The effect of climate variability on the perennial pasture zone of southeastern Australia

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Abstract The effect of climate variability on pasture production was investigated using the GrassGro decision support tool. Long-term simulations were conducted for Hamilton, Victoria (118 years), Lucindale, South Australia (109 years) and Campbell Town, Tasmania (95 years). In each case appropriate pasture species were grown on a common district soil type and using nearby climatic data. A Merino wether flock was simulated at Hamilton and ewe/lamb flocks were simulated at Lucindale and Campbell Town. At all three localities, simulated annual pasture growth varied greatly (3,000 to 16,000 kg DM/ha at Hamilton). Total annual rainfall accounted for slightly more than half of the variation in annual total pasture growth with mid-late autumn and spring rainfall being particularly important. Pasture growth was more effected by temperature or waterlogging than rainfall in winter. The timing of the seasonal break in autumn was found to be related to annual pasture growth. Early breaks were consistently followed by above average pasture growth and the opposite was true for late breaks. A break close to the average date (21 April for Hamilton and Campbell Town and 30 April for Lucindale) could not be used as a reliable predictor of annual pasture growth. The Southern Oscillation Index (SOI) is a strong indicator of potential rainfall in northern and eastern Australia. Our study found little relationship between the SOI and rainfall at Hamilton but the relationship was somewhat stronger at Lucindale and Campbell Town. The combination of low winter mean SOI and low soil moisture at the end of winter was found to be a strong indicator of poor pasture growth in spring.

INTRODUCTION

Climatic variability is greater in Australia than in any other country, and is a major constraint to the productivity and profitability of agricultural systems (Nicholls 1994) Indeed, the challenge to producers is to adopt crop, pasture and animal production management strategies which best deal with this variability. The effect of climate variability is not only due to rainfall and temperature, but also soil moisture, evaporation rate, solar radiation and waterlogging. All these factors have significant effects on the growing season length, production and quality of pastures and subsequent animal production.

Modelling is a useful way of integrating all the effects of climatic variability on agricultural production. Decision support tools such as GrassGro, MetAccess and Rainman offer farmers opportunities to reduce the risks associated with climate variability. To investigate the effects of varying climatic conditions on pasture and animal production, simulation studies were conducted for three localities in southeastern Australia - Hamilton in southwestern Victoria, Lucindale in southeastern South Australia and Campbell Town in north-central Tasmania. These sites varied in rainfall amount and distribution and were chosen to cover a wide climatic range.

The Southern Oscillation is recognised as having a strong influence on Australia's climate (Partridge 1994). Its effects are particularly strong in northern and eastern Australia where approximately 40% of the variability of the rainfall can be explained by the Southern Oscillation Index (SOI). However it's impact on southern Australia is still unclear. The SOI is calculated from fluctuations in the air pressure differences between Tahiti and Darwin (Bureau of Meteorology 1994). The SOI ranges from -30 to +30 and, in general, low values correspond with dry conditions in eastern Australia (El Niño) and high values corresponds with above average rainfall (La Niña). The relationships between SOI and rainfall, pasture growth, soil moisture and supplementary feeding were investigated and are reported here.

MATERIALS AND METHODS

The GrassGro decision support tool (Moore *et al.* 1997) was used to simulate pasture and animal production at the 3 study sites. GrassGro was developed by the CSIRO Division of Plant Industry and it combines the GrazFeed animal intake and nutrition models (Freer *et al.* 1997), soil moisture and pasture growth models (Moore *et al.* 1997) with a set of management rules and a simple gross margin calculator. From a user-specified starting state, a paddock's soil moisture content changes according to daily rainfall and evaporation data. Pasture grows in response to the soil moisture status and daily temperature and radiation data. Animals consume available pasture and respond according to the intake, production and reproduction models in GrazFeed. A wide range of soil types and pasture species are available within GrassGro and these cover most environments of temperate Australia. All meat and wool sheep and beef breeds are included. The location and climatic information for the simulation sites is presented in Table 1.

For each locality a weather set was constructed using data collected from nearby meteorological stations. Daily measurements of rainfall, maximum and minimum temperature, evaporation, wind and solar radiation were used by GrassGro to simulate pasture growth and animal production.

Table 1. Location and climate of the sites for GrassGro simulations

	Hamilton	Lucindale	Campbell Town
Latitude	37°44'	36°58'	41°56'
Longitude	142°01'	140°01'	147°30'
Rainfall (yearly average)	697 mm	620 mm	608 mm
Evaporation (yearly average)	1301 mm	1453 mm	1057 mm
Mean maximum temperature - January	25°C	28°C	24°C
Mean minimum temperature - January	10°C	12°C	9°C
Mean maximum temperature - July	12°C	14°C	12°C
Mean minimum temperature - July	4°C	5°C	1°C
Mean number of rain days per year	172	134	118

The simulation for Hamilton ran from 1881 to 1998 and was based on a well fertilised perennial ryegrass (*Lolium perenne*) and subterranean clover (*Trifolium subterraneum*) pasture. The Lucindale simulation was from 1888 to 1996 on a well fertilised phalaris (*Phalaris aquatica*) and subterranean clover pasture with some Capeweed (*Arctotheca calendula*) present. The third simulation, for Campbell Town, ran from 1901 to 1995 on a moderately fertile perennial ryegrass, subterranean clover pasture with some annual grass present. All simulations ran from 1 January to 31 December and full details on the starting parameters are available on request.

RESULTS

Rainfall

The relationship between annual rainfall and annual pasture growth for all three sites is shown in Figure 1. Prominent features of these graphs are the drought years 1967 and 1982 and the above average years 1946 and 1952. Although there were strong relationships between rainfall and pasture growth, it is apparent that other factors are involved. For instance, at Hamilton, "average" pasture growth can result from rainfall totals anywhere between 500 and 900 mm/yr and "average" rainfall produced between 5,000 - 13,000 DM kg/ha/yr.

To further interpret the effect of rainfall on pasture growth the relationship between rainfall and pasture growth for each season was investigated. Figure 2 shows this analysis for Hamilton. Rainfall is most important for pasture growth in spring and autumn.

Autumn Break

A particularly important event each year is the autumn break - the time when conditions are suitable for pasture growth to commence after summer. The timing of the autumn break is generally believed by graziers to have a profound effect on the subsequent growing season.

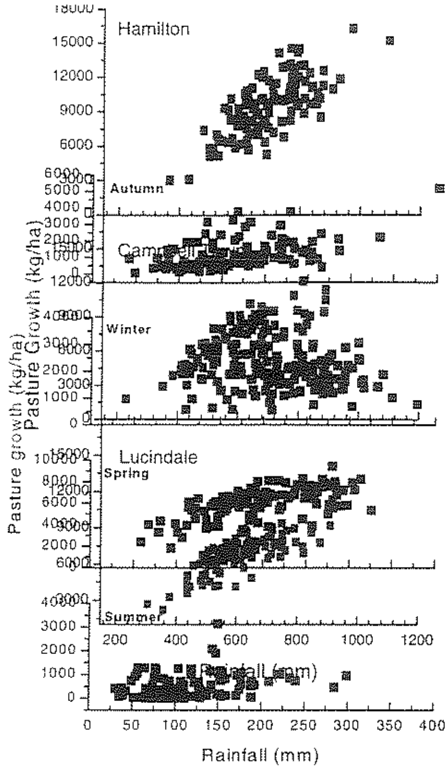
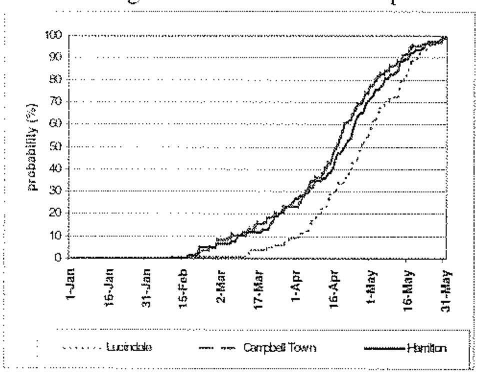


Figure 1. Annual pasture growth versus annual rainfall for the three sites.

Figure 2. Seasonal pasture growth versus rainfall at Hamilton 1881-1998

The simulated autumn break was taken to be the date when GrassGro predicted a successful subterranean clover seed germination. The cumulative probability of autumn breaks occurring from the 1 January to 31 May as predicted by GrassGro is shown in Figure 3. The break occurred as early as the 10 February in Hamilton, 20 February in Campbell Town and the 7 February in Lucindale. False breaks were occasionally predicted with subterranean clover seed germinating but failing to survive. These dates, as well as the breaks predicted to occur after 31 May, were omitted. There was a 50% probability of the break occurring in Hamilton and Campbell Town



by 21 April and by the 30 April in Lucindale. The

Figure 3. Distribution of autumn break dates

Hamilton autumn break dates from 1965 - 1990 were compared and validated with actual dates of the start of autumn rains in Hamilton, recorded by Dr Henry Birrell at the Pastoral and Veterinary Institute. The comparison of Birrell's and GrassGro's dates is presented in Figure 4.

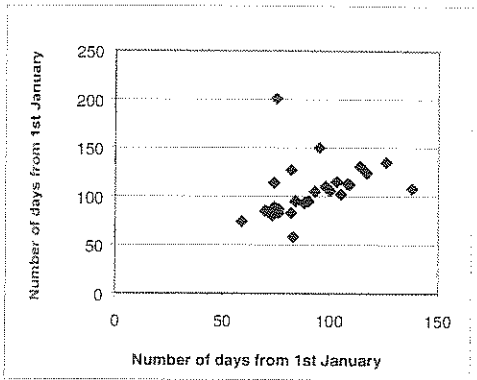


Figure 4. Comparsion between observed and predicted autumn break dates at Hamilton.

Other climatic factors

It is apparent that factors other than rainfall are important drivers of pasture growth at certain times of the year. The effects of temperature and waterlogging on pasture production was investigated for May-September at each site. GrassGro calculates the effect of temperature and waterlogging on the potential growth of the individual pasture species on a daily basis. This effect is expressed as a growth limit between 0 and 1 - with 1 being non-limiting. The results indicate that waterlogging and temperature can severely retard subterranean clover growth and that temperature can limit perennial ryegrass and phalaris growth.

The Southern Oscillation Index

The influence of the SOI on the climate and pasture production was examined for each site and Lucindale was found to be the most strongly influenced. Winter mean SOI values were classified into the phases as defined by Stone and Auliciems (1992). The probability of spring pasture production was then plotted against SOI phase. At Lucindale, a strongly negative winter mean SOI indicates a reduced spring growth potential (Figure 5) The effect was similar but smaller for Campbell Town and particularly Hamilton.

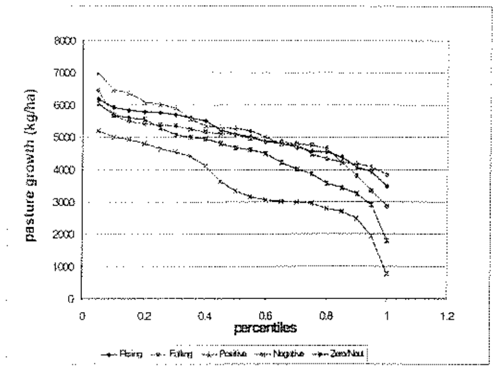


Figure 5. Relationship between SOI phase in winter and pasture growth potential at Lucindale

The combination of a strongly negative mean winter SOI value and low soil moisture at the end of winter was an even stronger indicator of poor pasture growth in spring at Lucindale (Figure 6).

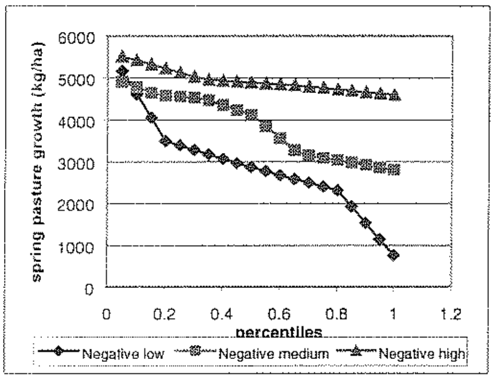


Figure 6. Effect of winter soil moisture status on spring pasture growth when winter SOI phase is negative at Lucindale.

DISCUSSION

Sixty five percent of years at Hamilton had rainfall totals within 100 mm of the long term average (700mm). The corresponding figures are 59%, 620mm for Lucindale and 56%, 600mm for Campbell Town. Annual pasture growth, however, is more variable than annual rainfall, indicating that annual rainfall is only one factor affecting pasture growth. The distribution of rainfall was found to be important at all three localities. Pasture growth in autumn and spring was most responsive to rainfall. Pasture growth in winter was more affected by temperature and waterlogging than by rainfall.

The timing of the autumn break had a profound effect on pasture growth for the rest of the year. At Hamilton, a break prior to April always resulted in above average annual pasture growth. A break after April is more likely to result in poor growth and breaks close to the mean of mid-April resulted in an unpredictable outcome. The relationship between potential pasture growth and autumn breaks at the other sites was more variable and more likely to result in an unpredictable outcome. GrassGro simulated false breaks on occasion in response to heavy rainfall events in January and early February. These do occur occasionally and can result in a reduction of the subterranean clover seed banks and the growing points and root reserves of perennial grasses.

The SOI is not as useful at predicting rainfall in south-eastern Australia as it is in eastern and northern Australia. Low mean winter SOI values do, however, indicate below average spring pasture growth. This is particularly so if soil moisture levels at the end of winter are low.

CONCLUSIONS

Simulated pasture growth at Hamilton, Lucindale and Campbell Town has been shown to be strongly affected by climatic conditions. The amount and distribution of annual rainfall, winter temperatures and waterlogging and the timing of the autumn break are key determinants of pasture growth.

The SOI has a small influence on pasture growth at Hamilton and a slightly larger influence at Lucindale and Campbell Town. It is useful as a predictive tool when combined with other indicators such as soil moisture.

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