simulations of a finewool wether flock at Yass NSW grazing 1000 ha of a mixed annual-perennial pasture continuously stocked at rates of 12 (grey line) or 15 wethers/ha (black line). The values do not represent an historical farm balance sheet but indicate the effect of the sequence of variable seasons on production risks. The horizontal dotted lines indicate the magnitude of losses sustained during some of the large droughts during the century. After an initially promising start in the early 1890s, the exceptionally severe drought of 1896-99 and the frequency of droughts until the 1920s resulted in a large amount of accumulated "debt". In reality, these large negative balances would not be financed without debt retirement through sale of land or capital from another source, which, indeed, occurred historically. Gains and losses between these major drought periods represent more typical fluctuations in cash balances. The graph illustrates the critical effect of stocking rate on the ability to generate income and accumulate positive balances from good seasons. See text for details of costs and prices.

While financial losses were slightly greater at the higher stocking rate, the rate of recovery in good seasons was faster at 15 than at 12 wethers/ha. Economic viability depends on an enterprise's ability to turn abundant grass in good years into profit. At low stocking rates this is not possible. The savings in feed costs in dry years from low stocking rates are marginal compared with the gains that can be made in good years at a higher stocking rate.

Historically, debt may have been greater if feed prices were higher than those modelled and if livestock prices collapsed during droughts, while gains would be modified by fluctuations in commodity prices for supplement, livestock and wool and taxation policies and interest rates. In reality, risk management strategies such as selling livestock in droughts to reduce feed costs and judicious purchase of additional stock in better seasons would reduce debt and enhance gains. Changes to productivity from shifts in pasture species composition and intermittent investment in maintenance of soil fertility would also modify these simplistic predictions. Businesses are unable to sustain negative cash balances for long. The limitations of this economic analysis are discussed further in the caption to Figure 4.

Predictive capacity
While these small upward shifts in rainfall and minimum temperatures over the past century seem to have been beneficial to graziers at this location, we do not know the consequences of further climate change. The high level of variability throughout the century makes it difficult to determine whether the trends observed here will continue. These trends are not predictive. In other words, the direction of a trend at the end of the dataset can tell us nothing about its future direction.

While it is important to recognise that climate change is an ongoing reality the immediate challenge for pastoral enterprises is to manage the high degree of variability in pasture production that occurs from year-to-year. This study, looking at long term records, should not make us pessimistic about the future. The recent run of poor years has been experienced in the past – "we have been here before" - and we should probably expect at least as much variability in future weather patterns. We need to recognise the extent of this variability and, as an industry, design robust and responsive grazing enterprises that improve the capacity of farm businesses to recover from bad seasons rather than focus solely on minimising debt.

Conclusion
Annual and seasonal rainfall is highly variable and the magnitude of this variability has not changed over the past century. The total amount of rainfall and mean minimum winter and summer temperatures have increased to a small extent over the past 117 years. Simulation suggests that these changes may have driven increases in pasture production and gross margins. However, it is the high level of variability in weather patterns that influences annual pasture supply and it is the variability in this that presents the greatest challenge to producers, now as much as it has in the past. The fact that graziers have handled great variability in weather historically should be a source of optimism in the face of current unfavourable conditions.

Acknowledgements
Application of GrassGro to grazing industry issues is funded by Australian Wool Innovation Pty Ltd.

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