FINAL REPORT

Resilient Landscapes: Simulation modelling of pasture species and practices for drought resilience

A report prepared for Holbrook Landcare Network

Prepared by:

Susan Robertson
Gulbali Institute, Charles Sturt University

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Executive Summary

This study was commissioned by Holbrook Landcare Network as part of the '*Creating landscape-scale change through drought resilient pasture systems'* project, funded by the Future Drought Fund via the Southern NSW Drought Resilience Adoption and Innovation Hub.

Choice of pasture species and their management impact on the profitability of livestock systems and the resilience of an enterprise to drought. The purpose of this study was to demonstrate the impact of choice of pasture species and management practices on resilience of pasture/sheep systems to drought, enabling producers to better prepare for future droughts.

Simulation using GrassGro™ software (Donnelly *et al.* 1997) was used to investigate producer-identified choices of pasture species and management practices in regions of southern NSW associated with the farming groups Holbrook Landcare Network, Riverine Plains, FarmLink Research, Central West Farming Systems and Monaro Farming Systems. Models for 8 locations (Mangoplah, Bookham, Finley, Temora, Boorowa, Condobolin, Nimmitabel and Bombala) were developed and pasture growth compared with published values, where available, to improve the reliability of results. Sheep enterprises typical of each region were used to evaluate the impact of various choices on risks to sustainability, sheep production and enterprise gross margins long-term and in drought years. All simulations were conducted for the period 1970 to 2019 to encompass the long-term seasonal variation including several periods of drought. Producer groups provided feedback on preliminary results to better match typical management and perceptions of performance before the final analyses were conducted.

Key findings from the study were:

- Stocking rate is a key driver of sheep production per hectare but must be optimised to avoid overgrazing, risk of low groundcover, and excessive feeding costs. Low stocking rates reduce these risks but generate low wool and meat sales which may limit the build-up of financial reserves.
- Unproductive pastures limit sheep production and the ability to generate income. Pastures with a higher growth potential are likely to increase sheep production long-term although they may not improve production in drought years.
- Established summer-active perennial pastures such as Lucerne, which extend the growth period, reduce supplementary feed requirements and promote higher sale weights of lambs grown over the summer/autumn period. While Lucerne may not increase production during

drought due to a lack of growth in summer/autumn without rainfall, higher cash flow in other years may improve farm financial position long-term, improving resilience through droughts.

- Flexibility in the duration of rotational grazing, rather than set-timed grazing, reduces the risk of overgrazing pastures, the need for supplementary feeding and improved gross margins from sheep enterprises. While providing periods of rest is critical for the persistence of perennial pastures, set-timed rotational grazing resulted in overgrazing during periods of low pasture growth, reducing the growth of lambs.
- Pasture species have different patterns of growth. A feedbase with more than one type of pasture may reduce feed gaps. Mixtures of different species within a paddock require careful consideration as dominance by one species may not result in increased production.

Contents

1. Introduction

Drought is a feature of the Australian climate, and the resilience of pasture-based livestock systems long-term is important to the social and financial function of rural communities. Resilience is impacted by producers' choice of pasture species and how the pasture/livestock system is managed to generate wool and meat for income. This study investigated the long-term impact of commonly used species and practices on the production and risks to sheep enterprises in southern Australian farming systems.

Perennial pastures potentially increase pasture production and extend the pasture growing season compared with annual pastures. The deeper root system of perennials allows access to soil water at depth, but perennials require the capacity to persist through prolonged periods of low rainfall. Annual pastures regenerate each year from a seedbank, but persistence can be limited through low seed-set, overgrazing which reduces the seedbank, and susceptibility to false autumn breaks if the level of hard-seededness is not suitable for the environment. Inadequate persistence leads to less productive pastures, increased potential for soil erosion, and a need to re-sow pasture, increasing costs. In addition to sown annual pastures, some farming systems use volunteer annual species. These reduce establishment and maintenance costs but may be less productive than managed pastures.

Grazing management is a key practice used to manage the persistence of pastures. Rotational grazing is recommended to improve the persistence of Lucerne pasture (*Medicago sativa*) with Lucerne (Southwood and Robards 1975) and Phalaris (*Phalaris aquatica*) (Watson *et al.* 2000) sensitive to heavy grazing during drought. More recent studies show that a range of grazing strategies can provide similar persistence of Lucerne, with the key factor an adequate period of rest from grazing (Burnett *et al.* 2018). However, producers continue to be interested in different grazing strategies.

The choice of pasture species will alter the production and pattern of pasture supply, influencing production and profit from sheep enterprises. Periods of no or slow growth due to pasture maturity, lack of water or excessive cold can create a feed gap for sheep enterprises, requiring either a reduction in stocking rate or supplementary feeding to meet energy requirements. Combining species with different growth patterns potentially minimises the feed gap, although the complementarity of the species mix will influence pasture persistence and productivity, and resilience to drought of both pasture and the grazing sheep enterprise.

This study considered each of the above factors for impacts on the resilience of a pasture/sheep system to drought, with factors chosen in collaboration with southern Australian farming groups.

2. Project objectives

The purpose of this study was to evaluate the impact of pasture species and management practices on the productivity and resilience of pasture/sheep systems to drought to assist producers prepare for future droughts. The pasture species and management practices evaluated were specified by farming groups in southern Australia associated with the Southern NSW Drought Hub.

3. Methodology

GrassGro™ 3.4.3 software (Donnelly *et al.* 1997) was used to simulate regional pasture and sheep production across southern NSW. The model uses daily historical weather records for a location with a user-defined soil type, pasture and livestock variables to simulate pasture growth and livestock feed intake and production for a specified management system.

Pasture-only systems were modelled because GrassGro does not model crops. Simulations were run using single species or mixes of annual and perennial pastures to allow the impact on different types of pastures to be defined. The key location parameters used for each location are shown in Appendix 1, pasture parameters in Appendix 2, and average monthly pasture growth rates provided in Appendix 3.

For each location, simulations were conducted between 1965 to 2019 with data for the first 5 years excluded for initialisation of the model and only data 1970 to 2019 used in subsequent analysis. Drought years within the time period were designated using a combination of low annual pasture production, high quantities of production feeding in containment and low annual rainfall. This classification meant that low pasture availability for one year resulting in heavy feeding in autumn of the next meant both years were classed as drought years, even if the drought ended during the second year.

3.1 Questions modelled

<u>Holbrook Landcare Network</u>

- *Practice*: Does higher growth potential increase productivity/profit/resilience to drought when using a native perennial grass pasture at Bookham?
- *Species*: Does use of perennials (Phalaris) increase productivity/profit/resilience to drought compared with an annual early grass (ie Barley Grass) pasture at Mangoplah?

Riverine Plains

- *Practice*: Does rotational grazing of a Lucerne/Subterranean Clover pasture using a fixed time period increase pasture utilisation and sheep enterprise profitability in a range of seasons at Finley, compared to a set stocked system, using either autumn or winter lambing systems?
- *Species*: Does a Lucerne pasture increase production and resilience to drought compared with a volunteer Annual Ryegrass pasture (used as a break between cropping) at Finley?

FarmLink

- *Practice*: Does rotational grazing rather than set stocking of a Phalaris pasture impact on production and resilience to drought at Boorowa?
- *Species*: How do commercially available pastures (Subterranean Clover, Annual Medic, Lucerne, Phalaris, Cocksfoot) differ in productivity and impact sheep production over a range of seasonal conditions at Temora?

Central West Farming Systems

- *Practice*: Do pasture mixtures (Lucerne vs Lucerne/Subterranean Clover vs Lucerne/Cocksfoot) increase resilience to drought above pure Lucerne stands for sheep enterprises at Condobolin?
- *Species*: What is the growth pattern of Lucerne, Cocksfoot, Subterranean Clover and Annual Medic pastures long-term and in response to drought, and how does this impact on sheep enterprise resilience to drought at Condobolin?

Monaro Farming Systems

- *Practice*: – What is the impact of Lucerne v Phalaris and Lucerne/Phalaris pastures on soil moisture, feed gaps and sheep production at Nimmitabel?
- *Species*: Do Perennial Ryegrass and Phalaris pastures have different growth patterns and nutritive value which will improve sheep enterprise resilience to drought at Bombala?

3.2 Key parameters for assessing drought resilience

Key parameters for the management of sheep systems at each location are shown in Table 1. Drought resilience for each modelled system was considered multi-faceted and could be determined based on the financial viability of the enterprise, the health of the livestock, and the health of the pasture. A key determinant of pasture resilience is species persistence. Whilst GrassGro simulates the persistence of annual species through variance in seed production, the persistence of perennials cannot be modelled. Impacts of drought have therefore been assessed through other factors within the system, particularly the extent of supplementary feeding, livestock reproduction and growth rates, ewe condition score, groundcover and pasture growth.

3.3 Model rules applied

Supplementary feeding rules at Mangoplah, Bookham, Temora and Nimmitabel allowed feeding of whole barley grain to sheep when the condition score of the thinnest animals in a group fell below 2.5. At Finley and Mangoplah the thinnest mature ewes were allowed to fall to condition 1.5 before feeding, while at Condobolin and Bombala the thinnest ewes fell to condition 2.0. All stock were fed in a feedlot to maintain a condition score of 2.5 under the production feeding drought rule when groundcover fell below 70%, and were released to pasture when available green dry matter exceeded 200 kg DM/ha. Weaners were fed under this rule because under the meat and grain prices used feeding resulted in higher gross margins than a flexible sale date dependant on pasture conditions, and seasonal impact is still captured in the quantity of supplement fed. A flexible policy may be more suitable under different price scenarios.

A rotational grazing system was used for perennial pastures at all locations, with an approximate 6 week grazing period staggered between paddocks. Annual pastures were set-stocked, or used a flexible policy with sheep moved to the next paddock each 21 days if growth was improved.

Annual gross margins were calculated in GrassGro using the costs and prices shown in Appendix 4. Enterprise expenses were obtained from the most recent NSW DPI gross margins for sheep, based on 2022 values. Wool and meat prices were expanded to a grid rather than using a single value, to account for seasonal variation in sale weight and fibre diameter. Average prices for 2022 were used and sourced from Meat & Livestock Australia (www.mla.com.au) and AWI and Australian Wool Innovation (www.wool.com.au). Meat prices were adjusted for the month sold using the average monthly percentage price pattern for the trade lamb indicator relative to the average in 2018-2022, providing a premium for sales in winter. An annual pasture maintenance cost of $73/ha was usually applied for improved pastures, but this was varied at some sites based on Farming Group input.

Table 1 ***Description of key sheep enterprise parameters for each location.***

	Mangoplah	Bookham	Finley (autumn lambing)	Finley (winter lambing)	Temora	Boorowa	Condobolin	Nimmitabel	Bombala
Sheep enterprise	2nd cross lambs (BLM x Dorset ram)	Self-replacing Merino	2nd cross lambs (BLM x Dorset ram)		Merino x Dorset ram	Merino x Dorset ram	Self-replacing Merino	Composite	Self-replacing Merino
Standard reference weight	70	60	75		60	60	60	70	45
Fibre diameter (μ)(GFW kg) ewes	20 (5.4)	17.5 (5.4)	28 (4.5)		20 (5.4)	20 (5.4)	22 (6.0)	28 (2.5)	17.5 (4.5)
Ewes purchased	1 Jan	-	1 Oct	1 Jan	1 Jan	1 Jan	-	-	-
Joining date	1 Feb	15 Mar	1 Nov	25 Jan	1 Jan	1 Jan	1 Dec	18 Apr	15 Apr
Wean date	6 Oct	15 Nov	21 Jul	29 Sep	19 Sep	19 Sep	20 Aug	22 Dec	19 Dec
Sale lambs	15 Jan	15 Jan	1 Oct	23 Oct	1 Nov	1 Nov	26 Jan	28 Apr	30 May (21 months)
Sale excess young ewes	-	15 Jan (18 months)	-	-	-	-	28 Sep (17 months)	28 Apr	15 Dec (15 months)
Sale CFA	30 Nov	20 Dec	15 Sep	1 Dec	30 Sep	30 Sep	30 Sep	15 Feb	1 Jan
Shearing date	5 Oct	30 Nov	1 Nov	1 Nov	15 Sep	15 Sep	15 Sep	16 Feb	1 Dec
Base stocking rate (breeding ewes) (/ha)	3.5 (3.5)	2 (1.57)	3 (3)	3 (3)	3.5 (3.5)	3.5 (3.5)	1.8 (1.4)	4 (3.9)	5.1 (4.1)

4. Results

4.1. Holbrook Landcare Network (Mangoplah and Bookham)

Results and Discussion

Practice simulation question: Does higher growth potential increase productivity/profit/resilience to drought when using a native perennial grass pasture at Bookham?

Monthly pasture growth rates were not increased by a higher growth potential (as may occur with more fertile soils) in poor seasons. They were increased by approximately 5 kg DM/ha/day during spring in an average season, while in good seasons growth was increased in both autumn and spring (Figure 1).

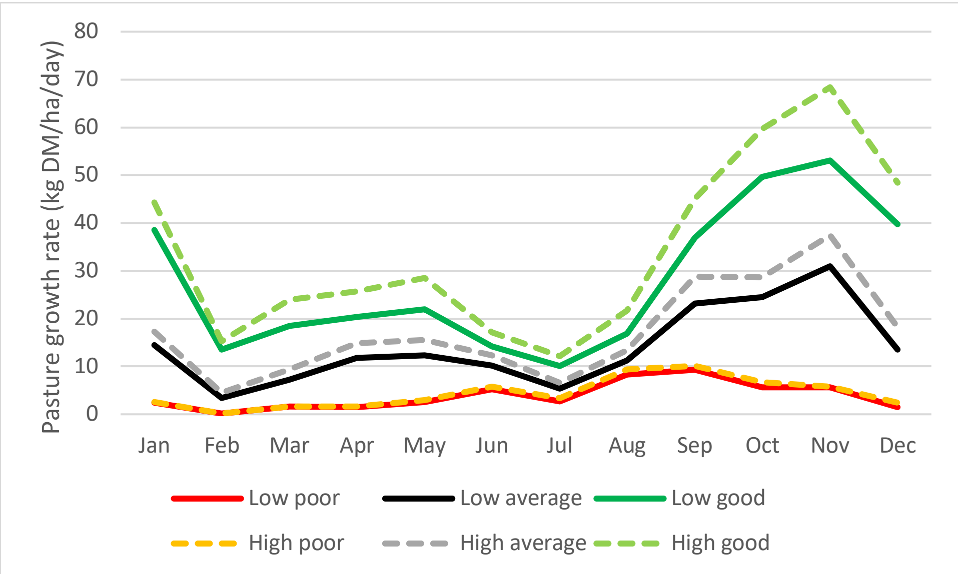


*Figure 1 **Mean monthly pasture growth rates for a native pasture with high or low growth potential in poor, average and good seasons at Bookham 1970-2019.***

A stocking rate of below 1 sheep (1.57 breeding ewes)/ha was needed for the low (base) growth potential pasture to meet the target sustainability threshold of not feeding more the 30 kg/ewe in 40% of years (Table 2). The higher growth potential pasture (soil fertility scalar increased by 10% to 0.7) allowed an increase of 1 sheep/ha to achieve the same feeding levels. Gross margins increased with higher stocking rates for both low and high growth potential pastures despite increasing quantities of supplementary feed, but with increasing variability (Figure 2). Gross margins were reduced for high growth potential pastures due to the increased maintenance cost assumed for pasture ($73/ha rather than $26/ha) if the stocking rate was only 1 sheep/ha, but were similar if 3 sheep/ha were carried due to the larger increase in feed costs associated with less pasture growth for low growth potential pastures. The largest impact of pasture growth potential was through altering the potential stocking rate and supplementary feeding costs as differences in wool value, number and weight of lambs produced were small due to filling feed gaps (Table 3).

Table 2 ***Mean sustainability variables for a native pasture with different stocking rates and growth potential at Bookham 1970-2019.***

Growth potential	Sheep/ha	Ewes/ha	Annual dse/ha	Jul dse/ha	% of years <800 kg DM/ha in Jan-Apr	% of years supplementary feed > 30 kg/ewe	Long-term pasture utilisation	Long-term average groundcover %	Number of months per year < 70% groundcover at 30th percentile
Low	1	0.8	2.2	1.9	0.5	36	11	91	0
	2	1.6	4.3	3.8	2	50	22	87	0
	3	2.3	6.2	5.6	4	64	31	83	0
	4	3.1	8.1	7.4	6	86	38	79	0
High	1	0.8	2.2	1.9	0	26	10	94	0
	2	1.6	4.4	3.6	0.5	36	19	91	0
	3	2.3	6.5	5.8	1	50	28	88	0
	4	3.1	8.4	7.6	3.5	60	35	84	0

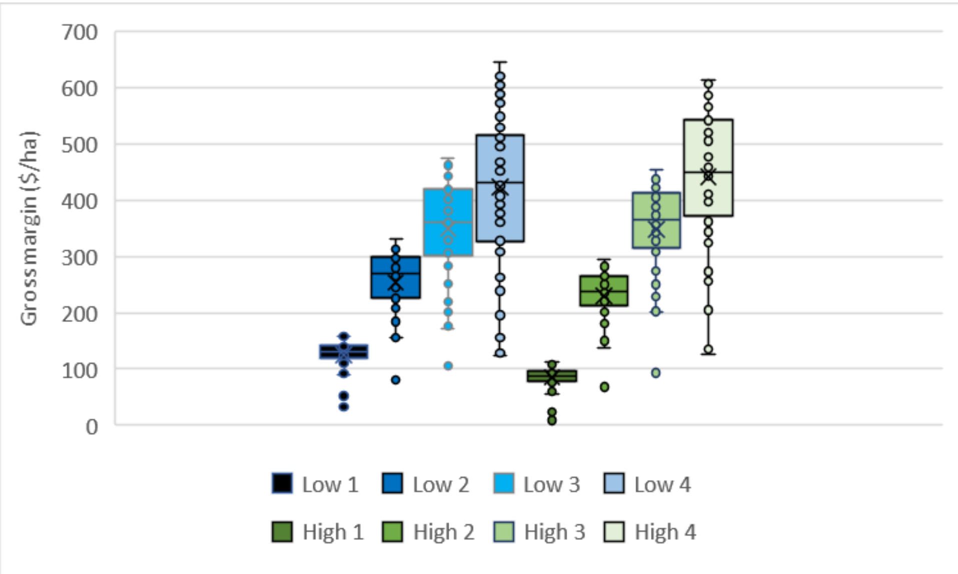


Figure 2 ***Box plots of gross margins for a self-replacing Merino enterprise grazing native pasture on high or low growth potential at different stocking rates (1, 2, 3 or 4 sheep/ha) at Bookham 1970-2019.*** *Boxplots represent median, range and interquartile range, and o indicates extreme values.*

The mean condition score of ewes in all simulations declined during late pregnancy before increasing with pasture growth in spring. High growth potential pastures enabled ewes to maintain a higher condition score throughout the year relative to low growth potential pastures for the same stocking rate. The higher growth potential pastures also allowed a similar condition score if ewes were stocked at 1 sheep/ha higher than those with lower potential (Figure 3).

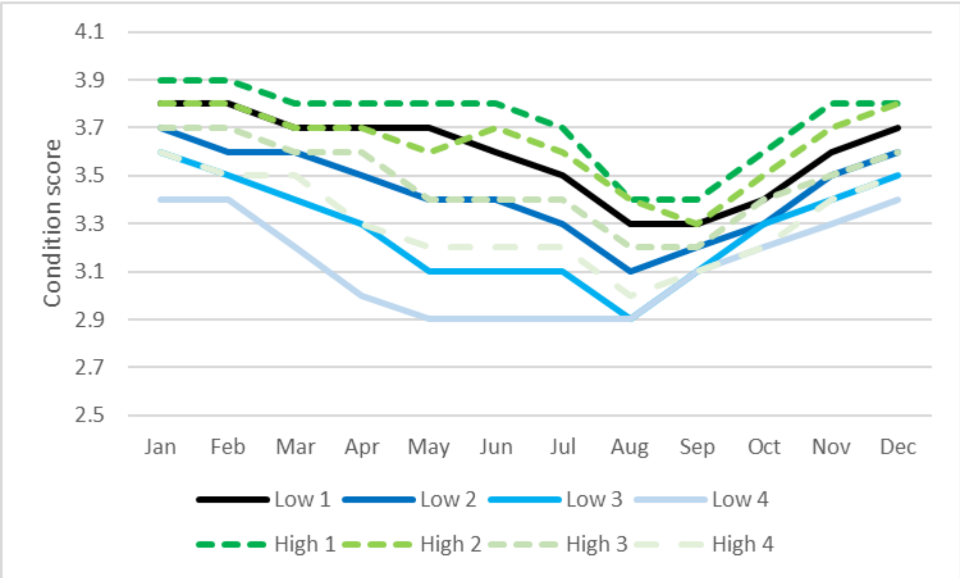


Figure 3 ***Monthly mean condition score of ewes in average seasons (50th percentile) for a self-replacing Merino enterprise grazing high or low growth potential native pastures at different stocking rates (1, 2, 3 or 4 sheep/ha) at Bookham 1970-2019.***

Table 3 ***Mean production variables and gross margin for a self-replacing Merino enterprise grazing native pasture with high or low growth potential at different stocking rates at Bookham 1970-2019.***

Growth potential	Sheep/ha	Lambs marked/ewe joined (%)	No. of lambs sold (no./ha)	Sale weight of lamb (kg)	Value of lamb sold ($/ha)*	Mean fibre diameter of ewes (μ)	Wool value ($/ha)	Supplement ($/ha)	Supplement (kg/ewe)	Mean (median)gross margin $/ha
Low	1	89	0.34	43.3	73	17.9	108	12	31	125 (130)
	2	88	0.67	42.1	141	17.8	212	38	48	253 (271)
	3	87	1.0	40.9	203	17.7	313	87	75	349 (362)
	4	86	1.33	40.2	265	17.6	412	155	100	423 (432)
High	1	90	0.35	44.0	75	17.9	108	7	19	85 (88)
	2	89	0.69	43.3	147	17.9	215	24	31	229 (238)
	3	88	1.0	42.2	211	17.8	318	55	46	348 (365)
	4	88	1.3	41.2	274	17.8	419	107	69	441 (449)

*Wether lambs, as surplus young ewes are sold as hoggets.

Performance in drought years

Drought was classified in 11 of the 50 years at Bookham (Figure 4). The gross margins, income from wool and sheep sales and supplementary feeding costs for poor (lowest 10%), average (50^{th} percentile) and good (highest 10%) seasons are shown in Table 4. The gross margins were lower for the high compared with low growth potential pasture when stocked at 1 sheep/ha due to similar income but higher costs due to pasture maintenance. At 2 sheep/ha the higher growth potential pasture generated higher income due to marginally higher sales from sheep although income from wool remained similar. The disadvantage was less in poor seasons because the high growth potential pasture enabled lower feeding costs, and this did not occur in average and good seasons. However, if the stocking rate was increased for the high growth potential pasture to carry sheep at the same risk of feeding (2 sheep vs 1 sheep/ha), the gross margins increased by over 165% in poor, average and good seasons, because the additional income was more than the difference in pasture maintenance costs. The cumulative effect of these factors on gross margin is shown in Figure 5 where the low growth potential pasture produced a higher financial level unless stocking rate was increased.

The cost of fertiliser has increased in recent years. While this simulation assumed an additional $47/ha would increase average annual pasture growth by 3 kg DM/ha, and spring growth by approximately 5 kg DM/ha, the response to fertiliser will vary between properties based on initial fertility levels. Soil testing is recommended to determine probable responses and the quantity of fertiliser, as the response, so cost:benefit may vary from the results of this simulation.

Wool production and lamb weights per head were similar if the stocking rate for high growth potential native pastures was increased to an equivalent risk of feeding as for the low growth potential pasture, and this occurred in both drought and other seasons (Table 5). Feeding to the same thresholds prevents lower production, with the impact of higher pasture growth potential evident in lower quantities of supplementary feed required.

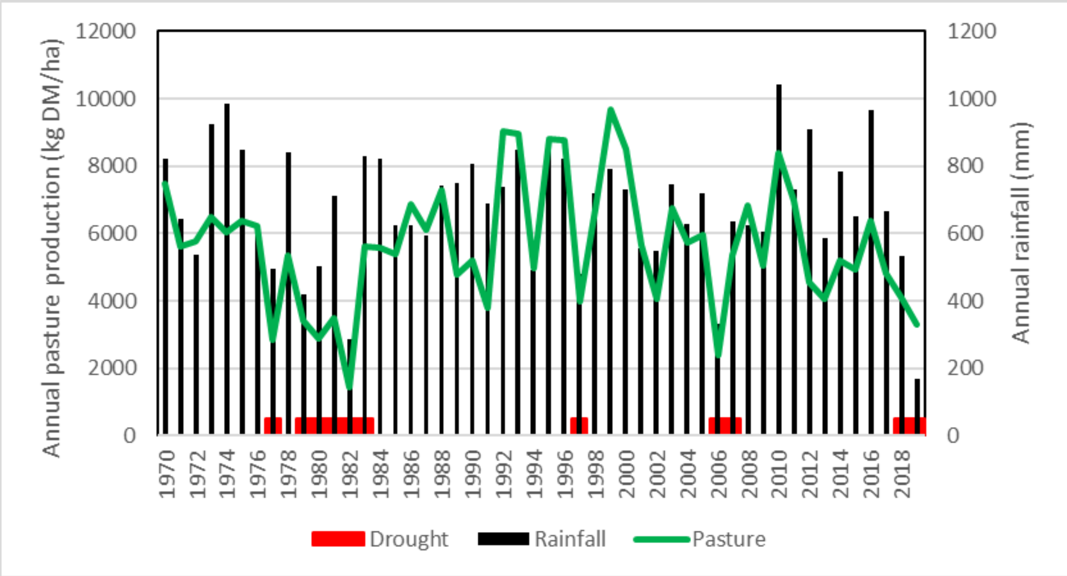


Figure 4 ***Annual rainfall (mm), production of native pasture (kg DM/ha) of low growth potential and classification as a drought year for Bookham 1970-2019.***

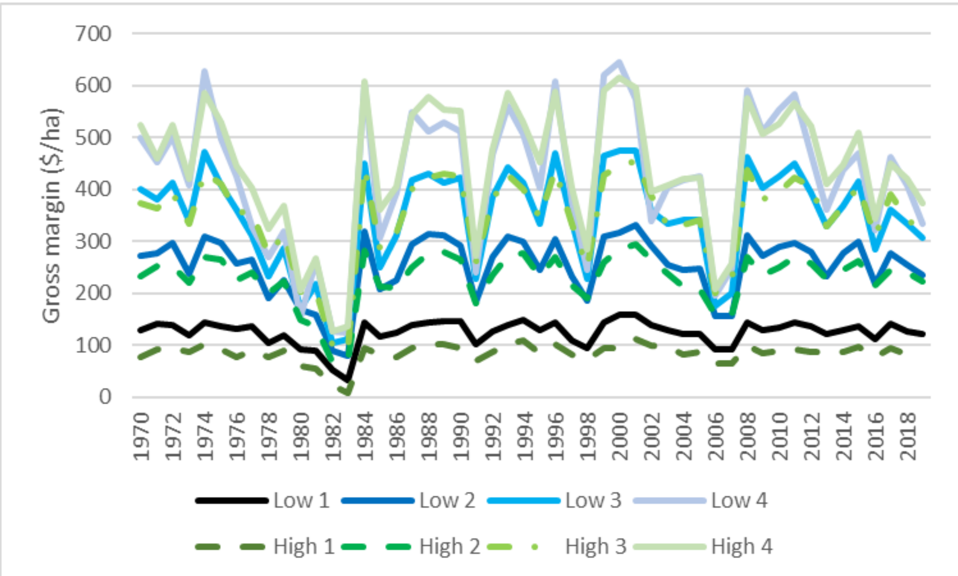


Figure 5 ***Annual gross margin ($/ha) for a self-replacing Merino enterprise grazing native pasture of high or low growth potential at different stocking rates (1, 2, 3, or 4 sheep/ha) at Bookham 1970-2019.***

Table 4 ***Mean gross margin and key income and cost variables in poor, average and good seasons for a self-replacing Merino enterprise grazing native pasture with high or low (base) growth potential at different stocking rates at Bookham 1970-2019.*** *Bold indicates the stocking rate for each pasture with equivalent sustainability indicators.*

Growth potential	Ewes/ha	Season	Gross margin $/ha	Total income ($/ha)	Total Expense ($/ha)	Net Wool Income ($/ha)	Sheep sale income ($/ha)	Maintenance supplement ($/ha)	Production supplement ($/ha)
Low	**1**	**poor**	**93**	**192**	**101**	**104**	**90**	**28**	**1**
		average	**130**	**209**	**74**	**108**	**101**	**3**	**0**
		good	**145**	**218**	**70**	**111**	**108**	**0**	**0**
	2	poor	167	376	214	201	174	59	52
		average	271	405	139	214	192	20	0
		good	312	432	114	221	214	0	0
	3	poor	217	558	342	295	257	98	112
		average	362	593	236	316	280	44	0
		good	462	630	164	326	305	9	0
	4	poor	245	725	443	382	340	148	178
		average	432	783	348	417	368	95	29
		good	591	832	289	433	399	20	0
High	1	poor	65	198	135	105	93	18	0
		average	88	209	120	108	101	0	0
		good	102	221	117	111	110	0	0
	2	**poor**	**158**	**391**	**226**	**206**	**181**	**49**	**15**
		average	**238**	**416**	**170**	**216**	**200**	**8**	**0**
		good	**276**	**441**	**161**	**223**	**219**	**0**	**0**
	3	poor	226	568	355	304	267	86	69
		average	365	611	244	320	291	27	0
		good	432	644	205	331	316	0	0
	4	poor	265	739	480	396	337	128	124
		average	449	800	353	422	375	72	0
		good	587	849	253	438	418	0	0

Table 5 ***Mean production from a self-replacing Merino enterprise grazing native pastures with low or high growth potential in drought or other years.*** *Bold indicates the stocking rate at equivalent feeding risk.*

Growth potential	Sheep/ha	Season	Lambs weaned/ewe joined (%)	Wether weight at weaning (kg)	Wether weight at 31 Dec (kg)	Weaner growth to 31 Dec (g/day)	Weaner growth Jan to May (g/day)	Production supplement (kg/ewe)	Clean fleece weight (kg/ewe)	Fibre diameter ewes (μ)
Low	1	**drought**	**89**	**29.8**	**36.9**	**135**	**89**	**20**	**3.8**	**17.7**
		other	**90**	**32.1**	**40.9**	**169**	**107**	**1**	**4.1**	**18.0**
	2	drought	88	28.9	35.6	128	86	34	3.6	17.6
		other	88	31.5	40.1	165	102	7	4.1	17.9
	3	drought	87	27.9	34.6	131	86	51	3.5	17.4
		other	87	30.9	39.1	158	96	18	4.0	17.8
High	1	drought	90	30.1	37.2	135	94	11	3.9	17.8
		other	91	32.6	41.7	175	111	0	4.1	18.0
	2	**drought**	**89**	**29.4**	**36.7**	**140**	**86**	**20**	**3.8**	**17.7**
		other	**89**	**32.3**	**41.1**	**171**	**105**	**1**	**4.1**	**18.0**
	3	drought	88	28.7	35.4	129	85	32	3.7	17.6
		other	89	31.6	40.3	168	101	7	4.1	17.9

Key Messages for practice simulation: growth potential of native pastures

- The cost to attain higher growth potential pastures needs to be balanced against additional income from production gains to be profitable. Soil testing is recommended to calculate potential responses in pasture growth to fertiliser application. Additional pasture grown needs to be utilised by stock to generate higher income.
- Pastures with higher potential growth will respond to a greater extent in average and good rather than poor seasons.
- Pastures with higher growth potential may enable higher stocking rates, which are a key driver of profit.
- Higher growth potential may increase pasture production and reduce the quantity of supplementary feed required in poor seasons.

Species simulation question: Does use of perennials (Phalaris) increase productivity/profit/resilience to drought compared with an annual early grass (ie Barley Grass) pasture at Mangoplah?

The study compared high growth potential Phalaris with high and low growth potential Barley Grass pasture, each with a Subterranean Clover content. Low growth potential annual pastures were simulated to depict typical degraded annual pastures of the region. An often discussed alternative to the establishment of a perennial pasture for this region is the fertilisation of the annual pasture base, so this has also been tested.

The pasture growth rates for Phalaris were up to 10 kg DM/ha/day higher than for a Barley Grass pasture during winter in the lowest 10% of seasons when using the same growth potential (soil fertility scalar) (Figure 6). In average seasons the growth of Phalaris continued longer into early summer than for Barley Grass but growth during winter was similar. In the best 10% of seasons Barley Grass grew at a similar rate to Phalaris from autumn due to early germination and growth during late summer. A lower growth potential reduced the growth rate of Barley Grass by approximately 10 kg DM/ha/day between May and September in poor seasons, but by over 25 kg DM/ha during spring in good seasons. While spring growth is generally of lower value due to abundant supply, excess production is important in providing a feed bank for grazing over summer/autumn.

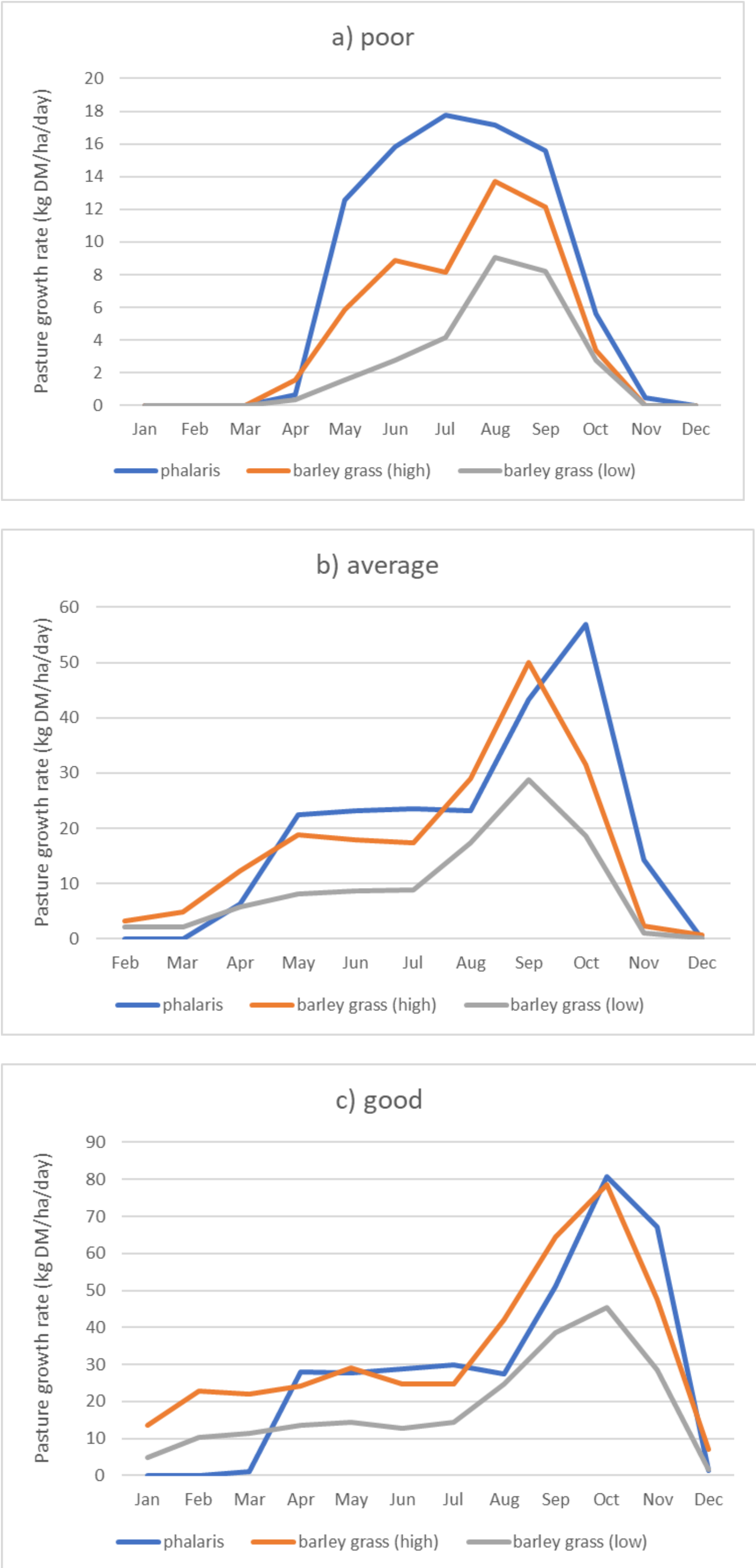


Figure 6 ***Mean monthly pasture growth rates for Phalaris/Subterranean Clover and a Barley Grass/Subterranean Clover pasture under high or low growth potential at Mangoplah in a) poor, b) average and c) good seasonal conditions when stocked at 3.5 ewes/ha.***

Stocking rates were varied to allow comparison of pasture types with similar risks to sustainability (Table 6). The targets for maintaining pasture above 800 kg DM/ha and to limit feeding of ewes to < 30 kg in 40% of years were not met at the base stocking rate of 3.5 ewes/ha grazing Phalaris pasture. They were almost achieved if a stocking rate of 2.5 ewes/ha was used, but this resulted in a large reduction in gross margin (Figure 7). The high fertility Barley Grass pasture achieved similar sustainability risks as Phalaris when grazed at 1 ewe/ha lower stocking rate, but feeding was still marginally above the target when grazed at 1.5 ewes/ha. The lower growth potential Barley Grass required excessive levels of feeding at all stocking rates tested which contributed to low gross margins.

Table 6 ***Mean sustainability variables for Phalaris and Barley Grass (BG) pastures of high or low growth potential and Phalaris pastures at different stocking rates at Mangoplah 1970-2019.***

Pasture	Ewes/ha	Annual dse/ha	July dse/ha	% of years <800 kg DM/ha in Jan-Apr	% of years feed > 30 kg/ewe	Long-term pasture utilisation (%)	Long-term average groundcover (%)	Months < 70% groundcover at 30th percentile
Phalaris	3.5	9.3	11.2	22	56	40	89	2
	2.5	7.0	8.3	12	34	31	92	0
BG high	3.5	8.7	10.8	28	70	35	85	2
	2.5	6.5	7.9	20	58	27	89	0
	1.5	4.1	4.9	9	36	17	93	0
BG low	3.5	7.3	9.3	60	100	32	76	5
	1.5	3.6	4.3	45	82	22	81	4
	0.5	1.3	1.5	26	72	8	88	0

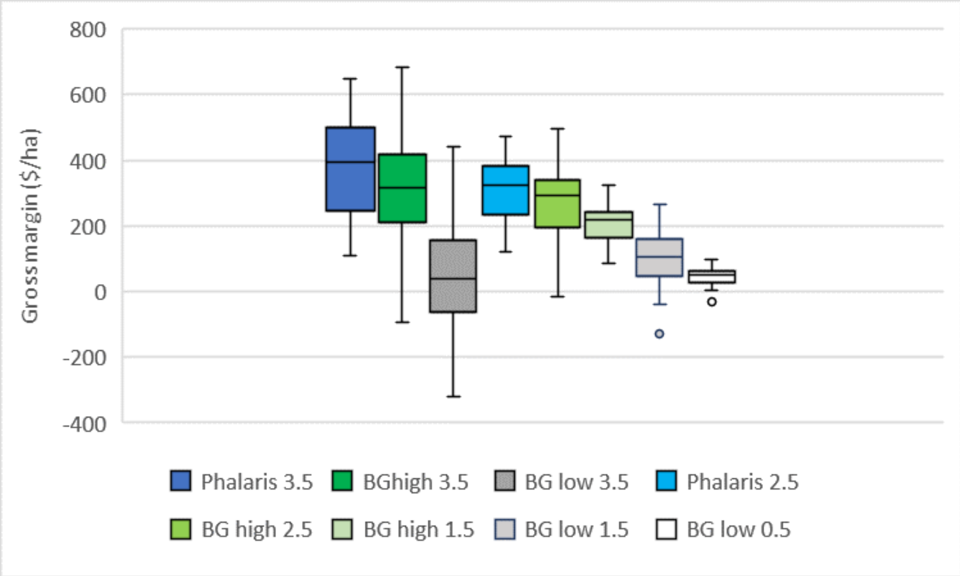


Figure 7 ***Box plots of gross margins for a prime lamb enterprise grazing Barley Grass (BG) of high or low growth potential and Phalaris pastures at different stocking rates (3.5, 2.5, 1.5, 0.5) at Mangoplah 1970-2019.*** *Boxplots represent median, range and interquartile range, and o indicates extreme values.*

The key role of stocking rate in driving meat and wool income from different pasture types is shown in Table 7. Heavy weight lambs were produced on less productive pastures, but the high cost of feeding limited the number of lambs which was viable to produce. Phalaris pasture allowed the production of more lambs per ewe and higher sale weights using less supplementary feed than Barley Grass pasture when compared at the same stocking rate. The value of wool produced was similar between with pasture types, in part due to low premiums for lower fibre diameter for the coarse wool produced.

Table 7 ***Mean production variables and gross margin for Phalaris and Barley Grass (BG) pastures of high or low growth potential and Phalaris pastures at different stocking rates (3.5, 2.5, 1.5, 0.5) at Mangoplah 1970-2019.***

Pasture	Ewes/ha	Lambs marked/ewe joined (%)	No. of lambs sold (no./ha)	Sale weight of lamb (kg)	Value of lamb sold ($/ha)	Wool value ($/ha)	Supplement ($/ha)	Supplement (kg/ewe)	Mean (median) gross margin ($/ha)
Phalaris	3.5	118	4.0	54.7	749	45	71	50	377 (394)
	2.5	121	2.9	56.4	569	32	29	29	304 (326)
BG high	3.5	110	3.8	50.5	665	44	113	71	358 (347)
	2.5	114	2.8	52.5	502	32	55	50	324 (317)
	1.5	116	0.9	57.9	322	20	21	31	204 (217)
BG low	3.5	103	3.5	44.3	546	45	257	168	60 (38)
	1.5	109	1.6	48.9	270	19	69	110	102 (104)
	0.5	113	0.54	51.7	98	6	16	76	48 (50)

The condition score of ewes in February at joining contributed to differences in the number of lambs marked/ewe joined, so lambs sold (Table 7). The monthly condition score of ewes in average seasons (the 50th percentile) varied between pasture types and tended to be higher in late summer and autumn for ewes grazing Phalaris pastures, although condition scores were similar during winter for Barley Grass and Phalaris (Figure 8). Higher condition scores provide a source of energy reserves which may reduce the need for supplementary feeding, but also influence the reproductive performance of ewes.

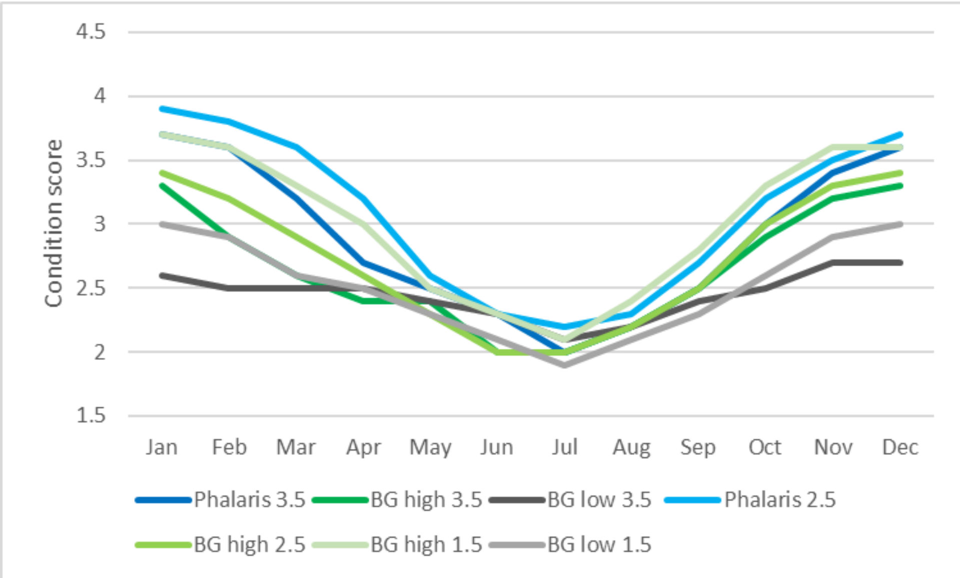


Figure 8 ***Monthly mean condition score of ewes in average seasons (50th percentile) for a prime lamb enterprise grazing Barley Grass (BG) of high or low growth potential and Phalaris pastures at different stocking rates (3.5, 2.5, 1.5) at Mangoplah 1970-2019.***

The gross margins, income from wool and sheep sales and supplementary feeding costs for poor (lowest 10%), average (50th percentile) and good (highest 10%) seasons are shown in Table 8. In poor seasons the gross margin for high fertility Barley Grass and Phalaris pastures were similar at the same stocking rate due to the higher income from sheep sales and lower feeding costs being offset by the higher pasture maintenance costs assumed for Phalaris. Phalaris pastures had a greater ability to generate income from stock sales in average and good seasons, although income from wool was similar between seasons. The low growth potential Barley Grass pasture was unable to support sufficient stocking rate to generate high incomes, and incurred high feeding costs when overstocked. The cash flow as indicated by annual gross margin from 1970-2019 over the historical range of seasons indicated a higher financial position for Phalaris pastures long-term when using the sustainable stocking rate or the same stocking rate (Figure 9). Variation in gross margin over time was considerably reduced when low stocking rates were used, but low stocking rates were unable to generate high cash flow.

Table 8 ***Mean gross margin and key income and cost variables in poor, average and good seasons for Phalaris and Barley Grass (BG) pastures of high or low growth potential and Phalaris pastures at different stocking rates (3.5, 2.5, 1.5, 0.5) at Mangoplah 1970-2019.*** *Bold indicates the stocking rate for each pasture which was the most sustainable.*

Pasture	Stocking rate (ewes/ha)	Season	Gross margin $/ha	Total income ($/ha)	Total Expense ($/ha)	Net Wool Income ($/ha)	Sheep sale income ($/ha)	Maintenance supplement ($/ha)	Production supplement ($/ha)
Phalaris	3.5	poor	160	772	601	42	730	64	120
		average	394	895	509	45	851	23	30
		good	538	1022	459	47	975	0	0
	2.5	**poor**	**151**	**582**	**426**	**30**	**549**	**35**	**59**
		average	**326**	**684**	**366**	**33**	**651**	**6**	**0**
		good	**419**	**776**	**338**	**34**	**743**	**0**	**0**
BG high	3.5	poor	159	687	586	43	644	119	141
		average	317	790	487	44	746	37	54
		good	528	947	378	47	902	0	0
	2.5	poor	153	515	387	30	484	57	85
		average	294	604	308	32	571	23	0
		good	429	728	269	33	697	0	0
	1.5	**poor**	**125**	**328**	**222**	**19**	**308**	**53**	**21**
		average	**217**	**385**	**174**	**19**	**365**	**5**	**0**
		good	**266**	**456**	**158**	**20**	**437**	**0**	**0**
BG low	3.5	poor	-132	581	741	43	537	111	303
		average	38	688	635	45	642	74	189
		good	262	787	464	46	742	17	61
	1.5	poor	4	273	274	18	254	59	93
		average	104	331	231	19	310	28	36
		good	192	397	166	20	378	0	0
	0.5	poor	20	95	87	6	89	24	19
		average	50	118	70	6	111	9	0
		good	79	138	53	7	131	0	0

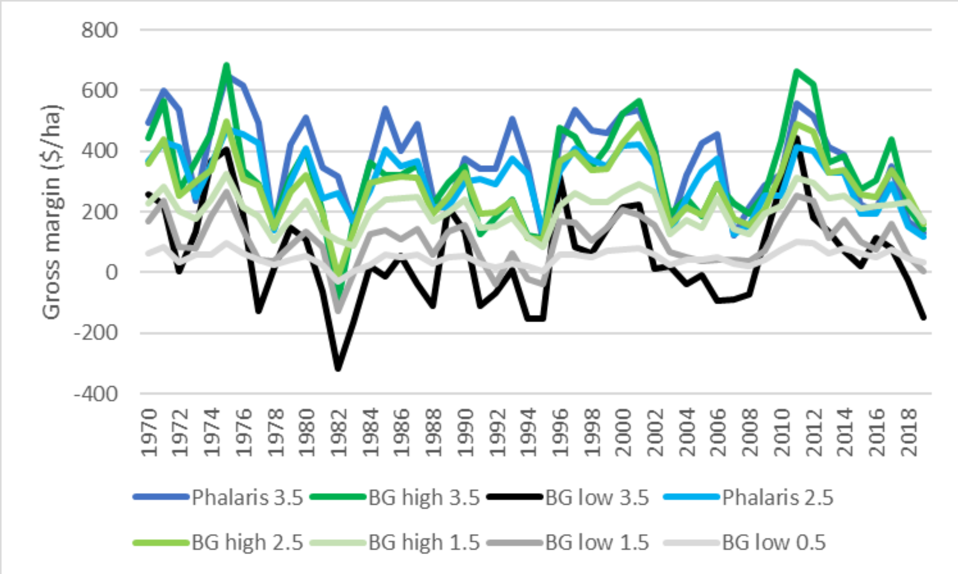


Figure 9 ***Annual gross margin ($/ha) for a prime lamb enterprise grazing Barley Grass (BG) of high or low growth potential and Phalaris pastures at different stocking rates (3.5, 2.5, 1.5, 0.5) at Mangoplah 1970-2019.***

Performance in drought years

Drought years occurred at Mangoplah in 7 periods including 18 years in the period 1970-2019 as shown in Figure 10. When Phalaris and high growth potential Barley Grass were compared at stocking rates with similar feeding levels, during drought years the sheep enterprise grazing Phalaris produced 4% more lambs per ewe, although lamb growth rates were similar (Table 9). However, the higher stocking rate enabled by Phalaris increased per hectare production.

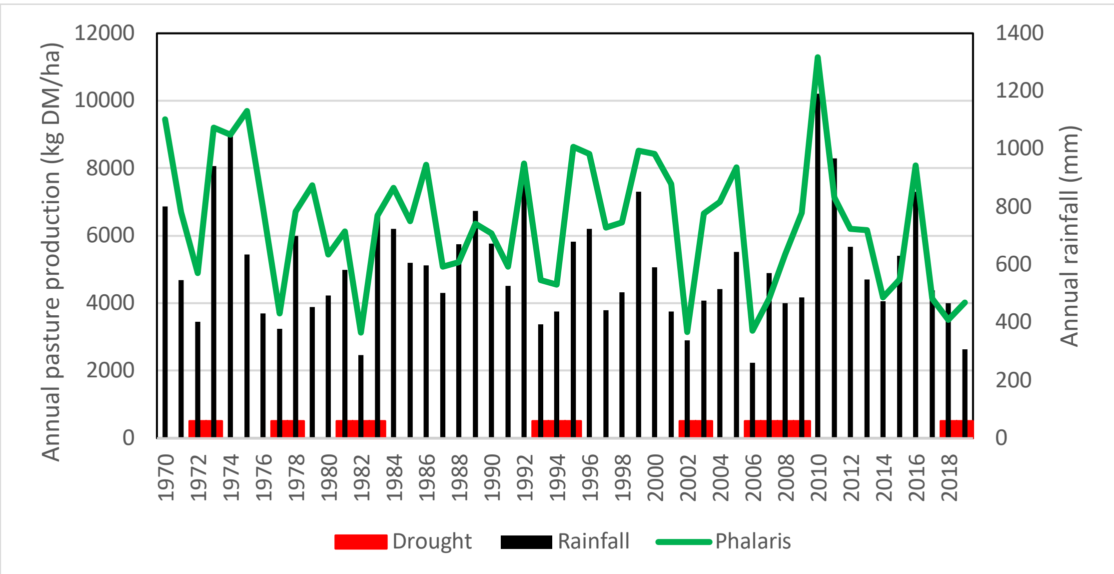


Figure 10 ***Annual rainfall (mm), production of Phalaris pasture (kg DM/ha) and classification as a drought year for Mangoplah 1970-2019.***

Table 9 ***Mean production from a prime lamb enterprise in drought years for Phalaris pasture 3.5 ewes/ha, high growth potential Barley Grass pasture 2.5 ewes/ha and low growth potential Barley Grass pasture 1.5 ewes/ha.*** *Bold indicates the stocking rate for each pasture which was the most sustainable.*

Pasture	Ewes/ha	Season	Lambs weaned/ewe joined (%)	Wether weight at weaning (kg)	Wether weight at 31 Dec (kg)	Weaner growth to 31 Dec (g/day)	Weaner growth Jan to May (g/day)	Production supplement (kg/ewe)	Clean fleece weight (kg/ewe)
Phalaris	3.5	drought	107	38	53	157	95	53	4
		other	119	39	59	206	90	21	4.3
	2.5	**drought**	**111**	**39**	**55**	**162**	**100**	**38**	**4**
		other	**122**	**40**	**60**	**211**	**110**	**8**	**4.3**
BG high	2.5	drought	103	36	51	152	94	50	3.8
		other	116	38	56	182	80	12	4.2
	1.5	**drought**	**107**	**37**	**53**	**156**	**91**	**16**	**4.1**
		other	**121**	**39**	**58**	**197**	**94**	**3**	**4.3**
BG low	1.5	drought	99	32	46	152	107	97	3.3
		other	112	36	53	182	85	47	4.0

Key messages for species simulation: changing the growth potential of pasture species

- Productive pastures allow higher stocking rates which are a key profit driver. Financial reserves will improve resilience of a business to drought.
- Gross margins may be increased through use of perennial rather than annual pastures if additional income produced is greater than establishment and maintenance costs. Long-term persistence is necessary to minimise costs.
- An established perennial Phalaris pasture was more productive than Barley Grass and growth was greater in poor seasons.
- Low growth potential pastures, as may be driven by low soil fertility, can cause large reductions in pasture production and the ability to generate income from sheep enterprises.
- Strategic sale of stock in response to dry seasons may reduce the impact on pasture persistence, risk of low groundcover and requirement for supplementary feeding.

4.2. Riverine Plains (Finley)

Results and Discussion

Practice simulation question: Does rotational grazing of a Lucerne/Subterranean Clover pasture using a fixed time period increase pasture utilisation and sheep enterprise profitability in a range of seasons at Finley, compared to a set stocked system, using either autumn or winter lambing systems?

The monthly growth rates for Lucerne pasture were similar whether set stocked or rotationally grazed (Figure 11). Poor seasons produced minimal growth but Lucerne grew at over 10 kg DM/ha/day in summer/autumn months in average seasons. In good seasons the slowest growth occurred during winter, while growth rates above 40 kg DM/ha/day were achieved from spring to autumn.

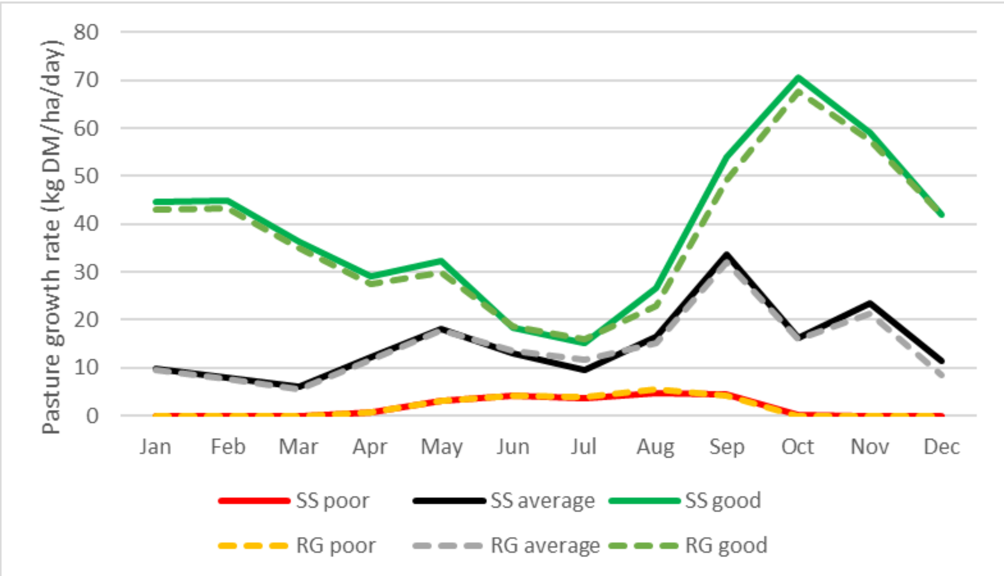


Figure 1 ***Mean monthly pasture growth rates for Lucerne pasture in poor, average and good seasons when set stocked (SS) or rotationally grazed (RG) at 2 ewes/ha at Finley 1970-2019.***

A stocking rate of 3 ewes/ha was considered typical of the region, but for both November and January times of joining resulted in supplementary feeding levels above the target of < 30 kg in 40% of years (Table 10). The threshold of < 800 kg DM/ha in 20% of years was also not achieved at 3 ewes/ha, but was obtained at 2 ewes/ha. The higher stocking rate increased the mean gross margin if pasture were set stocked or rotationally grazed but for the same stocking rate rotational grazing reduced the gross margin (Figure 12; Table 11). This impact was greater at the higher stocking rate and for November compared with January joining. Pasture utilisation was not increased by rotational grazing, but the incidence of pasture mass < 800 kg DM/ha was increased, associated with a requirement for higher levels of supplementary feeding.

Table 2 ***Mean sustainability variables for Lucerne pasture either set stocked or rotationally grazed (RG) by a First Cross ewe enterprise with November or January joining at Finley 1970-2019.***

Join	Grazing	Ewes/ha	Annual dse/ha	July dse/ha	% of years <800 kg DM/ha in Jan-Apr	% of years supplementary feed > 30 kg/ewe	Long-term pasture utilisation (%)	Long-term average groundcover (%)	Number of months per year when < 70% groundcover at 30th percentile
Nov	set	2	5.7	8.9	18	64	23	74	0
		3	8.3	12.1	24	76	33	72	10
	RG	2	5.5	7.8	19	66	22	79	1
		3	7.7	9.7	28	80	30	73	10
Jan	set	2	4.9	7.9	18	44	20	81	0
		3	7.1	11.3	20	52	29	76	7
	RG	2	4.8	7.2	17	48	20	81	0
		3	6.8	9.8	24	64	28	75	6

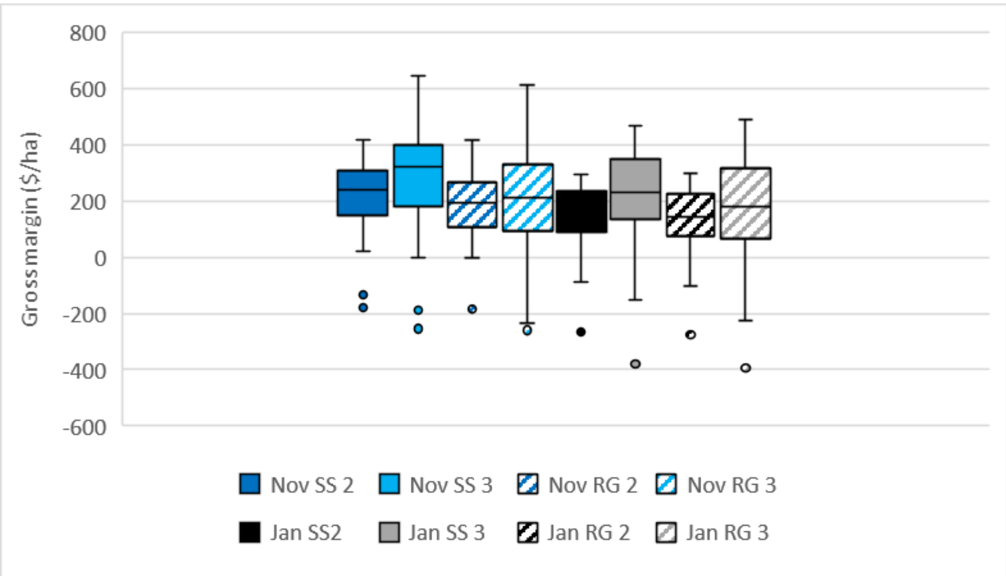


Figure 2 ***Box plots of gross margins for a First Cross ewe enterprise either set stocked (SS) or rotationally grazed (RG) for November and January joining when stocked at 2 or 3 ewes/ha at Finley 1970-2019.*** *Boxplots represent median, range and interquartile range, and o indicates extreme values.*

Rotational grazing caused a reduction in the number of lambs marked/ha and so the number of lambs sold/ha. It also reduced the weight of lambs when sold, with both factors reducing the total value of lamb sold per hectare and the impact being larger for the November time of joining (Table 12). The value of wool was similar between grazing strategies because fleece weight and fibre diameter were minimally altered. Rotational grazing was associated with a higher cost of supplementary feeding than set stocking, although differences in meat production were the key driver of the reduction in gross margins due to rotational grazing.

Grazing management influenced the condition score of ewes as set-stocked ewes were generally 0.2 score higher than rotationally grazed ewes. The condition score of ewes in all simulations declined during late pregnancy and the lambing period, but the loss was larger for ewes joined in November compared with January (Figure 13). The loss tended to increase at the higher stocking rate, but this was more evident for the January joining because maintenance energy requirement was less dependent on supplementary feed. November joining tended to allow a larger increase in ewe condition score after lambing, allowing November joined ewes to be joined in slightly higher condition score at joining. The higher number of lambs marked per ewe joined was associated with the greater condition score of ewes joined in November (Table 11).

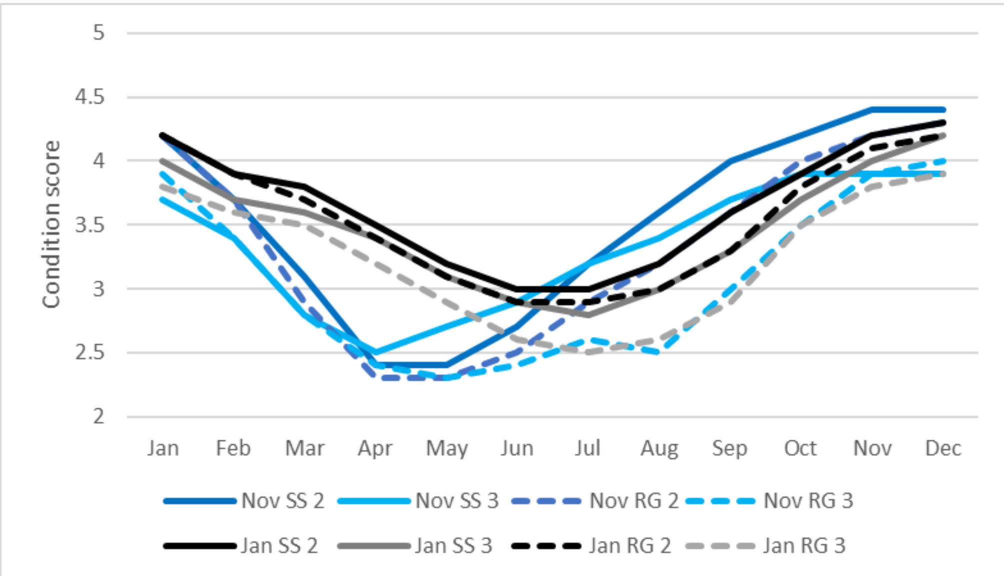


Figure 3 ***Monthly mean condition score of ewes in average seasons (50th percentile) for a First Cross ewe enterprise either set stocked (SS) or rotationally grazed (RG) at 2 or 3 ewes/ha for November and January joining at Finley 1970-2019.***

The gross margins, income from wool and sheep sales and supplementary feeding costs for poor (lowest 10%), average (50th percentile) and good (highest 10%) seasons are shown in Table 12. The cash flow as shown from annual gross margin from 1970-2019 showed generally higher values achieved for set stocking compared with rotational grazing, and the adverse impact of set timed rotational grazing was greater at the higher stocking rate (Figure 14).

Table 3 ***Mean production variables and gross margin for a First Cross ewe enterprise either set stocked (SS) or rotationally grazed (RG) for November and January joining when stocked 2 or 3 ewes/ha at Finley 1970-2019.***

Joining	Grazing	Ewes/ha	Lambs marked/ewe joined (%)	No. of lambs sold (no./ha)	Sale weight of lamb (kg)	Value of lamb sold ($/ha)	Wool value ($/ha)	Supplement ($/ha)	Supplement (kg/ewe)	Mean (median) gross margin ($/ha)
Nov	set	2	1.29	2.5	61.2	505	19	61	70	224 (240)
		3	1.27	3.7	57.6	707	29	114	90	303 (325)
	rotate	2	1.24	2.4	60.2	477	19	65	76	186 (193)
		3	1.21	3.6	54.8	643	29	126	100	218 (215)
Jan	set	2	1.20	2.4	47.7	377	19	36	44	142 (159)
		3	1.17	3.5	46.2	537	29	71	59	203 (232)
	rotate	2	1.18	2.3	47.5	370	19	39	48	131 (143)
		3	1.14	3.4	45.5	513	29	84	70	163 (181)

Table 4 ***Gross margin and key income and cost variables in poor, average and good seasons for a First Cross ewe enterprise either set stocked (SS) or rotationally grazed (RG) at 2 or 3 ewes/ha for November and January joining at Finley 1970-2019.***

Joining	Grazing	Ewes/ha	Season	Gross margin $/ha	Total income ($/ha)	Total Expense ($/ha)	Net Wool Income ($/ha)	Sheep sale income ($/ha)	Maintenance supplement ($/ha)	Production supplement ($/ha)
November	set	2	poor	79	486	434	18	466	36	119
			average	240	601	353	20	581	3	26
			good	384	712	294	21	693	0	0
		3	poor	88	677	641	27	649	33	221
			average	325	830	510	29	801	1	75
			good	547	1029	415	30	1000	0	0
	rotate	2	poor	39	456	448	18	437	47	116
			average	193	557	371	20	538	6	18
			good	362	683	292	21	663	0	0
		3	poor	29	599	658	27	570	82	207
			average	215	767	537	29	737	16	69
			good	482	939	420	30	909	0	0
January	set	2	poor	-35	328	375	18	310	16	75
			average	159	486	309	20	467	0	12
			good	262	550	287	20	530	0	0
		3	poor	-100	449	555	27	420	33	160
			average	232	679	442	29	648	0	40
			good	399	810	397	31	781	0	0
	rotate	2	poor	-56	315	374	18	297	29	69
			average	143	464	312	19	444	0	12
			good	259	545	285	20	525	0	0
		3	poor	-147	433	600	27	405	73	147
			average	181	653	461	28	625	2	38
			good	384	794	399	30	762	0	0

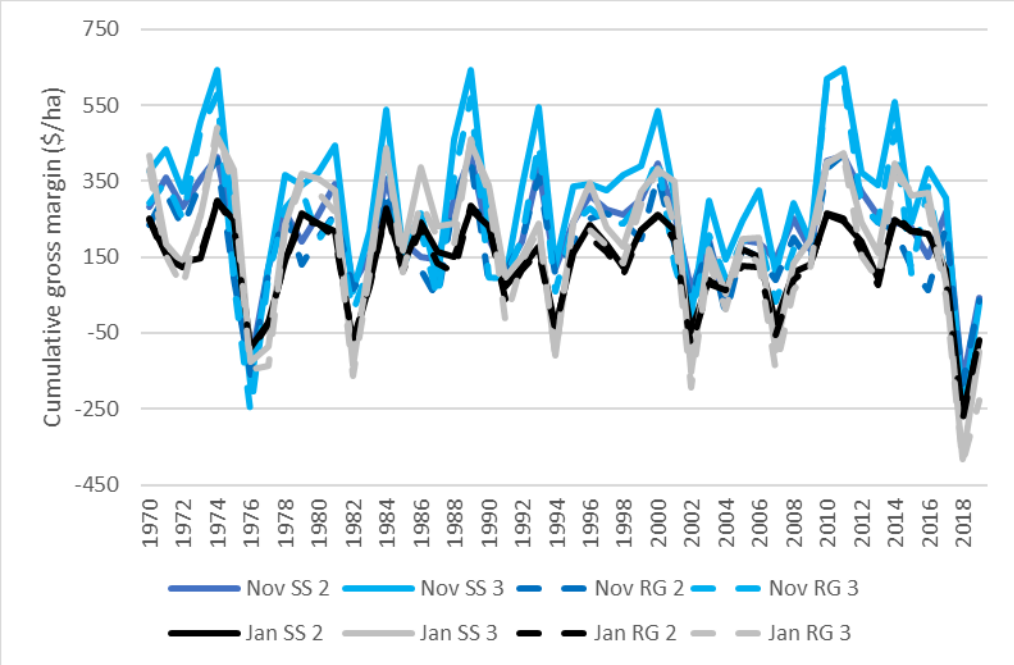


Figure 4 ***Annual gross margin ($/ha) for a First Cross ewe enterprise either set stocked (SS) or rotationally grazed (RG) at 2 or 3 ewes/ha for November and January joining at Finley 1970-2019.***

Performance in drought years

At Finley 9 years were classified as drought in the period 1970-2019 as shown in Figure 15. Rotational grazing increased the growth rate of weaners to sale compared with set stocking in both drought and other years for November joining. However, for January joining, rotational grazing did not increase weaner growth to sale in non-drought years, but did improve growth rates during drought years (Table 13). The quantity of production feeding was also similar in drought and other years for set stocked or rotational grazing.

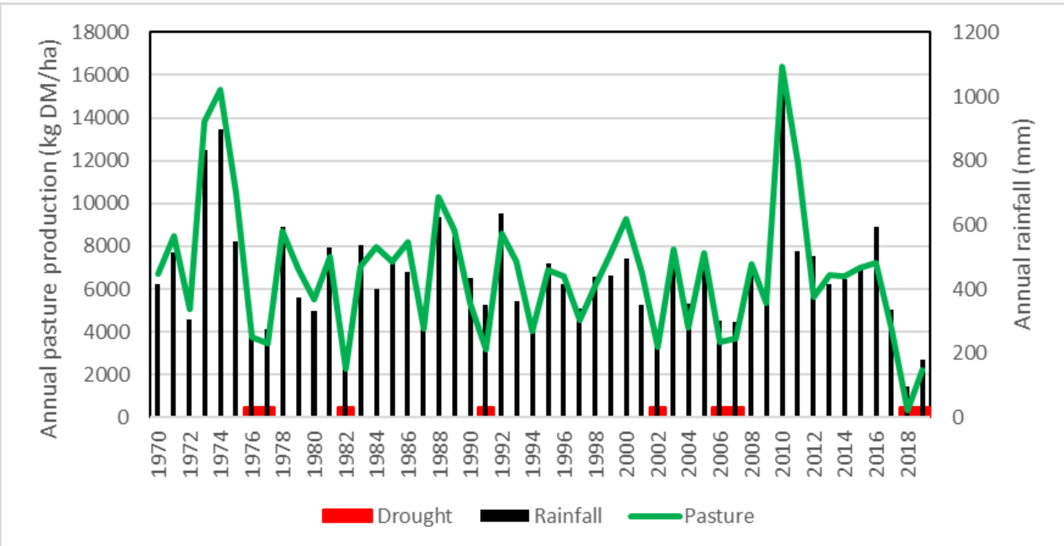


Figure 5 ***Annual rainfall (mm), production of Lucerne pasture (kg DM/ha) and classification as a drought year for Finley 1970-2019.***

Table 5 ***Mean production from a First Cross ewe enterprise either set stocked (SS) or rotationally grazed (RG) at 2 or 3 ewes/ha for November and January joining at Finley 1970-2019.***

Joining	Grazing	Ewes/ha	Season	Lambs weaned/ewe joined (%)	Wether weight at weaning (kg)	Weaner growth to sale (g/day)	Total meat sold (kg/ha)	Production supplement (kg/ewe)	Clean fleece weight (kg/ewe)
November	set	2	drought	125	35.9	179	134	131	3.3
			other	129	41.7	294	178	40	3.5
		3	drought	123	33.6	91	187	171	3.2
			other	127	40.0	252	252	61	3.3
	rotate	2	drought	120	34.6	230	126	125	3.3
			other	123	39.4	404	167	40	3.4
		3	drought	118	31.4	138	169	166	3.2
			other	120	36.2	423	229	57	3.3
January	set	2	drought	113	32.9	96	105	100	3.1
			other	121	43	335	145	23	3.7
		3	drought	110	30.2	63	147	133	2.8
			other	118	41.8	332	209	34	3.7
	rotate	2	drought	109	32.1	188	102	101	2.9
			other	119	42.3	314	142	24	3.6
		3	drought	106	28.8	194	138	132	3
			other	115	40	336	201	35	3.6

Key Messages for practice simulation: rotational grazing vs set stocking of Lucerne

- Rotational grazing or rest periods are required to allow Lucerne pastures to persist, particularly through periods of drought, although the persistence of Lucerne could not be modelled directly in this instance.
- Set periods of rotational grazing may reduce ewe condition and lamb growth. Optimising the length of rotations will minimise reductions in sheep production.
- Autumn/winter lambing required high quantities of supplementary feed. Increasing stocking rate increased gross margins but also the quantity of feeding.
- Later joining reduced the need for supplementary feeding but reduced lamb sale weight if lamb sale date was not delayed.
- Strategic sale of stock in response to dry seasons may reduce the impact on pasture persistence, risk of low groundcover and requirement for supplementary feeding.

Species simulation question: Does a Lucerne pasture increase production and resilience to drought compared with a volunteer Annual Ryegrass pasture (used as a break between cropping) at Finley?

Monthly pasture growth rates in poor seasons were similar for volunteer Ryegrass and Lucerne pastures. In average years Lucerne extended the growing season with higher growth from late spring and autumn when ryegrass was not productive. Ryegrass produced similar high growth to Lucerne during good spring seasons, but as an annual was unable to maintain growth from late spring (Figure 16).

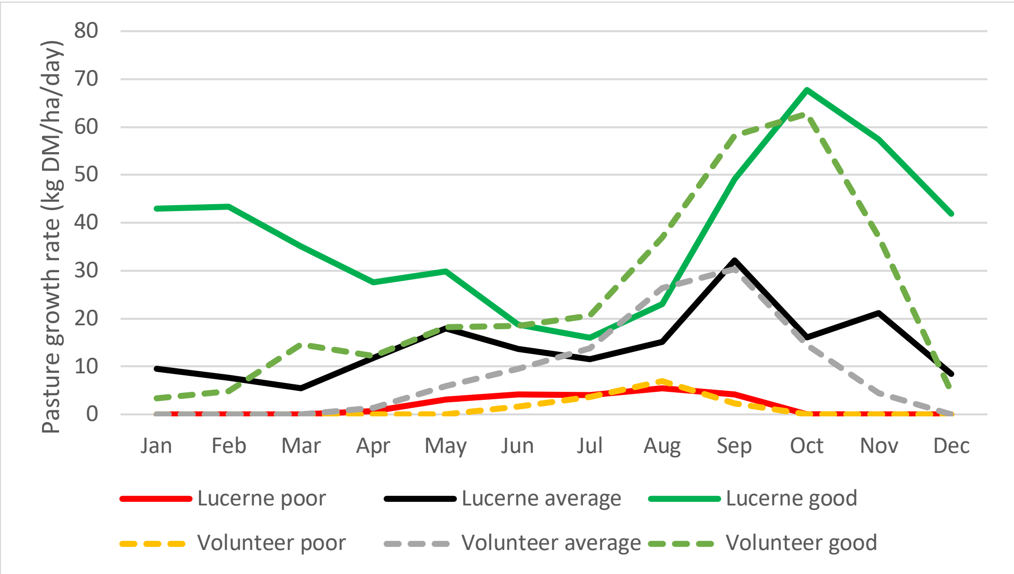


Figure 6 ***Mean monthly pasture growth rates for volunteer Ryegrass and rotationally grazed Lucerne pastures in poor, average and good seasons at Finley 1970-2019.***

A volunteer Annual Ryegrass pasture was unable to support the same stocking rate as a rotationally grazed Lucerne pasture as indicated by the higher incidence of feeding and a high percentage of years with < 800 kg DM/ha biomass in autumn (Table 14). The mean gross margins for a Lucerne pasture were over $100/ha higher than for volunteer pasture (Figure 17) primarily due to lower feed costs and the higher sale weights of lambs (Table 15).

Table 6 ***Mean sustainability variables for a volunteer Ryegrass or Lucerne pasture stocked at 2 or 3 ewes/ha at Finley 1970-2019.***

Pasture	Sheep/ha	Annual dse/ha	July dse/ha	% of years <800 kg DM/ha in Jan-Apr	% of years supplementary feed > 30 kg/ewe	Long-term pasture utilisation (%)	Long-term average groundcover (%)	Number of months per year when < 70% groundcover at 30th percentile
Ryegrass	2	4.6	5.9	54	100	23	85	4
	3	6.7	8.4	62	100	31	81	6
Lucerne	2	5.5	7.8	19	66	22	79	1
	3	7.7	9.7	28	80	30	73	10

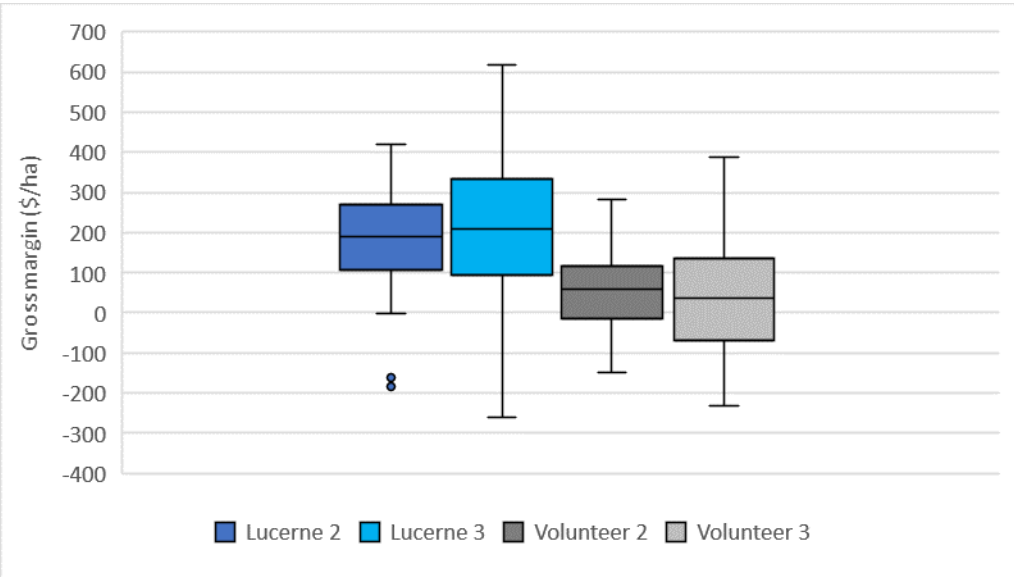


Figure 7 ***Box plots of gross margins for First Cross ewe enterprise grazing volunteer Ryegrass or Lucerne at different stocking rates (2 or 3 ewes/ha) at Finley 1970-2019.*** *Boxplots represent median, range and interquartile range, and o indicates extreme values.*

The mean condition score of ewes grazing either volunteer Ryegrass or Lucerne declined rapidly during pregnancy (Figure 18). Condition score was maintained at a lower level for ewes grazing Ryegrass, and for Ryegrass a higher stocking rate did not lead to further reduction in condition score because ewes were being supplementary fed to maintain condition.

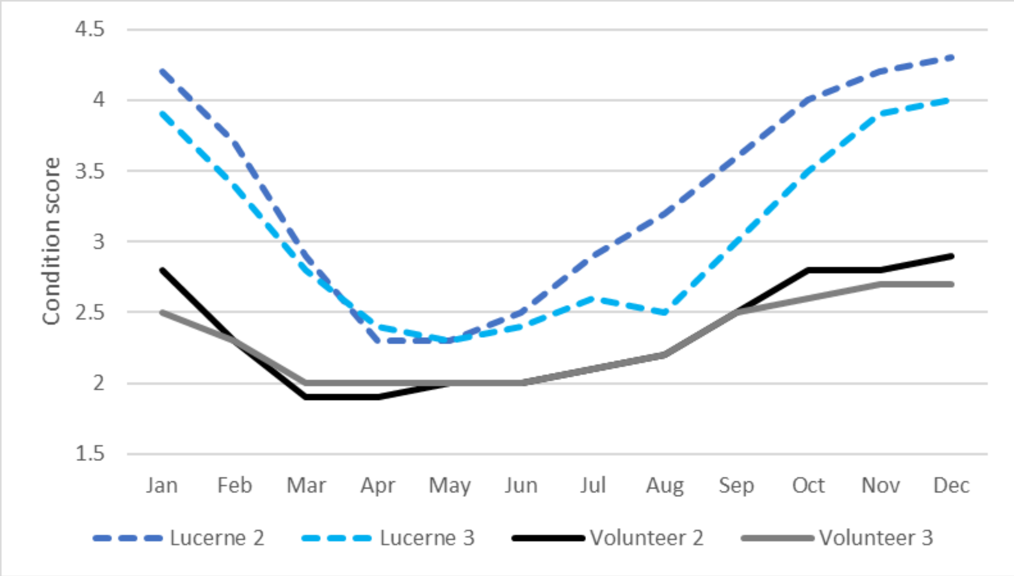


Figure 8 ***Monthly mean condition score of ewes in average seasons (50th percentile) for a First Cross ewe enterprise grazing volunteer Ryegrass or Lucerne pastures at different stocking rates (2 or 3 ewes/ha) at Finley 1970-2019.***

Performance in drought years

Pasture production was usually below 2500 kg DM/ha in years classified as drought (Figure 19). The total expenses for a volunteer pasture were similar to Lucerne in poor years due to higher supplementary feed, but no pasture maintenance costs. However, volunteer pastures produced a negative gross margin in poor years due to excessive feed costs while Lucerne was able to maintain a positive gross margin due to higher income from sale of sheep (Table 16). Volunteer pastures were unable to achieve the ewe and lamb growth obtained from Lucerne pasture in average and good seasons, resulting in lower income in those seasons. The cash flow as shown by annual gross margin over time resulted in a large financial benefit from Lucerne pasture Figure 20.

Table 7 ***Mean production variables and gross margin for a First Cross ewe enterprise grazing volunteer Ryegrass or Lucerne pastures at different stocking rates (2 or 3 ewes/ha) at Finley 1970-2019.***

Pasture	Sheep/ha	Lambs marked/ewe joined (%)	No. of lambs sold (no./ha)	Sale weight of lamb (kg)	Value of lamb sold ($/ha)	Mean fibre diameter of ewes (μ)	Wool value ($/ha)	Supplement ($/ha)	Supplement (kg/ewe)	Mean (median)gross margin $/ha
Ryegrass	2	1.12	2.2	47.5	349	27.5	19	151	172	59 (64)
	3	1.12	3.3	45.7	500	27.3	28	245	187	50 (36)
Lucerne	2	1.24	2.4	60.2	477	28.6	19	65	76	186 (193)
	3	1.21	3.6	54.8	643	28.4	29	126	100	218 (215)

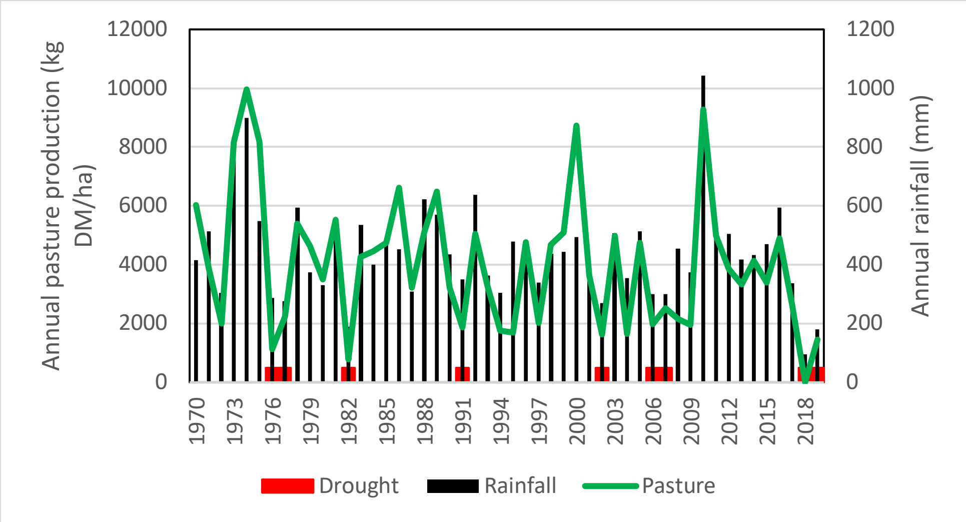


Figure 9 ***Annual rainfall (mm), production of a volunteer Ryegrass pasture (kg DM/ha) and classification as a drought year for Finley 1970-2019.***

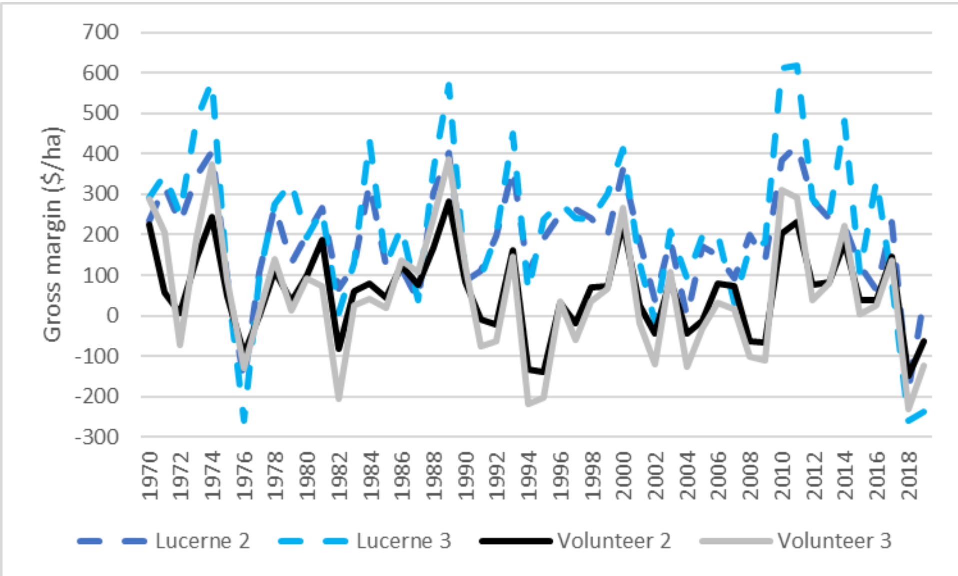


Figure 10 ***Annual gross margin ($/ha) for a First Cross ewe enterprise grazing volunteer Ryegrass or Lucerne pastures at 2 or 3 ewes/ha at Finley 1970-2019.***

Key Messages for species simulation: Lucerne vs volunteer annual pasture

- Productive pastures allow higher stocking rates and reduced feeding which may increase production and profit and lead to greater financial resilience of the enterprise.
- Pasture species with a longer growing season (e.g. Lucerne compared with Annual Ryegrass) may reduce the need for supplementary feed and support higher stocking rates or promote greater weight gain in sheep.

Table 8 ***Mean gross margin and key income and cost variables in poor, average and good seasons for a First Cross ewe enterprise grazing volunteer Ryegrass or Lucerne pastures at 2 ewes/ha at Finley 1970-2019.***

Pasture	Stocking rate (ewes/ha)	Season	Gross margin $/ha	Total income ($/ha)	Total Expense ($/ha)	Net Wool Income ($/ha)	Sheep sale income ($/ha)	Maintenance supplement ($/ha)	Production supplement ($/ha)
Ryegrass	2	poor	-66	347	441	18	328	150	201
		average	64	424	360	19	406	53	94
		good	206	527	297	19	507	1	0
Lucerne	2	poor	39	456	448	18	437	47	116
		average	193	557	371	20	538	6	18
		good	362	683	292	21	663	0	0

4.3. FarmLink (Boorowa and Temora)

Results and Discussion

Practice simulation question: Does rotational grazing rather than set stocking of a Phalaris pasture impact on production and resilience to drought at Boorowa?

The pasture growth rates for Phalaris were up to 12 kg DM/ha/day higher in spring when rotationally grazed rather than set stocked, although growth was also increased during autumn (Figure 21). Growth rates were similar for all types of rotational grazing in poor, average and good seasons, and rotational grazing did not extend the growing season for Phalaris.

Pasture utilisation was 4% higher when Phalaris was set stocked rather than rotationally grazed. This was associated with a higher risk of low pasture biomass between January and April, and a higher risk of supplementary feeding the June lambing ewes when stocked at 5 ewes/ha (Table 17). The flexible rotation system increased pasture utilisation while reducing the risk of low pasture availability and the risk of supplementary feeding. However, there was a low risk of groundcover falling below the 70% threshold for sustainability for any of the grazing systems. The median gross margin for the flexible rotation was $66/ha higher than the other systems which were all similar (Figure 22).

Table 9 ***Mean sustainability variables for Phalaris when set stocked or rotationally grazed for 6 or 10 weeks or using a flexible grazing rotation with 5 ewes/ha at Boorowa 1970-2019.***

Pasture	Sheep/ha	Annual dse/ha	July dse/ha	% of years <800 kg DM/ha in Jan-Apr	% of years supplementary feed > 30 kg/ewe	Long-term pasture utilisation (%)	Long-term average groundcover (%)	Months per year < 70% groundcover at 30th percentile
Set stocked	5.0	9.9	14.6	22	100	39	87	0
Rotation 6 weeks	5.0	9.9	14.4	12	94	34	91	0
Rotation 10 weeks	5.0	9.9	14.2	12	94	33	92	0
Rotation 6 weeks flexible	5.0	10.0	14.9	8	92	35	92	0

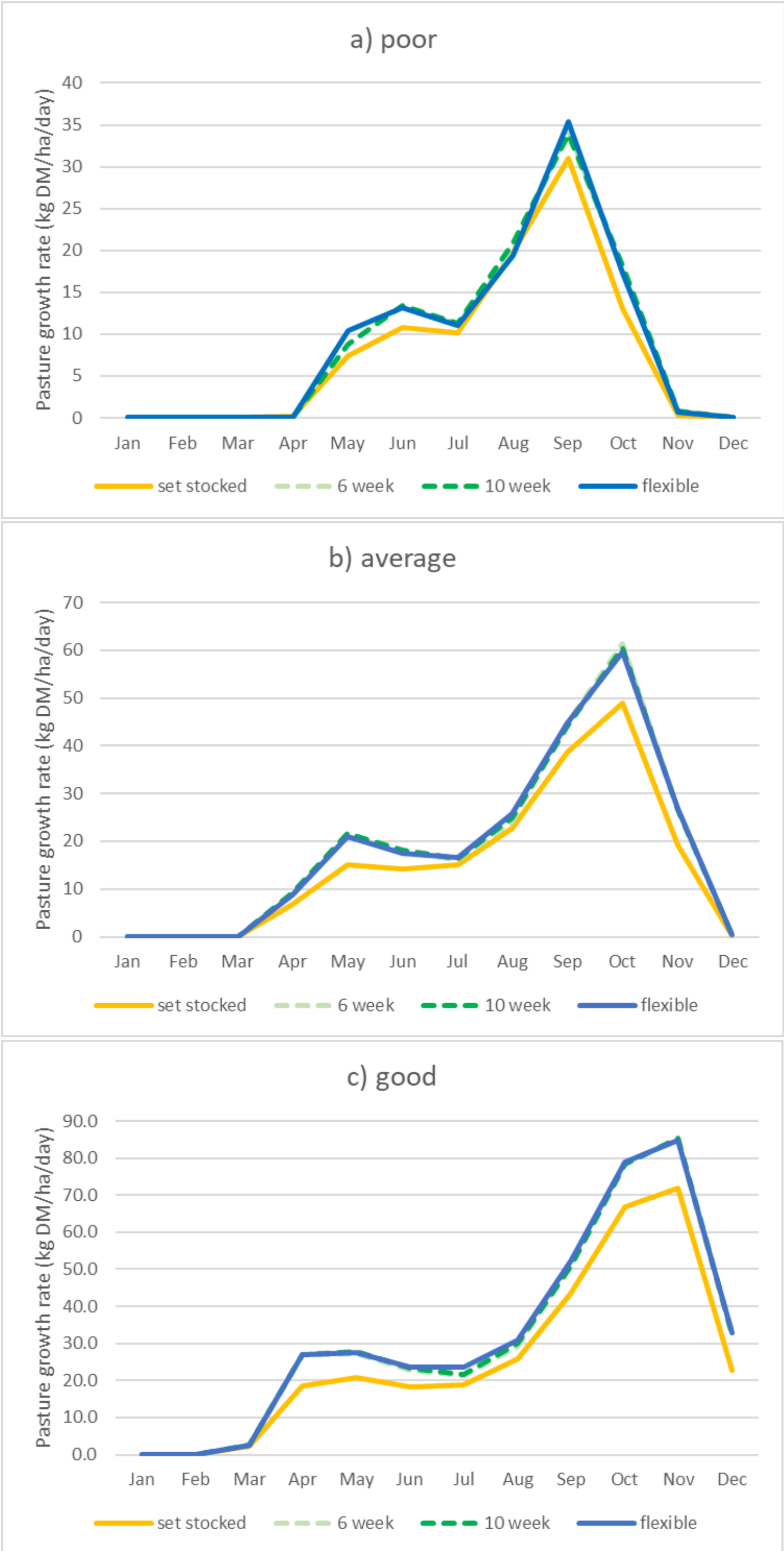


Figure 11 ***Average monthly pasture growth rates for Phalaris when set stocked or rotationally grazed for 6 or 10 weeks or using a flexible grazing rotation at Boorowa in a) poor, b) average and c) good seasonal conditions when stocked at 5.0 ewes/ha.***

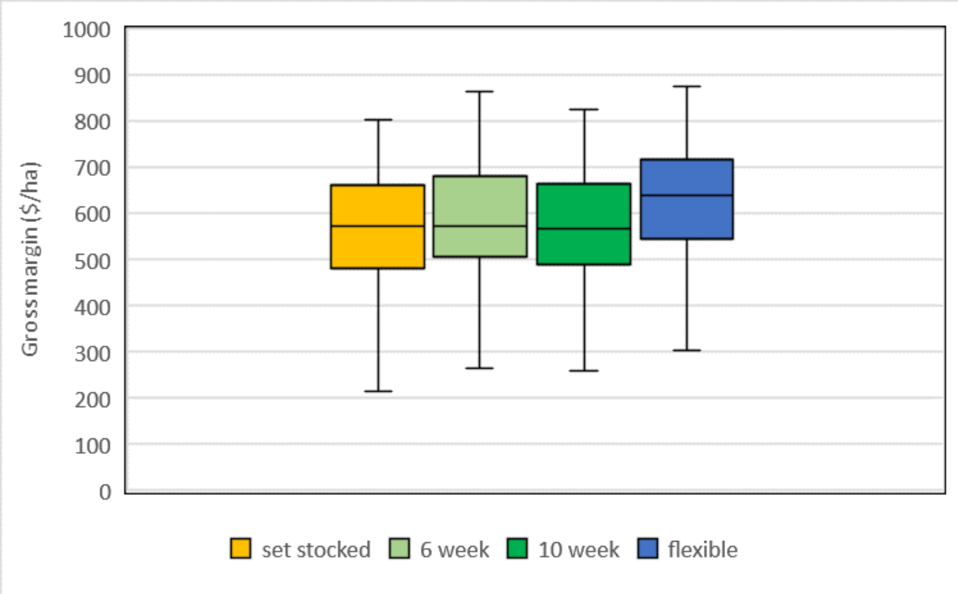


Figure 12 ***Box plots of gross margins for a Merino x Dorset enterprise when set stocked or rotationally grazed for 6 or 10 weeks or using a flexible grazing rotation at 5 ewes/ha at Boorowa 1970-2019.*** *Boxplots represent median, range and interquartile range.*

The higher gross margin from the flexible rotation was largely due to reduced supplementary feeding costs although the average sale weight of lambs was at least 0.4 kg higher (Table 18). A longer duration of grazing, 10 weeks rather than 6 weeks, increased the requirement for supplementary feeding to levels similar to the set stocked system.

Table 10 ***Mean production variables and gross margin for a Merino x Dorset enterprise when set stocked or rotationally grazed for 6 or 10 weeks or using a flexible grazing rotation at 5 ewes/ha at Boorowa 1970-2019.***

Grazing	Lambs marked/ewe joined (%)	No. of lambs sold (no./ha)	Sale weight of lamb (kg)	Value of lamb sold ($/ha)	Wool value ($/ha)	Supplement ($/ha)	Supplement (kg/ewe)	Mean (median) gross margin ($/ha)
Set stocked	95	4.7	43.3	650	226	189	99	557 (573)
6 week	96	4.7	43.9	666	226	176	91	585 (574)
10 week	96	4.7	43.8	665	226	194	101	566 (567)
flexible	96	4.7	44.3	674	228	148	76	626 (640)

The monthly condition score of ewes in average seasons (the 50th percentile) declined during late summer/autumn but was increasing after May until November in all grazing systems (Figure 23). Condition score declined to a lower level and further into late pregnancy (May) for set stocked ewes although these ewes were able to increase condition during spring to a similar level as the 6 and 10 week rotationally grazed ewes. Ewes grazed in the flexible system maintained a higher condition during early pregnancy than the other rotational systems and regained condition more rapidly during spring. The differences in condition scores between grazing systems did not result in differences in the percentage of lambs marked per ewe (Table 18).

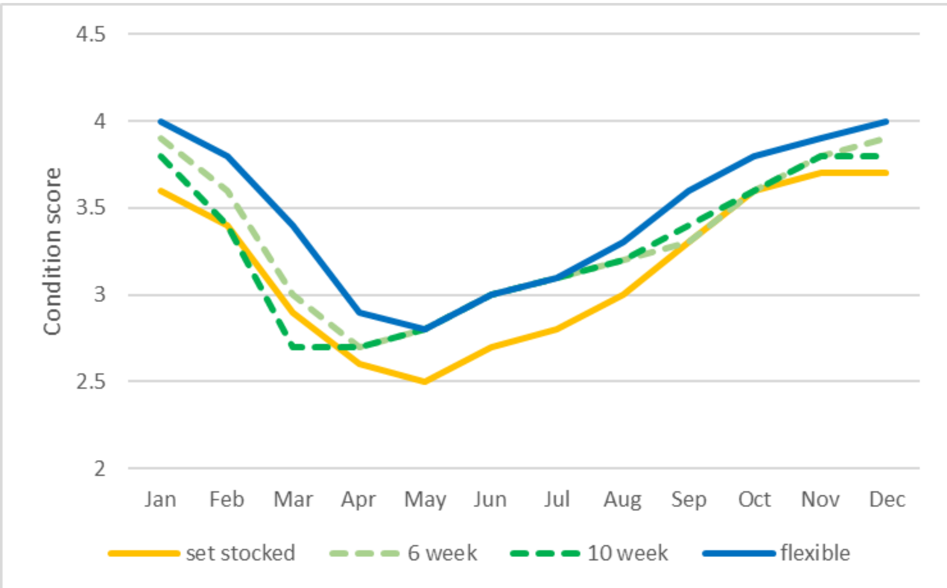


Figure 13 ***Monthly mean condition score of ewes in average seasons (50th percentile) for a Merino x Dorset enterprise when set stocked or rotationally grazed for 6 or 10 weeks or using a flexible grazing rotation at 5 ewes/ha at Boorowa 1970-2019.***

The gross margins, income from wool and sheep sales and supplementary feeding costs for poor (lowest 10%), average (50th percentile) and good (highest 10%) seasons are shown in Table 19. The gross margin, income from stock sales and supplementary feed for set stocked and 6 or 10 week rotational grazing were similar in poor seasons. The flexible rotation did not increase sheep sale income in poor years, but reduced feed costs by at least $34/ha. In average and good seasons rotational grazing enabled a small increase in sheep sale income in comparison to set stocking, but did not consistently reduce expenses. Sheep sale income was increased by $18 to 39/ha by the flexible system in average seasons while also reducing feed costs. The cash flow as shown by annual gross margin over the long term was similar for set stocked and fixed-time rotational grazing systems, while the flexible system was generally higher (Figure 24).

Table 11 ***Mean gross margin and key income and cost variables in poor, average and good seasons for a Merino x Dorset enterprise when set stocked or rotationally grazed for 6 or 10 weeks or using a flexible grazing rotation at 5 ewes/ha at Boorowa 1970-2019.***

	Season	Gross margin $/ha	Total income ($/ha)	Total Expense ($/ha)	Net Wool Income ($/ha)	Sheep sale income ($/ha)	Maintenance supplement ($/ha)	Production supplement ($/ha)
set stocked	poor	350	866	517	210	668	167	182
	average	573	1021	452	224	799	94	79
	good	737	1117	382	247	874	52	0
6 week	poor	359	876	510	213	664	222	115
	average	574	1040	458	227	812	143	0
	good	784	1129	356	239	894	86	0
10 week	poor	334	853	533	211	649	254	102
	average	567	1043	467	228	820	156	0
	good	771	1126	374	238	892	90	0
flexible	poor	428	855	478	212	652	191	112
	average	640	1064	414	230	838	104	0
	good	808	1140	339	241	906	55	0

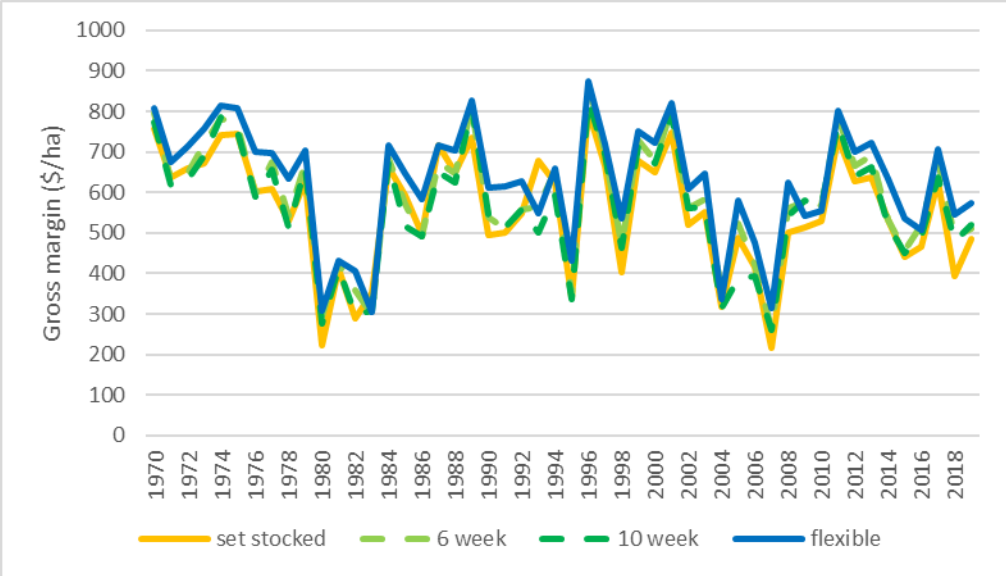


Figure 14 ***Annual gross margin ($/ha) for a Merino x Dorset enterprise when set stocked or rotationally grazed for 6 or 10 weeks or using a flexible grazing rotation at 5 ewes/ha at Boorowa 1970-2019.***

Performance in drought years

Drought years were classified at Boorowa in 7 periods including 12 years in the period 1970-2019 as shown in Figure 25. The weight of lambs at weaning and growth rate from weaning to sale on 1 November were similar for set stocked and rotationally grazed systems during drought and other years (Table 20). However, the quantity of supplement required for confined feeding was approximately halved by all types of rotational grazing compared with set stocking.

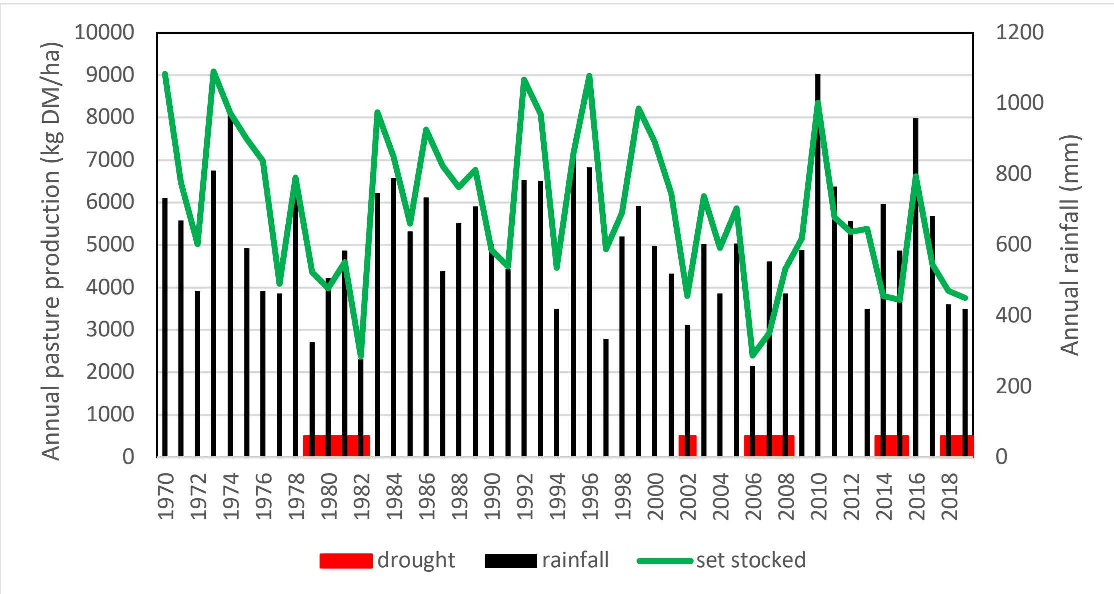


Figure 15 ***Annual rainfall (mm), production of Phalaris pasture (kg DM/ha) and classification as a drought year for Boorowa 1970-2019.***

Table 12 ***Production from a Merino x Dorset enterprise when set stocked or rotationally grazed for 6 or 10 weeks or using a flexible grazing rotation at 5 ewes/ha at Boorowa 1970-2019.***

Grazing	Season	Lambs weaned/ewe joined (%)	Wether weight at weaning (kg)	Weaner growth to sale (g/day)	Production supplement (kg/ewe)	Clean fleece weight (kg/ewe)
Set stocked	drought	92	31.5	185	75	3.4
	other	95	33.9	228	34	3.9
6 week	drought	93	31.4	200	33	3.7
	other	96	33.6	243	15	3.9
10 week	drought	93	31.5	196	34	3.7
	other	96	33.6	242	12	3.9
flexible	drought	93	32.5	190	37	3.8
	other	96	34.3	236	15	4.0

Key Messages for practice simulation: rotational grazing vs set stocking of Phalaris

- Rest periods or rotational grazing are needed for the persistence of Phalaris pastures, although persistence of Phalaris could not be modelled directly in this instance.
- Rank pasture of low nutritive value (as occurs when total pasture production is high and utilisation limited ie low stocking rates) reduces lamb growth rates, although not simulated in this study.
- Rotational grazing increased the growth rate of Phalaris pasture during the growing season in this simulation, although this does not occur in all situations.
- A flexible rotation with stock moved on pasture availability reduced supplementary feed costs compared with fixed time rotations or set stocking.
- Strategic sale of stock in response to dry seasons may reduce the impact on pasture persistence, risk of low groundcover and requirement for supplementary feeding.

Species simulation question: How do commercially available pastures (Subterranean Clover, Annual Medic, Lucerne, Phalaris, Cocksfoot) differ in productivity and impact sheep production over a range of seasonal conditions at Temora?

Mean monthly pasture growth rates were less than 2 kg DM/ha/day between November and May in poor seasons, except for Lucerne (Figure 26). The growth rates of Lucerne in winter were less than for other pastures in poor, average and good seasons, but Lucerne was capable of higher growth over summer/autumn, extending the period of green feed.

A stocking rate of 3.5 breeding ewes/ha produced a low risk of groundcover falling below the 70% threshold for any pasture species. The annual species Subterranean Clover and Annual Medic resulted in a higher percentage of years with pasture biomass < 800 kg DM/ha between January and April than for Phalaris and Cocksfoot, but Lucerne rarely fell below this quantity (Table 21). The growth of Lucerne during summer/autumn was the reason for this. Lucerne reduced the percentage of years where more than 30 kg grain/ewe was fed to 44%, whereas all other pastures required ewes to be fed above this quantity in most years. The median gross margin for Lucerne was $154/ha higher than for any other pasture (Figure 27), largely due to lower feeding costs and higher weight so value of sheep sold (Table 22).

Table 13 ***Mean sustainability variables for Subterranean Clover, Annual Medic, Lucerne, Phalaris and Cocksfoot pastures grazed at 3.5 ewes/ha at Temora 1970-2019.***

Pasture	Sheep/ha	Annual dse/ha	July dse/ha	% of years <800 kg DM/ha in Jan-Apr	% of years supplementary feed > 30 kg/ewe	Long-term pasture utilisation (%)	Long-term average groundcover (%)	Months per year when < 70% groundcover at 30th percentile
Subterranean Clover	3.5	6.9	10.3	47	88	26	85	2
Medic	3.5	7.2	10.9	42	80	28	88	1
Lucerne	3.5	7.6	11.0	2.5	44	20	88	0
Phalaris	3.5	6.8	10.1	25	98	28	89	1
Cocksfoot	3.5	6.9	10.2	34	96	29	87	2

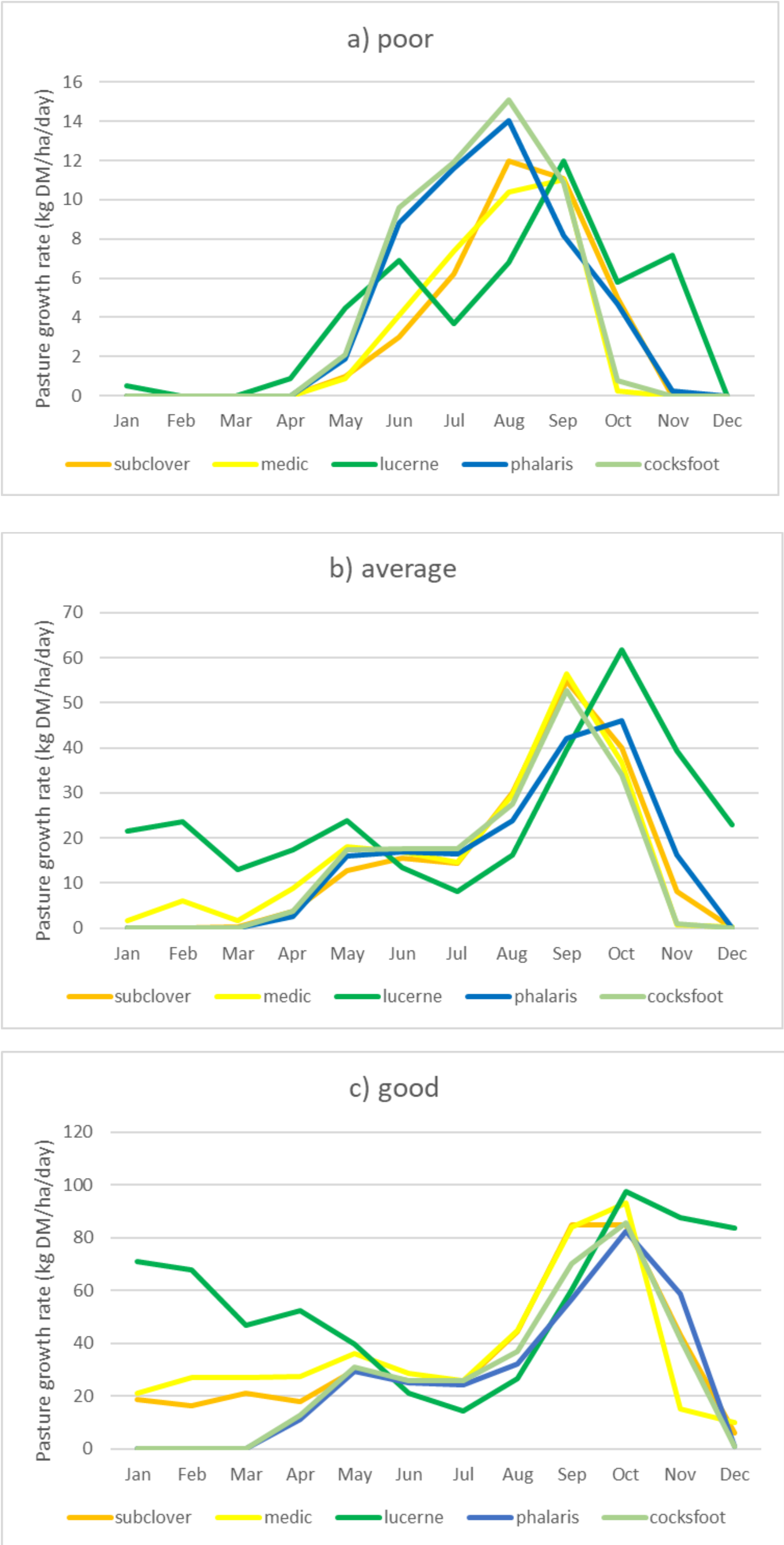


Figure 16 ***Mean monthly pasture growth rates for Subterranean Clover, Annual Medic, Lucerne, Phalaris and Cocksfoot pastures in a) poor, b) average and c) good seasons when grazed at 3.5 ewes/ha at Temora 1970-2019.***

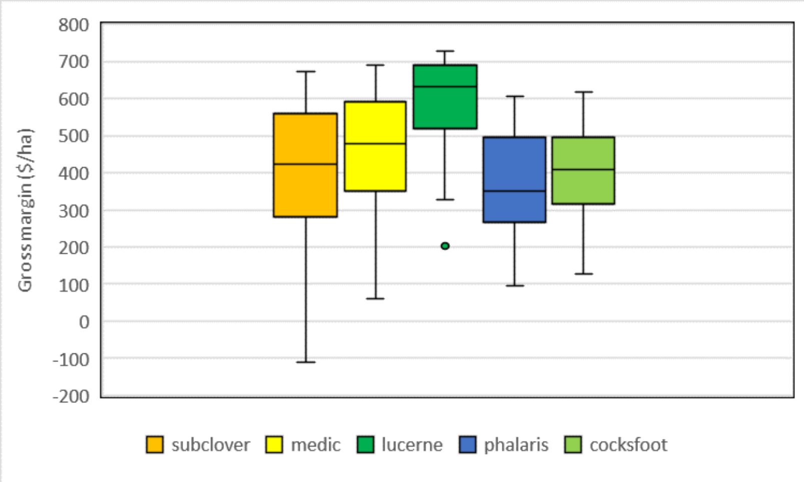


Figure 17 ***Box plots of gross margins for a Merino x Dorset enterprise grazing Subterranean Clover, Annual Medic, Lucerne, Phalaris or Cocksfoot pastures grazed at 3.5 ewes/ha at Temora 1970-2019.*** *Boxplots represent median, range and interquartile range, and o indicates extreme values.*

The mean condition score of ewes in all simulations declined between January and May during late pregnancy before ewes re-gained condition during winter/spring. Lucerne enabled ewes to maintain a higher condition score than other pastures throughout the year, but Phalaris and Cocksfoot generally maintained ewes in the same condition as Subterranean Clover when grazed at the same stocking rate. Annual Medic allowed higher ewe condition than Subterranean Clover (Figure 28), due to some pasture growth over summer/autumn.

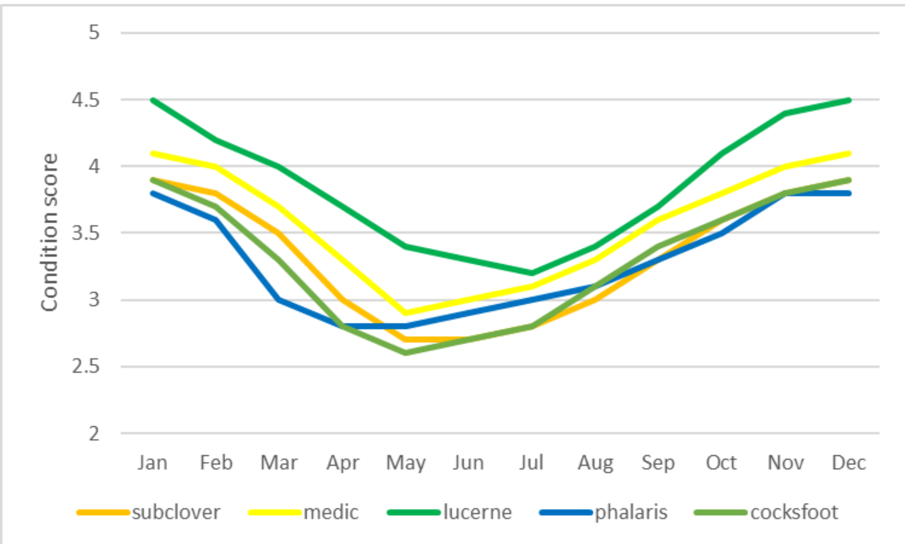


Figure 18 ***Monthly mean condition score of Merino ewes in average seasons (50th percentile) grazing Subterranean Clover, Annual Medic, Lucerne, Phalaris or Cocksfoot pastures grazed at 3.5 ewes/ha at Temora 1970-2019.***

Performance in drought years

Drought was classified in 10 of the 50 years at Temora (Figure 29). The gross margins, income from wool and sheep sales and supplementary feeding costs for poor (lowest 10%), average (50^{th} percentile) and good (highest 10%) seasons are shown in Table 23. Subterranean Clover and medic pastures produced sheep enterprise gross margins above those of Phalaris and Cocksfoot in average and good seasons due to higher sheep growth rates so sale income, associated with higher pasture growth early in the year and the nutritive value of pasture in spring. However, in poor seasons Subterranean Clover produced a lower income from sheep sales, associated with lower pasture growth over autumn/winter than Phalaris or Cocksfoot and less green pasture available in spring. Lucerne pasture allowed lower feeding costs than all other pastures in average seasons due to the longer period of pasture growth. In poor seasons feeding costs were \$62 to \$147/ha lower for Lucerne than for other pastures, while Lucerne also generated > \$100/ha higher sheep sale income in poor years.

Table 14 ***Mean production variables and gross margin for a Merino x Dorset enterprise grazing Subterranean Clover, Annual Medic, Lucerne, Phalaris or Cocksfoot pastures at 3.5 ewes/ha at Temora 1970-2019.***

Pasture	Lambs marked/ewe joined (%)	No. of lambs sold (no./ha)	Sale weight of lamb (kg)	Value of lamb sold ($/ha)*	Mean fibre diameter of ewes (µ)	Wool value ($/ha)	Supplement ($/ha)	Supplement (kg/ewe)	Mean (median)gross margin $/ha
Subterranean Clover	101	3.5	44.9	497	20.4	168	138	101	409 (425)
Medic	102	3.5	47.0	526	20.5	172	116	85	463 (479)
Lucerne	105	3.6	51.0	591	20.6	175	59	40	589 (633)
Phalaris	101	3.5	42.2	467	20	155	143	105	364 (352)
Cocksfoot	101	3.5	43.1	482	20.1	157	128	94	394 (408)

*Wether and ewe lambs.

The effect of pasture type on sheep enterprise cash flow as shown by annual gross margins over time is shown in Figure 30 where Lucerne was generally higher over the long term, although differences between Subterranean Clover, Phalaris and Cocksfoot were small. Lucerne pastures allowed greater resilience of the sheep enterprise to drought. The number of lambs weaned per ewes was 5-6% higher in drought years than for other pasture types, although a similar increase occurred in non-drought years (Table 24). While more lambs may increase feeding costs in drought years, producers could strategically sell some ewes to reduce costs. Despite more lambs produced, Lucerne enabled 2.5 to 10.5 kg higher sale weights of lambs in drought years than other pastures due to higher weaner growth rates. This was achieved with lower quantities of supplementary feeding which reduced costs.

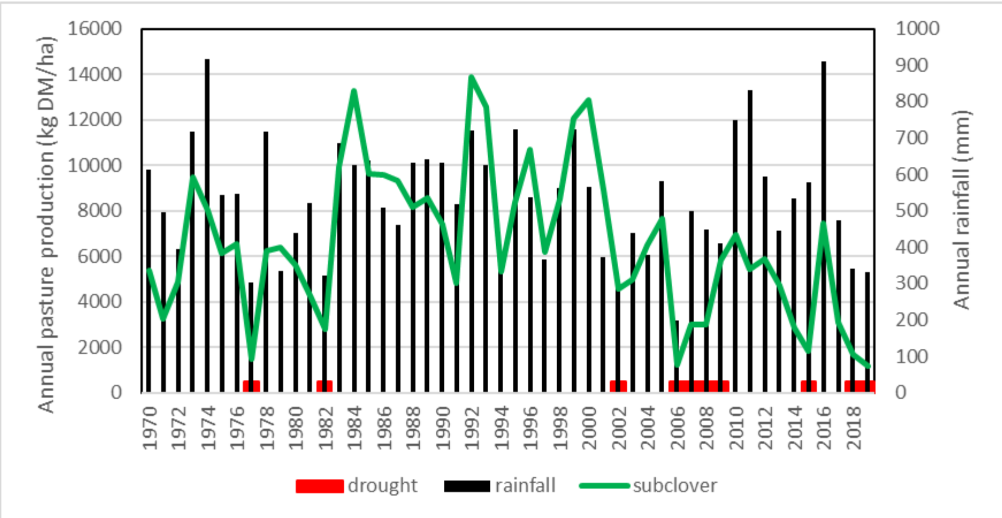


Figure 19 ***Annual rainfall (mm), production of Subterranean Clover pasture(kg DM/ha) and classification as a drought year for Temora 1970-2019.***

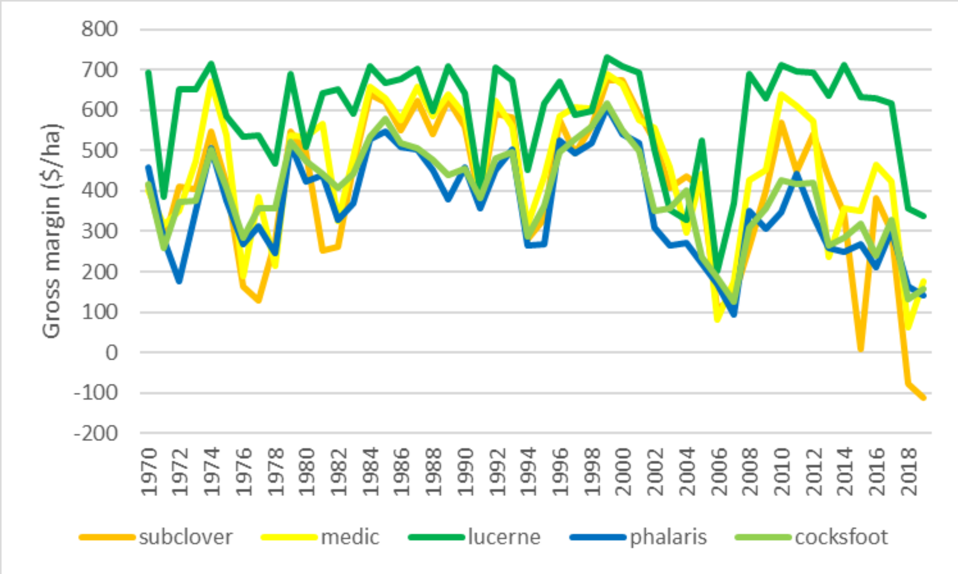


Figure 20 ***Annual gross margin ($/ha) for a Merino x Dorset enterprise grazing Subterranean Clover, Annual Medic, Lucerne, Phalaris or Cocksfoot pastures at 3.5 ewes/ha at Temora 1970-2019.***

Key Messages for species simulation: Subterranean Clover, Annual Medic, Lucerne, Phalaris or Cocksfoot

- Productive pastures with longer growing seasons support faster weaner growth, higher ewe condition and reduce supplementary feeding.
- Cocksfoot and Phalaris had a similar growing season as Annual Medic and Subterranean Clover, but increased winter growth in drought years.
- Lucerne pasture allowed higher ewe condition, lamb sale weight and reduced supplementary feeding, so produced the highest sheep enterprise gross margins long-term.
- Lucerne has slower winter growth than common temperate pastures which creates a feed gap.
- The suitability of these species for the Temora region will depend on their persistence which could not be modelled in this instance.

Table 15 ***Mean gross margin and key income and cost variables in poor, average and good seasons for a Merino x Dorset enterprise grazing Subterranean Clover, Annual Medic, Lucerne, Phalaris or Cocksfoot pastures at 3.5 ewes/ha at Temora 1970-2019.***

Pasture	Season	Gross margin $/ha	Total income ($/ha)	Total Expense ($/ha)	Net Wool Income ($/ha)	Sheep sale income ($/ha)	Maintenance supplement ($/ha)	Production supplement ($/ha)
Subterranean Clover	poor	138	577	427	143	426	106	179
	average	425	792	352	170	631	55	56
	good	619	876	257	189	693	13	0
Annual Medic	poor	212	641	427	148	493	126	182
	average	479	832	323	177	654	58	8
	good	642	892	231	188	707	5	0
Lucerne	poor	368	754	393	164	588	103	43
	average	633	891	246	176	718	25	0
	good	708	930	220	187	751	0	0
Phalaris	poor	207	617	408	141	465	156	137
	average	352	721	358	157	573	91	0
	good	519	824	296	166	656	56	0
Cocksfoot	poor	239	627	397	144	470	125	134
	average	408	747	329	158	596	70	42
	good	529	828	284	167	660	29	0

Table 16 ***Mean production from a Merino x Dorset enterprise grazing Subterranean Clover, Annual Medic, Lucerne, Phalaris or Cocksfoot pastures at 3.5 ewes/ha at Temora 1970-2019.***

Pasture	Season	Lambs weaned/ewe joined (%)	Wether weight at weaning (kg)	Weaner growth weaning to sale (g/day)	Production supplement (kg/ewe)	Clean fleece weight (kg/ewe)	Fibre diameter ewes (µ)
Subterranean Clover	drought	98	26.2	161	139	3.6	19.8
	other	101	36.0	252	38	4.4	20.5
Annual Medic	drought	99	32.8	177	78	3.9	20.2
	other	102	36.7	253	30	4.4	20.6
Lucerne	drought	104	36.7	208	22	4.4	20.6
	other	105	38.5	301	9	4.4	20.6
Phalaris	drought	98	30.1	144	62	3.5	19.8
	other	100	33.1	226	28	3.8	20.1
Cocksfoot	drought	98	30.4	163	69	3.5	19.8
	Other	101	33.8	228	33	3.9	20.1

4.4. Central West Farming Systems (Condobolin)

Results and discussion

Practice simulation question: Do pasture mixtures (Lucerne vs Lucerne/Subterranean Clover vs Lucerne/Cocksfoot) increase resilience to drought above pure Lucerne stands for sheep enterprises at Condobolin?

Monthly pasture growth rates were similar for Lucerne and mixes with Subterranean Clover or Cocksfoot in poor, average and good seasons (Figure 31). Neither Dalkeith Subterranean Clover nor Cocksfoot could compete successfully with the established Lucerne pasture, so while they persisted in the simulation, their monthly growth rates were less than 2 kg DM/ha except in good seasons, when their growth was between 4 and 15 kg DM/ha/day. A less vigorous Lucerne pasture may allow higher production from Subterranean Clover or Cocksfoot companion species.

The sustainability indicators were similar for Lucerne and mixed pastures when stocked at 1.4 breeding ewes/ha (equivalent to 1.8 sheep/ha), although including either Subterranean Clover or Cocksfoot with Lucerne increased groundcover in poorer seasons (Table 25). Mean gross margins were similar for all pasture types (Figure 32). These results could be expected when pasture growth rates were similar resulting in similar lamb and wool production and feeding requirements (Table 26). While producer feedback indicated more conservative stocking rates (1 ewe/ha) are used, these were not simulated as the species simulations indicated lower profitability (see later section).

Table 17 ***Mean sustainability variables for Lucerne, Lucerne/Subterranean Clover and Lucerne/Cocksfoot pasture mixes grazed at 1.4 breeding ewes/ha at Condobolin 1970-2019.***

Pasture	Sheep/ha	Annual dse/ha	July dse/ha	% of years <800 kg DM/ha in Jan-Apr	% of years feed > 30 kg/ewe	Long-term pasture utilisation (%)	Long-term average groundcover (%)	Number of months per year < 70% groundcover at 30th percentile
Lucerne	1.8	4.1	4.9	23	72	16	77	8
Lucerne/ Subterranean Clover	1.8	4.1	5.0	23	72	16	79	2
Lucerne/Cocksfoot	1.8	4.1	4.9	22	74	16	79	4

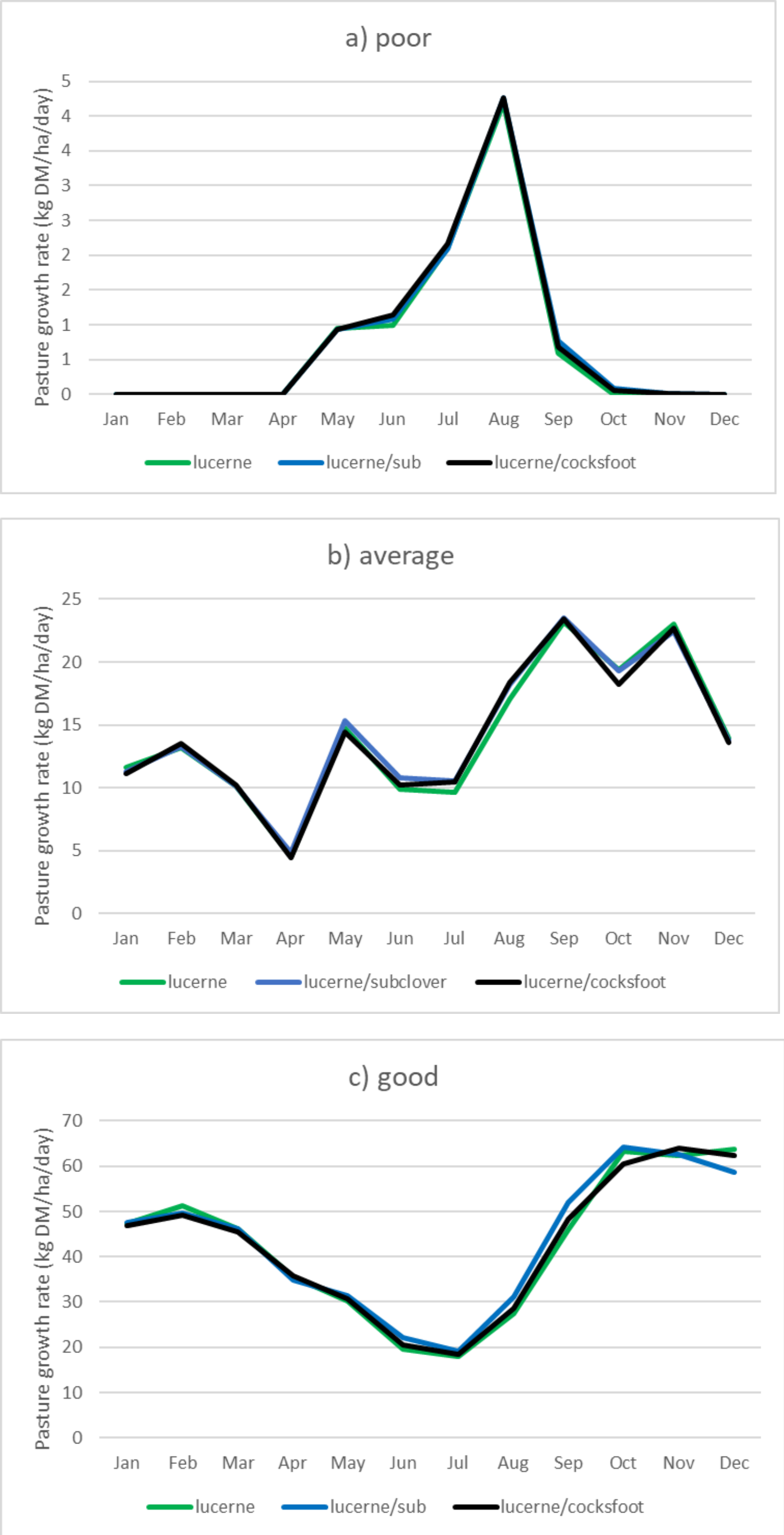


Figure 21 ***Mean monthly pasture growth rates for Lucerne, Lucerne/Subterranean Clover and Lucerne/Cocksfoot pasture mixes grazed at 1.4 breeding ewes/ha in a) poor, b) average and c) good seasons at Condobolin 1970-2019.***

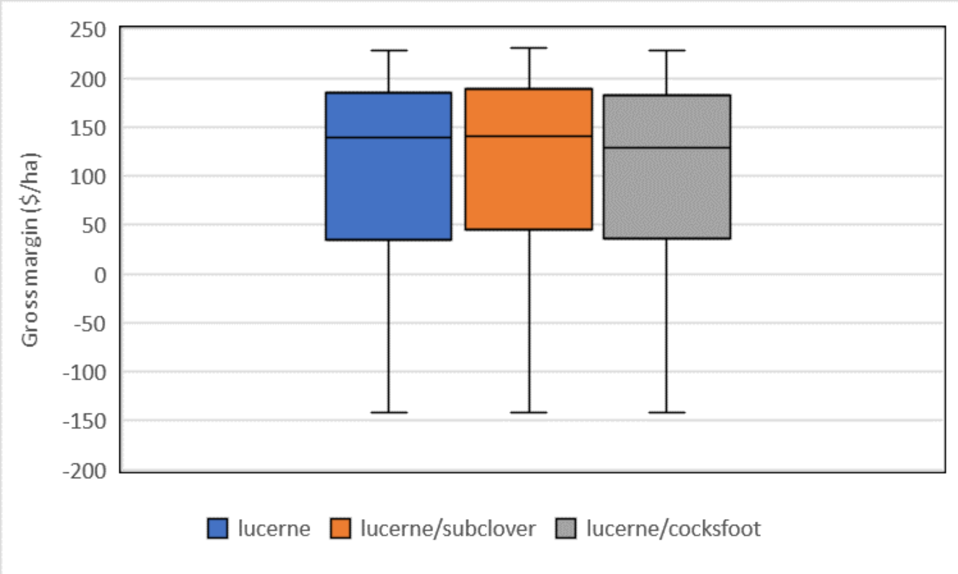


Figure 22 ***Box plots of gross margins for a self-replacing Merino enterprise grazing Lucerne, Lucerne/Subterranean Clover and Lucerne/Cocksfoot pasture mixes at 1.4 breeding ewes/ha at Condobolin 1970-2019.*** *Boxplots represent median, range and interquartile range.*

The mean condition score of ewes was similar for the different pasture types in all months (Figure 33), contributing to the same number of lambs being produced in each farm system (Table 26).

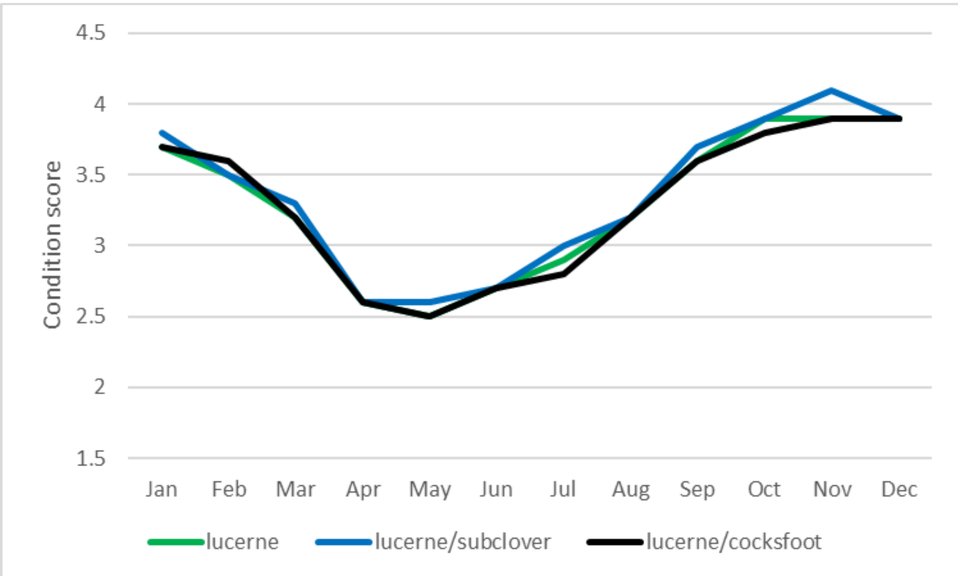


Figure 23 ***Monthly mean condition score of ewes in average seasons (50th percentile) for a self-replacing Merino enterprise grazing Lucerne, Lucerne/Subterranean Clover or Lucerne/Cocksfoot pasture mixes at 1.4 breeding ewes/ha at Condobolin 1970-2019.***

Table 26 ***Mean annual production variables and gross margin for a self-replacing Merino enterprise grazing Lucerne, Lucerne/Subterranean Clover and Lucerne/Cocksfoot pasture mixes at 1.4 breeding ewes/ha at Condobolin 1970-2019.***

Pasture	Lambs marked/ewe joined (%)	No. of lambs sold (no./ha)	Sale weight of lamb (kg)	Value of lamb sold ($/ha)*	Mean fibre diameter of ewes (µ)	Wool value ($/ha)	Supplement ($/ha)	Supplement (kg/ewe)	Mean (median)gross margin ($/ha)
Lucerne	103	7.0	57.1	189	22.4	79	66	84	110 (139)
Lucerne/Subterranean Clover	103	7.0	57.4	190	22.5	80	61	79	117 (141)
Lucerne/Cocksfoot	103	7.0	56.2	187	22.4	79	64	82	111 (129)

*Wether lambs, as surplus young ewes are sold as hoggets.

Performance in drought years

The 10 of 50 years classified as drought at Condobolin were associated with substantially lower herbage production by Subterranean Clover (Figure 34). The gross margins, income from wool and sheep sales and supplementary feeding costs for poor (lowest 10%), average (50th percentile) and good (highest 10%) seasons are shown in Table 27. The performance of the sheep enterprise was similar between pasture types in all seasons, with minimal differences in drought compared with other years (Table 28). However, the Lucerne/Subterranean Clover mix reduced total costs by $12/ha in poor seasons in comparison to Lucerne, through lower feed costs. The effect of this on cash flow as shown by annual gross margins can be seen in Figure 35 after the series of drought years 2002 to 2008. The higher financial performance indicates the Lucerne/Subterranean Clover pasture allowed the sheep enterprise to be more resilient to drought, although the impact was small. If the Subterranean Clover was a larger component of the total pasture, the impact may differ.

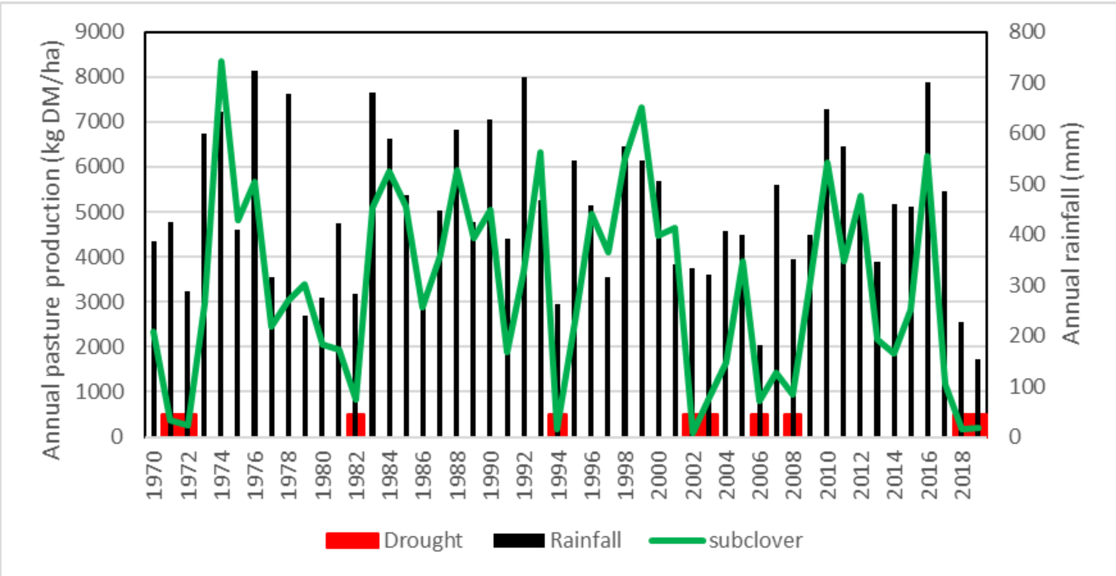


Figure 24 ***Annual rainfall (mm), production of Subterranean Clover pasture (kg DM/ha) and classification as a drought year for Condobolin 1970-2019.***

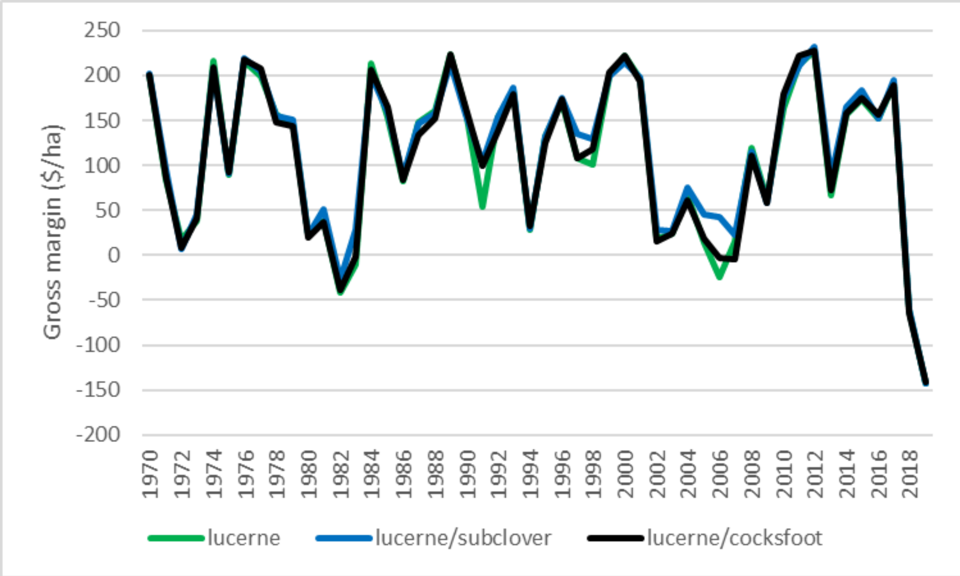


Figure 35 ***Annual gross margin ($/ha) for a self-replacing Merino enterprise grazing Lucerne, Lucerne/Subterranean Clover or Lucerne/Cocksfoot pasture mixes grazed at 1.4 breeding ewes/ha at Condobolin 1970-2019.***

Table 27 ***Mean gross margin and key income and cost variables in poor, average and good seasons for a self-replacing Merino enterprise grazing for Lucerne, Lucerne/Subterranean Clover and Lucerne/Cocksfoot pasture mixes grazed at 1.4 breeding ewes/ha at Condobolin 1970-2019.***

Pasture	Season	Gross margin $/ha	Total income ($/ha)	Total Expense ($/ha)	Net Wool Income ($/ha)	Sheep sale income ($/ha)	Maintenance supplement ($/ha)	Production supplement ($/ha)
Lucerne	poor	12	295	310	86	205	45	129
	average	139	348	211	106	241	6	32
	good	214	381	167	113	269	0	0
Lucerne/Subterranean Clover	poor	22	295	298	92	201	42	120
	average	141	349	207	107	245	6	31
	good	208	378	166	112	269	0	0
Lucerne/Cocksfoot	poor	-2	292	306	86	204	44	130
	average	129	344	212	106	239	6	31
	good	210	380	167	112	273	0	0

Table 28 ***Production from a self-replacing Merino enterprise grazing Lucerne, Lucerne/Subterranean Clover and Lucerne/Cocksfoot pasture mixes grazed at 1.4 breeding ewes/ha in drought or other years at Condobolin 1970-2019.***

Pasture	Season	Lambs weaned/ewe joined (%)	Wether weight at weaning (kg)	Wether weight at 31 Dec (g/day)	Weaner growth to 31 Dec (g/day)	Production supplement (kg/ewe)	Clean fleece weight (kg/ewe)
Lucerne	drought	101	20.6	36.2	105	132	4.0
	other	103	34.0	59.4	156	41	4.6
Lucerne/Subterranean Clover	drought	101	21.1	37.2	108	126	4.1
	other	103	34.8	59.8	156	36	4.7
Lucerne/Cocksfoot	drought	101	20.4	35.7	102	130	4.0
	other	103	34.2	59.1	153	38	4.6

Key Messages for practice simulation: Lucerne vs Lucerne mixes

- The addition of companion species to pasture mixes has the potential to fill feed gaps.
- Competition between pasture species may limit the production or persistence of individual species. Choose species that will persist in the mix and under the management applied.
- A Subterranean Clover/Lucerne or Cocksfoot/Lucerne mix improved groundcover compared to a pure Lucerne pasture.
- A Subterranean Clover/Lucerne mix resulted in similar sheep production, but allowed a small reduction in feeding in poor seasons.
- A Cocksfoot/Lucerne mix did not improve sheep production or resilience to drought compared with a pure Lucerne pasture.
- Lucerne influenced sheep production responses because it produced a large quantity of feed and particularly summer/autumn feed, and dominated other species in the pasture mixes simulated.

Species simulation question: What is the growth pattern of Lucerne, Cocksfoot, Subterranean Clover and Annual Medic pastures long-term and in response to drought, and how does this impact on sheep enterprise resilience to drought at Condobolin?

Pasture growth rates were negligible for annual pastures and Cocksfoot between November and April in poor, average and good seasons (Figure 36). Lucerne did not grow during summer/autumn in poor seasons, but growth rates were usually above 10 kg DM/ha/day throughout the year in all seasons and extended the period of growth compared with other species. Cocksfoot had higher growth rates than Lucerne during winter in all seasons, but did not grow during the summer/autumn period. During poor seasons perennial pastures provided up to 4 kg DM/ha/day higher growth than annuals, although all growth rates were low and the growing season was short.

A single stocking rate typical of the region (1.4 breeding ewes/ha of pasture = 1.8 sheep/ha; 4 dse/ha annual average; 4.9 dse/ha in July) was used for all comparisons. Producer feedback indicated that 1.4 ewes/ha was at the higher end of regional practice, so some more conservative comparisons were also conducted using 1.0 breeding ewe/ha of pasture (= 1.3 sheep/ha; 2.5 dse/ha annual average; 2.8 dse in July). The risk to sustainability from different pasture species and stocking rates is shown in Table 29. Using a May lambing Merino enterprise required supplementary feeding of ewes above the target 30 kg/ewe in the majority of years, although Lucerne pastures required less feeding of sheep than other pasture types. A stocking rate of 1.0 rather than 1.4 ewes/ha improved groundcover and reduced feeding requirements, but the lower feed costs were outweighed by the lower value of lamb and wool sold per hectare (Table 30), reducing median gross margins for Lucerne and Subterranean Clover. The lower stocking rate was therefore not considered in further comparisons.

The sheep enterprise gross margins for Lucerne were higher than for other pastures when stocked at 1.4 breeding ewes/ha (Figure 37), in part due to the lower cost of feeding. The minimum pasture biomass between January and April fell below the target of 800 kg DM/ha in more than 70% of years for all pastures except Lucerne. Property long-term average groundcover was near or above 70% for all pasture species, and in the lowest 30% of years there was little difference in the number of months that groundcover was below 70%.

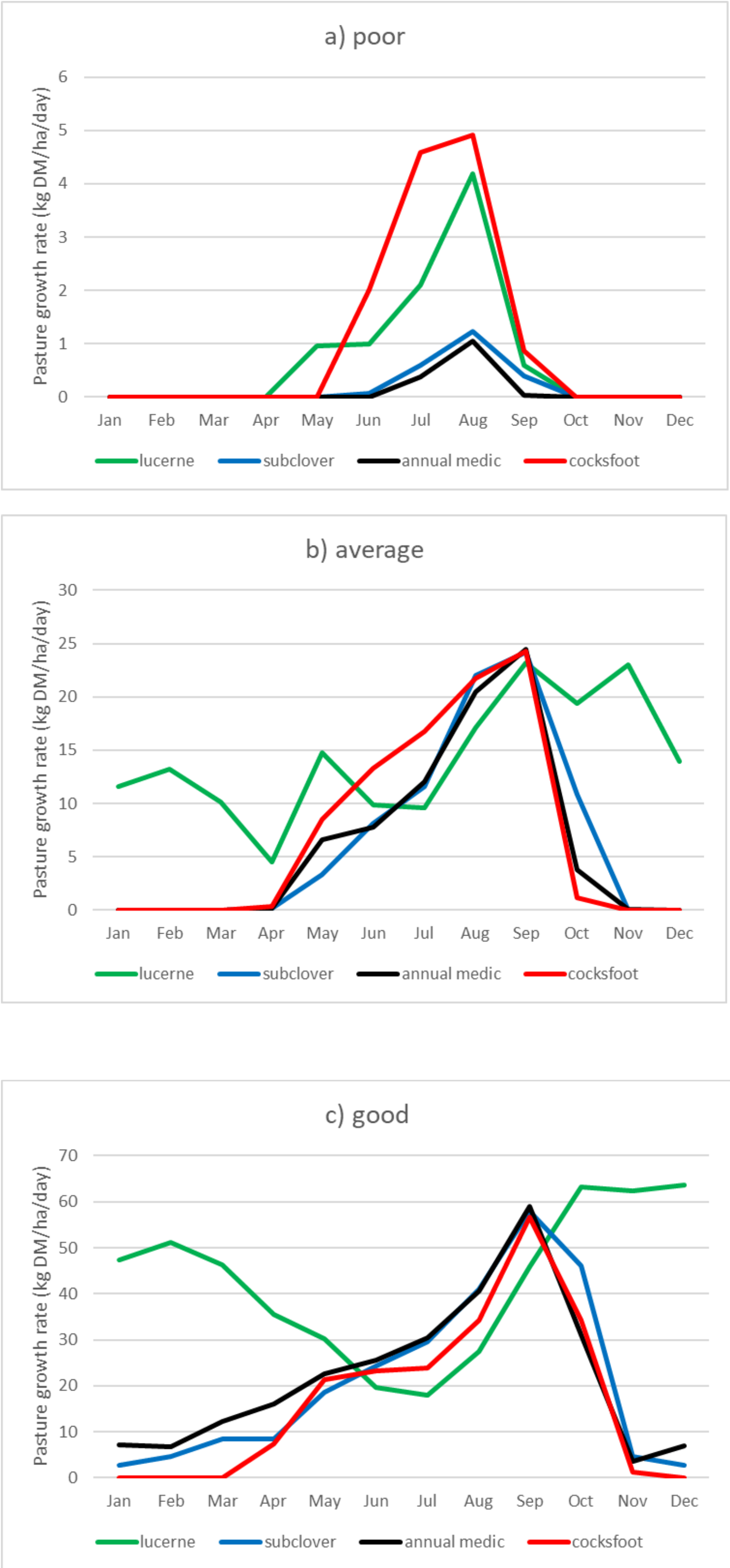


Figure 25 ***Mean monthly pasture growth rates for Lucerne, Subterranean Clover, Annual Medic and Cocksfoot pasture at Condobolin in a) poor, b) average and c) good seasonal conditions when stocked at 1.4 breeding ewes/ha.***

The simulation reflects a single pasture species across a farm which may not represent a typical feedbase where crop stubbles or grazing crops may be available for part of the year, and a range of pasture types are used. However, the simulation of a single pasture type shows the complete impact if this management were used, highlighting the effect of both feed gaps and the level of nutrition provided by the pasture.

Table 18 ***Mean sustainability variables for different pasture species grazed at 1.4 or 1.0 breeding ewes/ha at Condobolin 1970-2019.***

Pasture	Sheep/ha	Annual dse/ha	July dse/ha	Years <800 kg DM/ha in Jan-Apr (%)	Years supplementary feed > 30 kg/ewe (%)	Long-term pasture utilisation (%)	Long-term average groundcover (%)	No. months/yr < 70% groundcover at 30th percentile
Lucerne	1.8	4.1	4.9	23	72	16	77	8
Subterranean Clover	1.8	3.4	3.7	86	98	20	69	9
Annual Medic	1.8	3.5	3.9	85	94	21	70	9
Cocksfoot	1.8	3.5	4.1	77	98	23	79	7
Lucerne	1.0	3.0	3.7	20	62	12	79	0
Subterranean Clover	1.0	2.5	2.8	75	94	16	68	8

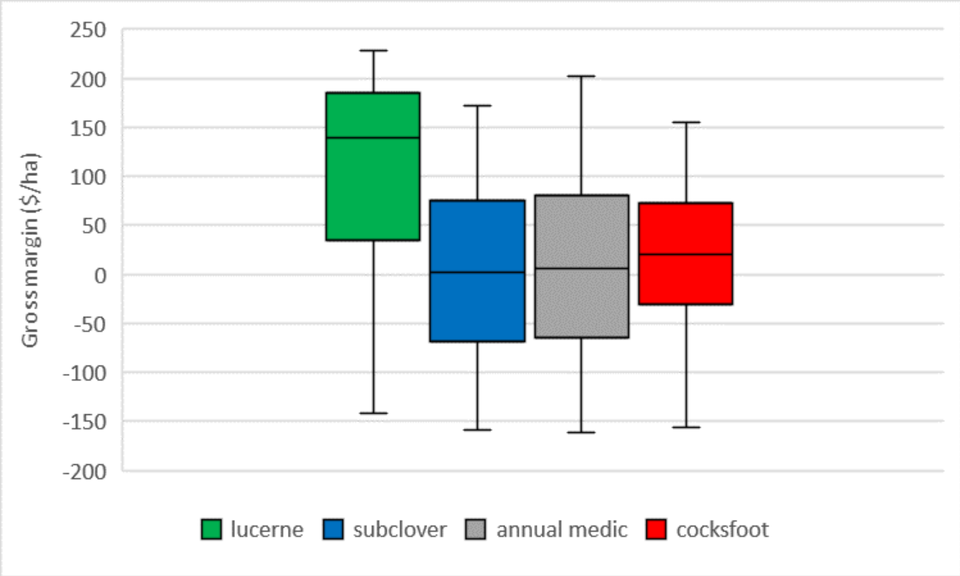


Figure 26 ***Box plots of gross margins for a self-replacing Merino enterprise grazing Lucerne, Subterranean Clover, Annual Medic or Cocksfoot pastures at 1.4 breeding ewes/ha at Condobolin 1970-2019.*** *Boxplots represent median, range and interquartile range.*

Lucerne pastures produced a higher gross margin through increased production and reduced costs when considered at the same stocking rate of ewes (Table 31). A lower requirement for supplementary feeding was the single largest factor causing the higher gross margins from Lucerne. The number of lambs sold per hectare was relatively similar between pasture types. However, Lucerne enabled lambs to be sold at higher average weights (> 10 kg/lamb) contributing at least $28/ha in higher income. Clean wool production from mature ewes was also 0.6 to 0.8 kg/ewe higher when grazing Lucerne compared with other pasture types, contributing at least $20/ha to the higher income.

In the Condobolin scenario, wether lambs were sold on 26 January each year. Weaner lambs would be expected to require supplementary feeding after October if pastures were not growing and providing an adequate high energy and protein feed source. Lucerne was the only pasture species which reliably produced high quality feed after October, demonstrating the advantage of Lucerne to retain lambs to higher weights with less feeding. An earlier sale date may be more appropriate for farm systems without a summer-active perennial to reduce the cost of supplementary feed.

Table 30 ***Mean annual production variables and gross margin for Lucerne, Subterranean Clover, Annual Medic and Cocksfoot pastures when grazed at 1.4 or 1.0 breeding ewes/ha at Condobolin 1970-2019.***

Pasture	Ewes/ha	Lambs marked/ewe joined (%)	No. of lambs sold (no./ha)	Sale weight of lamb (kg)	Value of lamb sold ($/ha)	Wool value ($/ha)	Supplement ($/ha)	Supplement (kg/ewe)	Mean (median) gross margin ($/ha)
Lucerne	1.4	103	0.70	57.1	189	102	66	80	110 (139)
Lucerne	1.0	104	0.51	58.1	138	74	50	77	67 (88)
Subterranean Clover	1.4	100	0.68	45.5	156	81	121	151	-31 (2)
Subterranean Clover	1.0	101	0.49	46.7	116	60	81	141	-10 (-12)
Annual Medic	1.4	100	0.68	46.5	161	82	116	144	9 (7)
Cocksfoot	1.4	100	0.68	43.0	153	80	101	128	16 (21)

The monthly condition score of ewes in average seasons (the 50th percentile) declined throughout late summer and autumn for all pasture types before increasing in winter and spring (Figure 38). The decline in condition was more rapid in autumn for ewes grazing Lucerne, but condition was regained earlier after lambing and this allowed ewes to be joined in higher condition (3.9 versus 3 to 3.2) than if grazing annual pasture or Cocksfoot. The percentage of lambs marked per ewe was 3% higher for those grazing Lucerne, associated with the higher condition score of ewes (Table 30).

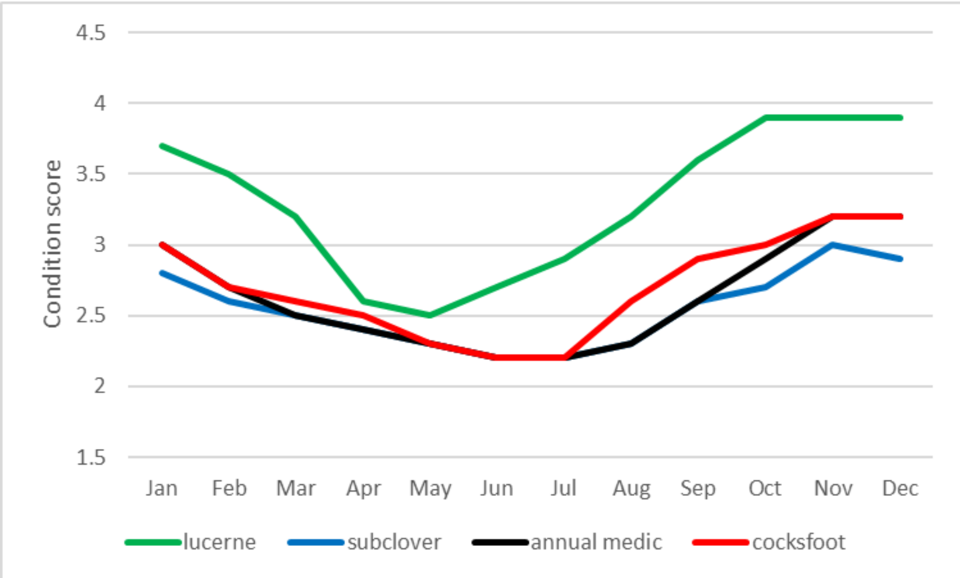


Figure 27 ***Monthly mean condition score of ewes in average seasons (50th percentile) for a self-replacing Merino enterprise grazing Lucerne, Subterranean Clover, Annual Medic or Cocksfoot pasture at 1.4 breeding ewes/ha at Condobolin 1970-2019.***

Performance in drought years

The gross margins, income from wool and sheep sales and supplementary feeding costs for poor (lowest 10%), average (50th percentile) and good (highest 10%) seasons are shown in Table 31. Positive gross margins were achieved on all pasture types in good seasons, but in average seasons gross margins were negligible (< $25/ha) with the exception of Lucerne. In poor seasons only Lucerne pasture achieved a positive gross margin, with < -$100/ha achieved for Subterranean Clover, medic and Cocksfoot pasture. Lower feed costs were the key reason for the higher gross margins from Lucerne in both average and poor seasons. Feed costs were mostly due to feeding in confinement, triggered when groundcover fell below 70%. Sheep were not released until > 200 kg available DM/ha. For annual pasture which had an approximate 6-month growth period, this meant sheep could be confined for long periods particularly in drought when pasture growth was low. While Lucerne allowed higher sheep production and income in drought years, this was also evident in good seasons due to the longer growth period of Lucerne into summer allowing lambs to attain higher sale weights.

The gross margins include the same pasture maintenance cost for all species ($73/ha). Differences in maintenance costs and the frequency of resowing may alter the comparisons.

The cash flow as shown by annual gross margin from 1970-2019 show the sheep enterprise grazing Lucerne tended to maintain a higher cash flow through droughts compared with other pastures (Figure 39). Subterranean Clover, Annual Medic and Cocksfoot achieved a relatively similar performance, but their gross margins all declined after 2001 with a series of drought years between 2002 to 2009. Cocksfoot pastures produced higher margins than the annual species, but the lack of summer-autumn growth restricted lamb sale weights and required high levels of supplementary feed.

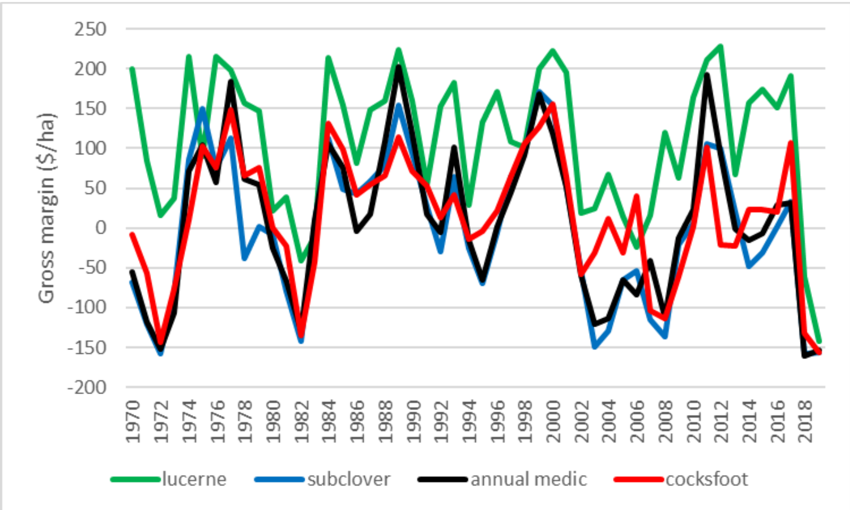


Figure 28 ***Annual gross margin ($/ha) for a self-replacing Merino enterprise grazing Lucerne, Subterranean Clover, Annual Medic or Cocksfoot pastures at 1.4 breeding ewes/ha at Condobolin in 1970-2019.***

Table 31 ***Mean gross margin and key income and cost variables in poor, average and good seasons for Lucerne, Subterranean Clover, Annual Medic and Cocksfoot pastures grazed by a self-replacing Merino ewe enterprise with 1.4 breeding ewes/ha at Condobolin 1970-2019.***

Pasture	Season	Gross margin $/ha	Total income ($/ha)	Total Expense ($/ha)	Net Wool Income ($/ha)	Sheep sale income ($/ha)	Maintenance supplement ($/ha)	Production supplement ($/ha)	Pasture maintenance ($/ha)
Lucerne	poor	12	295	310	86	205	45	129	73
	average	139	348	211	106	241	6	32	73
	good	214	381	167	113	269	0	0	73
Subterranean Clover	poor	-137	209	359	55	148	24	194	73
	average	2	292	284	82	208	4	119	73
	good	112	332	219	103	241	0	10	73
Annual Medic	poor	-118	218	360	59	155	20	197	73
	average	7	295	276	82	211	4	112	73
	good	119	336	214	101	245	0	30	73
Cocksfoot	poor	-106	224	336	67	163	39	173	73
	average	21	280	258	81	200	5	91	73
	good	107	325	213	95	228	1	0	73

Drought was classified in 10 of the 50 years at Condobolin as shown in Figure 40. The sheep enterprise grazing Lucerne pasture had higher weaning weights, growth post-weaning and higher wool production than for other pastures in non-drought years. Cocksfoot resulted in higher sheep production than the annual pastures with less supplement required. Both Cocksfoot and Lucerne improved the resilience of the sheep enterprise to drought. Weaning weights in drought were maintained at 60% rather than 50% of non-drought years as for annual pastures (Table 32). Additionally, weaner growth rates to 31 December in drought years were maintained at 52% (Cocksfoot) to 67% (Lucerne) of non-drought years, compared with 30 to 32% for annual pastures. While Lucerne did require a 3-fold increase in confined feeding in drought compared with non-drought years, the significantly lower level of supplement in non-drought years compared with other pastures contributed to the higher long-term financial performance. Higher cash reserves are expected to increase the resilience of a business to drought.

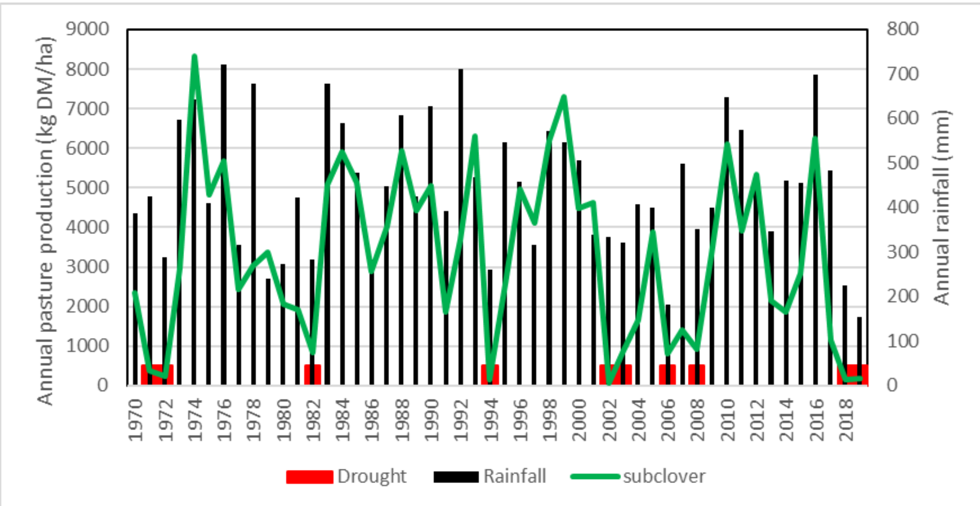


Figure 40 ***Annual rainfall (mm), production of Subterranean Clover pasture (kg DM/ha) and classification as a drought year for Condobolin 1970-2019.***

Table 319 ***Mean annual production from a self-replacing Merino enterprise in drought years for Lucerne, Subterranean Clover, Annual Medic and Cocksfoot pastures stocked at 1.4 breeding ewes/ha at Condobolin 1970-2019.***

Pasture	Season	Lambs weaned/ewe joined (%)	Wether weight at weaning (kg)	Wether weight at 31 Dec (kg)	Weaner growth to 31 Dec (g/day)	Production supplement (kg/ewe)	Clean fleece weight (kg/ewe)
Lucerne	drought	101	20.6	36.2	105	132	4.0
	other	103	34.0	59.4	156	41	4.6
Subterranean Clover	drought	99	13.4	20.2	46	233	3.0
	other	100	24.5	49.1	152	115	4.0
Annual Medic	drought	100	13.4	20.6	49	237	3.1
	other	100	25.7	50.2	153	108	4.1
Cocksfoot	drought	100	15.8	25.5	64	193	3.1
	other	100	25.2	45.2	123	93	3.9

Key Messages for species simulation: species comparison during drought

- More productive pastures allow higher sheep production with lower feed costs.
- An established Lucerne pasture allowed higher sheep production than Subterranean Clover, Annual Medic or Cocksfoot pastures in average and good seasons due to greater summer/autumn growth.
- Lucerne may reduce the volume of supplementary feeding in drought years compared with other pastures, reducing costs.
- The financial reserves gained during non-drought years are expected to improve business resilience to drought.
- Gross margins may be increased through use of perennial rather than annual pastures if additional income produced is greater than establishment and maintenance costs. Long-term persistence is necessary to minimise costs and this could not be modelled in this instance.
- Strategic sale of stock in response to dry seasons may reduce the impact on pasture persistence, risk of low groundcover and requirement for supplementary feeding.

4.5. Monaro Farming Systems (Bombala and Nimmitabel)

Results and discussion

Practice simulation question: What is the impact of Lucerne v Phalaris and Lucerne/Phalaris pastures on soil moisture, feed gaps and sheep production at Nimmitabel?

The pasture growth rates for Phalaris were lower than for Lucerne between December and March (Figure 41). During winter months Lucerne growth rates were zero or < 2.1 kg DM/ha due to the cold environment. While Phalaris also had very low growth during winter, it maintained growth for longer in late autumn, and grew more quickly at the end of winter than Lucerne, reducing the winter feed gap. However, Lucerne grew more quickly between December and March, more effectively filling the summer/autumn feed gap. This was most evident in average seasons when the growth of Phalaris in January/February was minimal but Lucerne grew at approximately 30 kg DM/ha/day, and in poor seasons when Phalaris did not grow while Lucerne grew at 5-10 kg DM/ha/day. The growth of a Phalaris/Lucerne mix tended to follow the same pattern as the Lucerne pasture, but the mix simulated was a very Lucerne dominant pasture with Phalaris a minor pasture component. The fertility scalar for the mixed pasture contributed to the higher growth of the mixed pasture because for pure stands the paddock fertility scalar was set lower for Lucerne than for Phalaris to achieve more realistic growth, which was not possible when grown in the same paddock.

The level of supplementary feeding was excessive at a stocking rate of 4 ewes/ha (Table 33) although this stocking rate was typical for the region. A pasture mass above 800 kg DM/ha in January to April was maintained in more than 20% of years for Phalaris but not Lucerne. Groundcover fell below the target 70% threshold more frequently in Lucerne than Phalaris. Note both pastures were pure species, and the addition of an annual legume to the Lucerne pasture is expected to increase groundcover. Groundcover was maintained at an adequate level in the Lucerne dominant mixed pasture.

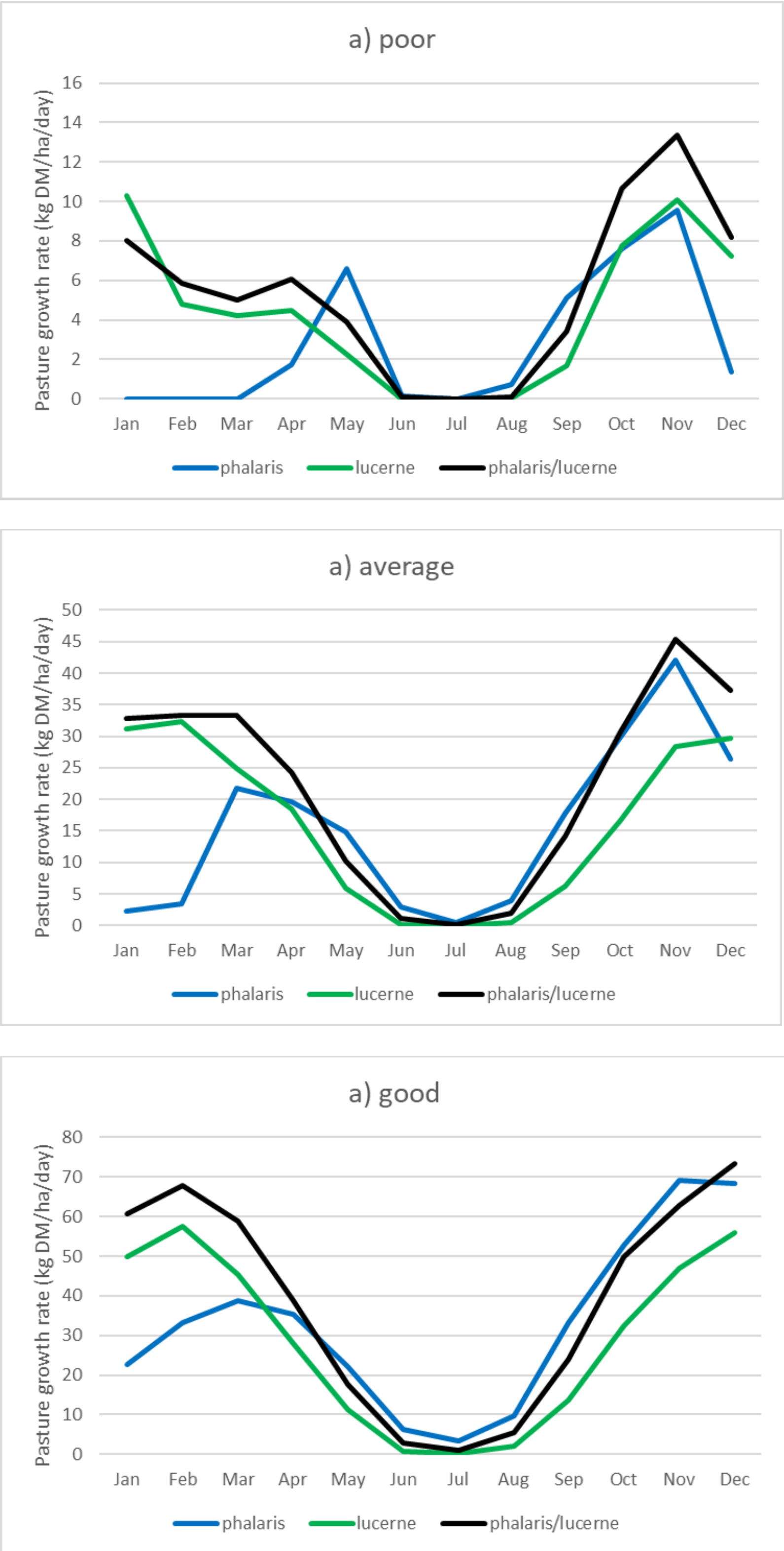


Figure 29 ***Mean monthly pasture growth rates for Phalaris, Lucerne and a Phalaris/Lucerne mix at Nimmitabel in a) poor, b) average and c) good seasonal conditions when stocked at 4.0 ewes/ha.***

Table 20 ***Mean sustainability variables for Phalaris, Lucerne and Phalaris/Lucerne pastures grazed at 4 ewes/ha at Nimmitabel 1970-2019.***

Pasture	Annual dse/ha	July dse/ha	% of years <800 kg DM/ha in Jan-Apr	% of years supplementary feed > 30 kg/ewe	Long-term pasture utilisation (%)	Long-term average groundcover (%)	Months per year < 70% groundcover at 30th percentile
Phalaris	11.4	7.0	10	82	46	85	0
Lucerne	12.5	6.4	26	45	54	62	12
Phalaris/Lucerne	13.0	6.7	3	66	44	80	3

The median gross margin for the sheep enterprise grazing Lucerne pastures was $225/ha higher than for Phalaris (Figure 42). This was driven by a higher sale weight of lamb (65 vs 52 kg) and a lower requirement for supplementary feed (Table 34). Higher sale weights of weaned lambs were associated with a 5 to 10% higher digestibility of the diet selected from Lucerne compared with Phalaris pasture during the summer/autumn period. In average years, supplementary feeding of mature ewes occurred mainly in September/October around the lambing period for both Phalaris and Lucerne. Wether weaners were rarely fed in average seasons.

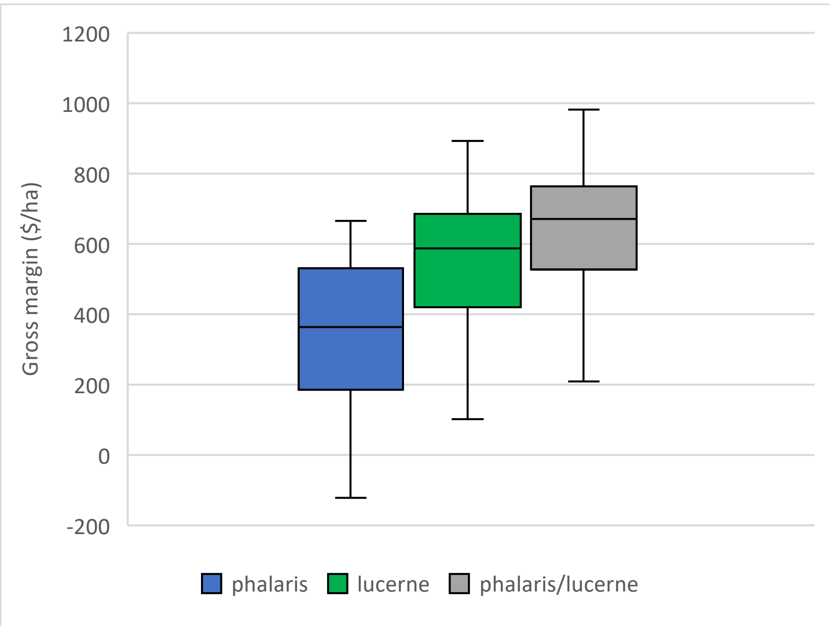


Figure 30 ***Box plots of gross margins for a composite enterprise grazing Phalaris, Lucerne of Phalaris/Lucerne pastures at 4 ewes/ha Nimmitabel 1970-2019.*** *Boxplots represent median, range and interquartile range.*

Table 21 ***Mean production variables and gross margin for a Composite enterprise grazing Phalaris, Lucerne or a Phalaris/Lucerne pasture at 4 ewes/ha at Nimmitabel 1970-2019.***

Pasture	Lambs marked/ewe joined (%)	No. of lambs sold (no./ha)	Sale weight of lamb[A] (kg)	Value of lamb sold ($/ha)	Wool value ($/ha)	Supplement ($/ha)	Supplement (kg/ewe)	Mean (median) gross margin ($/ha)
Phalaris	122	4.0	51.9	687	19	211	118	339 (363)
Lucerne	127	4.1	64.7	878	20	189	116	545 (588)
Phalaris/Lucerne	129	4.2	64.8	898	20	107	66	646 (671)

[A]Weights are for wether lambs.

The condition score of ewes in average seasons (the 50th percentile) grazing Lucerne pasture increased during late summer and autumn due to pasture growth and the ability to select a diet of higher digestibility, whereas those grazing Phalaris only maintained condition (Figure 43). This produced a higher condition at the April joining for those grazing Lucerne, which enabled 5% more lambs marked per ewe than Phalaris pastures (Table 34). However, the condition of ewes grazing Lucerne declined more rapidly during winter due to the lack of Lucerne growth during winter and selection of a diet up to 10% lower in digestibility compared with Phalaris. This meant that ewes grazing Lucerne or Phalaris were in the same condition score at lambing in September, before both rapidly increasing with pasture growth in spring. Loss of condition of ewes during late pregnancy needs to be managed as large losses will reduce lamb birthweights and the survival of lambs at birth. Restricted nutrition during late pregnancy may also reduce the staple strength of wool produced if ewes are not shorn close to this period, although the value of wool is more relevant to Merino rather than Composite ewes.

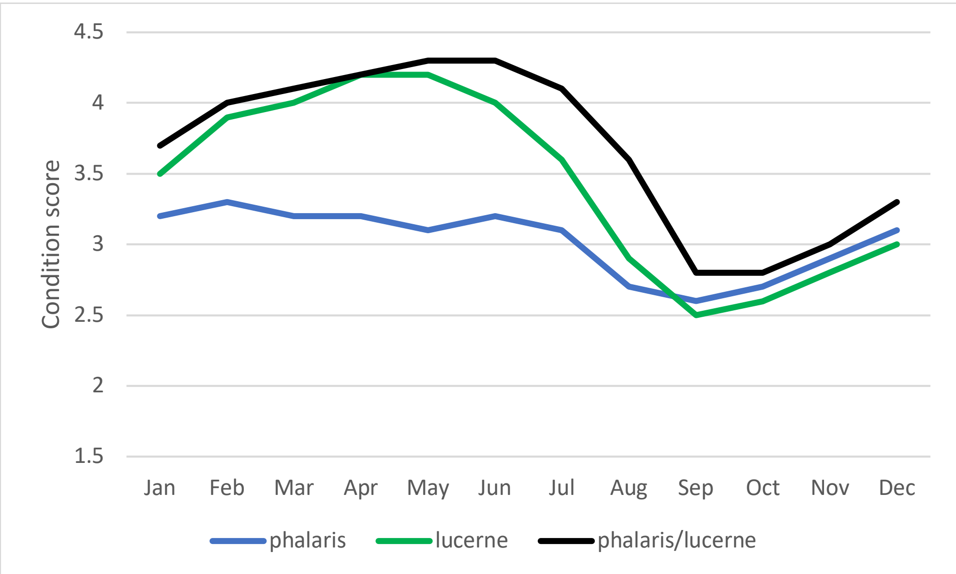


Figure 31 ***Monthly mean condition score of ewes in average seasons (50th percentile) for a composite enterprise grazing Phalaris, Lucerne or Phalaris/Lucerne pasture at 4 ewes/ha at Nimmitabel 1970-2019.***

Performance in drought years

The gross margins, income from wool and sheep sales and supplementary feeding costs for poor (lowest 10%), average (50th percentile) and good (highest 10%) seasons are shown in Table 35. The ability to increase lamb sale weights in all types of seasons was the driver for the higher gross margins of Lucerne compared with Phalaris pasture, since supplementary feed costs were relatively similar. The cash flow as indicated by annual gross margins from 1970-2019 demonstrated a generally higher financial position for Lucerne compared with Phalaris pasture (Figure 44). However, the stocking rate for a pure Lucerne pasture needs to be lower than for Phalaris to avoid groundcover below 70% for long periods. The optimal stocking rate for each species has not been evaluated, and differences in the frequency of re-sowing of pastures has also not been considered in this analysis.

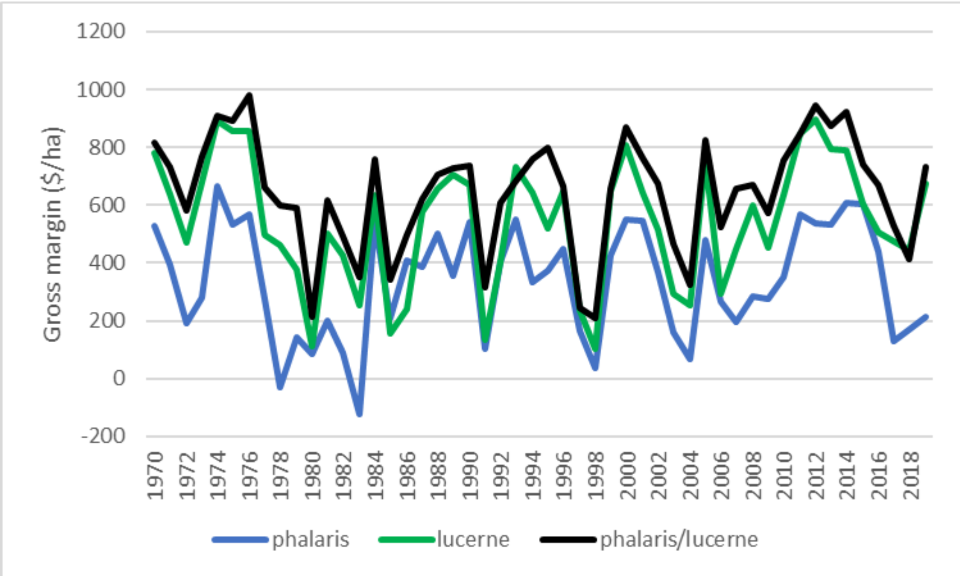


Figure 32 ***Annual gross margin ($/ha) for a composite enterprise grazing Phalaris, Lucerne or Phalaris/Lucerne pasture at 4 ewes/ha at Nimmitabel 1970-2019.***

Drought years were classified at Nimmitabel in 11 of the 50 years during the period 1970-2019 as shown in Figure 45. Lucerne pasture allowed weaners to grow at higher rates than Phalaris during drought as well as other years, without increasing supplementary feed costs (Table 36). Wool production was similar between seasons but higher for ewes grazing Lucerne due to the higher nutritive value of Lucerne during summer/autumn.

Table 22 **Mean gross margin and key income and cost variables in poor, average and good seasons for a composite enterprise grazing Phalaris, Lucerne or Phalaris/Lucerne pasture at 4 ewes/ha at Nimmitabel 1970-2019.**

Pasture	Season	Gross margin $/ha	Total income ($/ha)	Total Expense ($/ha)	Net Wool Income ($/ha)	Sheep sale income ($/ha)	Maintenance supplement ($/ha)	Production supplement ($/ha)
Phalaris	poor	89	732	661	18	712	279	191
	average	363	808	455	19	789	141	0
	good	553	879	279	20	859	16	0
Lucerne	poor	241	817	595	19	796	211	187
	average	588	999	451	20	978	139	0
	good	812	1143	310	22	1121	50	0
Phalaris/Lucerne	poor	343	836	510	20	817	190	100
	average	671	1023	348	20	1002	73	0
	good	878	1154	271	21	1134	0	0

Table 23 **Mean production from a composite enterprise in drought years for Phalaris, Lucerne or Phalaris/Lucerne pasture at 4.0 ewes/ha at Nimmitabel 1970-2019.**

Pasture	Season	Lambs weaned/ewe joined (%)	Wether weight at weaning (kg)	Weaner growth Jan to Apr (g/day)	Production supplement (kg/ewe)	Clean fleece weight (kg/ewe)
Phalaris	drought	120	29.9	115	61	2.1
	other	122	34.8	140	22	2.1
Lucerne	drought	125	32.7	159	67	2.4
	other	126	37.6	225	19	2.4
Phalaris/Lucerne	drought	126	33.4	169	37	2.5
	other	129	38.4	214	5	2.4

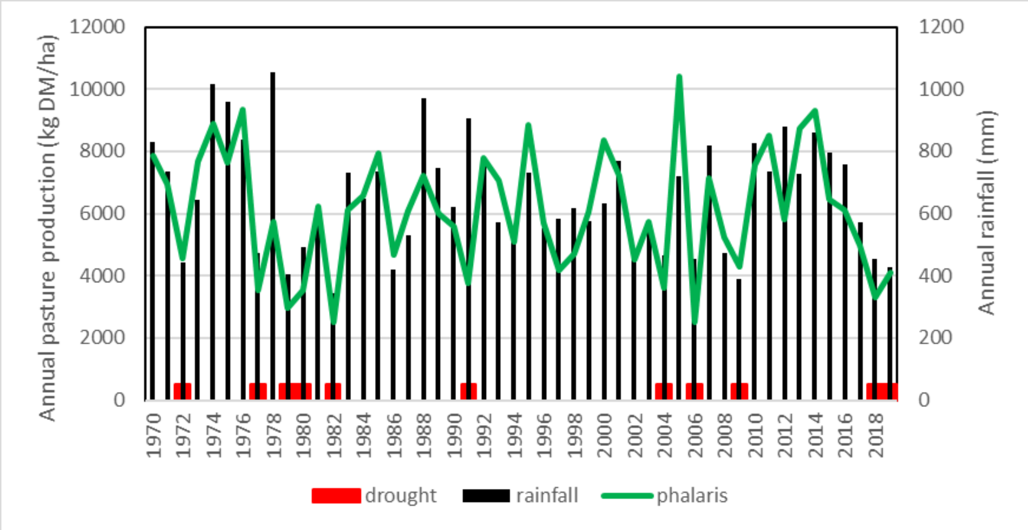


Figure 33 ***Annual rainfall (mm), production of Phalaris pasture (kg DM/ha) and classification as a drought year for Nimmitabel 1970-2019.***

Key Messages for practice simulation: feed gaps and production for Lucerne vs Phalaris

- Lucerne extends the winter feed gap compared with Phalaris, but fills the summer/autumn feed gap when Phalaris has poor growth.
- Sheep enterprises which can better utilise high quality summer/autumn pasture will gain more benefit from Lucerne, while enterprises with a high winter demand would be disadvantaged by Lucerne compared with Phalaris due to the different times of feed gap.
- An established Lucerne pasture provided higher quality feed and allowed faster lamb growth rates and sale weights compared with Phalaris when weaners were finished over the summer/autumn period, and the advantage occurred in drought and better seasons.
- Low groundcover in Lucerne pastures needs to be managed, and for pure stands may require lower annual stocking rates than Phalaris pastures to protect soils. Including other species with Lucerne will reduce the risk of low groundcover.
- Gross margins may be increased through use of Lucerne rather than Phalaris pastures if additional income produced is greater than establishment and maintenance costs. Long-term persistence is necessary to minimise costs and Lucerne may require more frequent re-sowing than Phalaris.
- Strategic sale of stock in response to dry seasons may reduce the impact on pasture persistence, risk of low groundcover and requirement for supplementary feeding.

Species simulation question: Do Perennial Ryegrass and Phalaris pastures have different growth patterns and nutritive value which will improve sheep enterprise resilience to drought at Bombala?

The monthly pasture growth rates for Phalaris and Perennial Ryegrass were similar in poor seasons. In average and good seasons Perennial Ryegrass maintained higher growth rates than Phalaris into summer and autumn, but winter and spring growth was similar (Figure 46).

A high level of groundcover was maintained for both Phalaris and Perennial Ryegrass pastures when stocked at 5.1 sheep/ha (Table 37). A pasture mass above 800 kg DM/ha in the January to April period was maintained in most years, but the Phalaris pasture did require supplementary feeding of ewes above 30 kg/ewe in more years than for Perennial Ryegrass. The median gross margin was $38/ha higher for Perennial Ryegrass compared with Phalaris pasture (Figure 47). This resulted mostly from lower supplementary feeding costs, with higher sale weights and weight of wool produced also contributing (Table 38).

Table 24 ***Mean sustainability variables for Phalaris and Perennial Ryegrass pastures at Bombala grazed at 4.1 ewes/ha 1970-2019.***

Pasture	Sheep/ha	Annual dse/ha	July dse/ha	% of years <800 kg DM/ha in Jan-Apr	% of years feed > 30 kg/ewe	Long-term pasture utilisation (%)	Long-term average groundcover (%)	Months < 70% groundcover at 30th percentile
Phalaris	5.1	11.7	8.8	9	36	40	91	0
Perennial Ryegrass	5.1	12.0	9.1	7	24	36	91	0

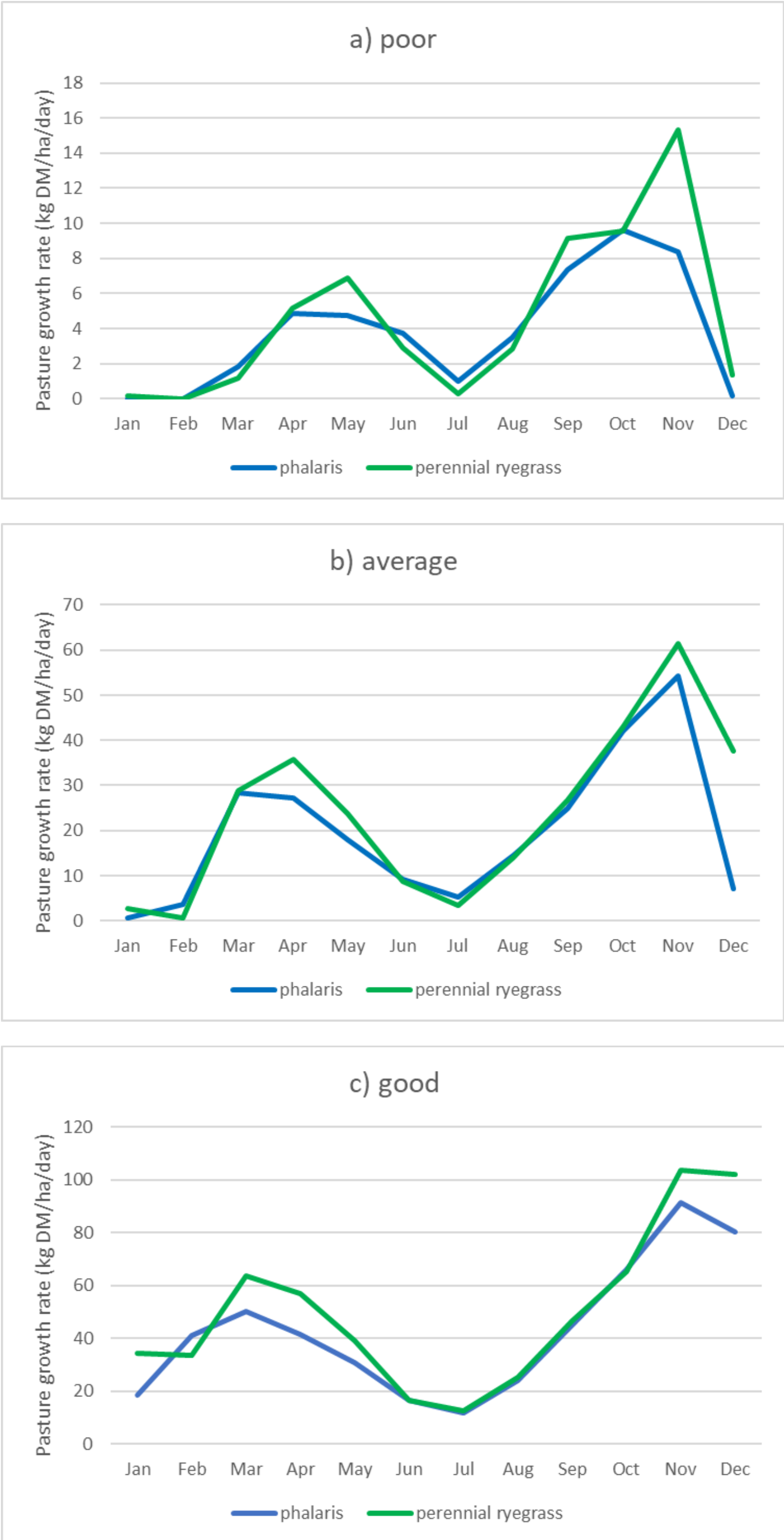


Figure 34 ***Mean monthly pasture growth rates for a Phalaris and Perennial Ryegrass pasture in a) poor, b) average and c) good seasons at Bombala 1970-2019.***

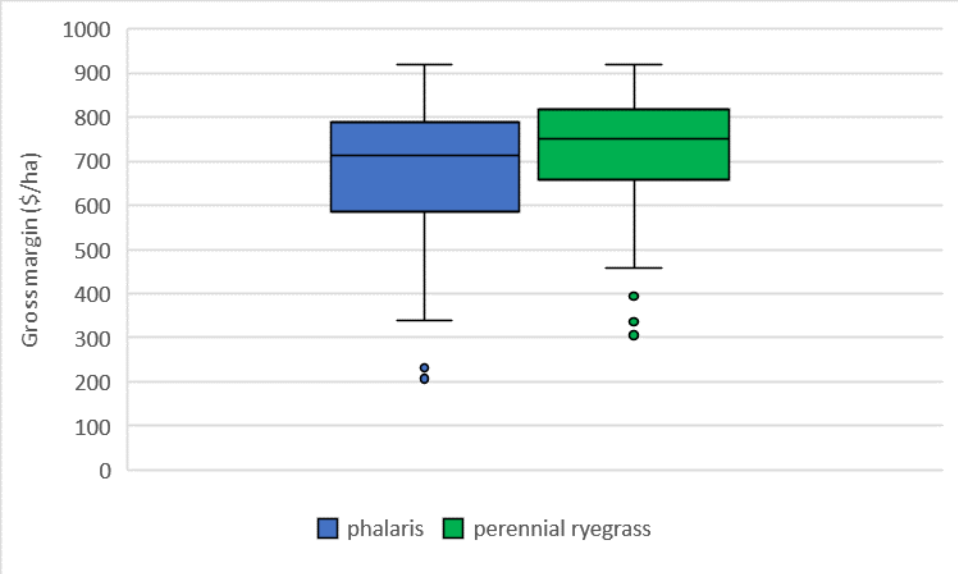
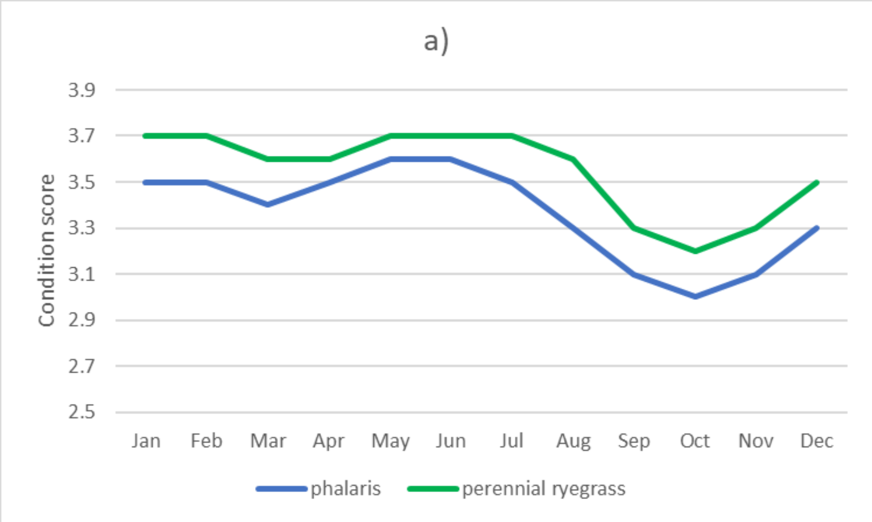


Figure 35 ***Box plots of gross margins for a self-replacing Merino enterprise grazing Phalaris and Perennial Ryegrass pastures at Bombala 1970-2019.*** *Boxplots represent median, range and interquartile range, and o indicates extreme values.*

The mean condition score of ewes was generally maintained at or above 3.5 between January and July. However, condition score declined rapidly during winter during late pregnancy and during the lambing period before increasing during late spring (Figure 48a). Controlling this loss has the potential to improve lamb survival and the staple strength of wool, although alternative management was not compared in this analysis. Perennial Ryegrass maintained ewes in 0.2 score higher throughout most of the year, although this did not result in more lambs marked per ewe joined (Table 38). The higher condition score of ewes grazing perennial ryegrass compared with Phalaris was associated with a higher digestibility of pasture consumed, rather than differences in the quantity of green pasture except during summer (Figure 48b). A higher condition score provides resilience against periods of low feed availability, or alternatively, indicates a higher stocking rate could be used.



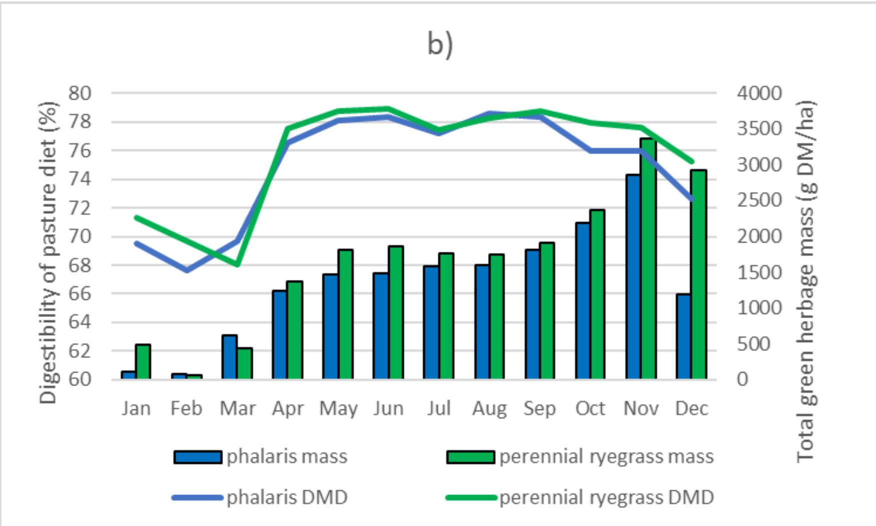


Figure 36 ***Monthly mean a) condition score of ewes and b) green pasture mass (kg DM/ha) digestibility of pasture diet (%) for young stock in average seasons (50th percentile) for a self-replacing Merino enterprise grazing Phalaris or Perennial Ryegrass pastures at Bombala 1970-2019.***

Table 25 ***Mean production variables and gross margin for a self-replacing Merino enterprise grazing Phalaris or Perennial Ryegrass pastures at Bombala 1970-2019.***

Pasture	Lambs marked/ewe joined (%)	No. of young stock sold (no./ha)*	Sale weight of wethers (kg)	Value of young stock sold ($/ha)*	Mean fibre diameter of ewes (µ)	Wool value ($/ha)	Supplement ($/ha)	Supplement (kg/ewe)	Mean (median)gross margin $/ha
Phalaris	90	2.6	56.2	409	17.8	610	87	29.1	668 (712)
Perennial Ryegrass	91	2.6	58.1	421	17.8	617	64	19.3	711 (750)

*Wether hoggets and surplus young ewe hoggets.

Performance in drought years

Drought was classified in 8 of the 50 years at Bombala (Figure 49). The gross margins, income from wool and sheep sales and supplementary feeding costs for poor (lowest 10%), average (50th percentile) and good (highest 10%) seasons are shown in Table 39. The gross margin for Perennial Ryegrass was \$65, \$38 and \$17/ha higher than Phalaris in poor, average and good seasons, indicating an advantage for Perennial Ryegrass in poor seasons. The benefit was largely associated with lower feeding costs. The cash flow indicated by annual gross margin over time produced a higher financial level for Perennial Ryegrass in the long term, although the difference was small (Figure 50). The differences should be viewed cautiously because the analysis assumes both pastures will persist and require re-sowing at the same frequency, whereas Phalaris is expected to have better persistence and the ryegrass production simulated may only represent productivity in the first 5 years after establishment (D. Alcock, personal communication).

When drought years were compared with other years, the reduction in the growth rate of weaners during drought were similar, but Perennial Ryegrass allowed higher weaning weights of lambs than Phalaris (Table 40). Ryegrass also allowed wool production to be maintained at a higher level during drought.

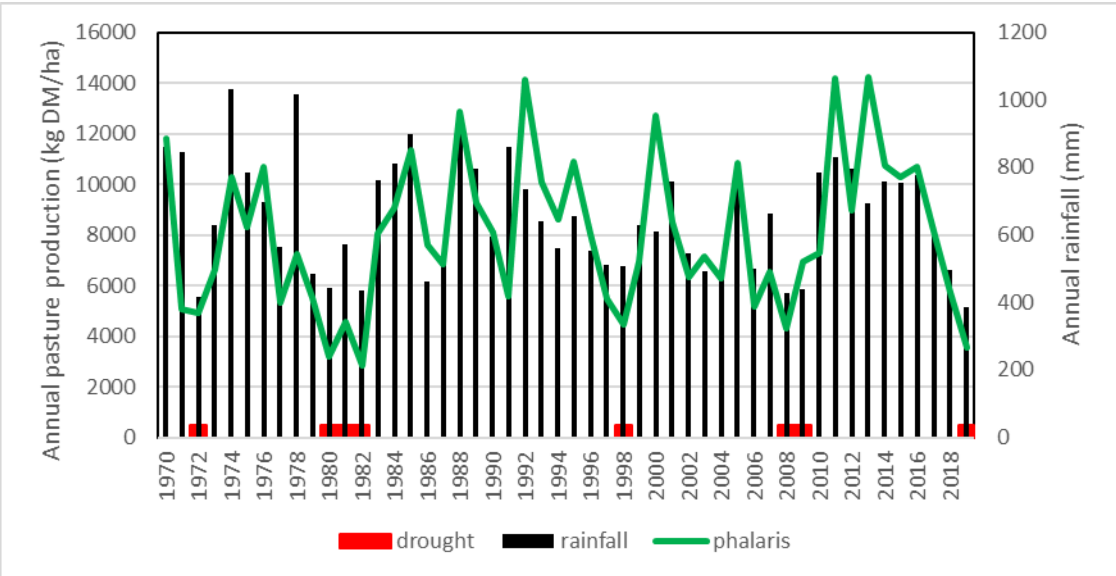


Figure 37 ***Annual rainfall (mm), production of Phalaris pasture (kg DM/ha) and classification as a drought year for Bombala 1970-2019.***

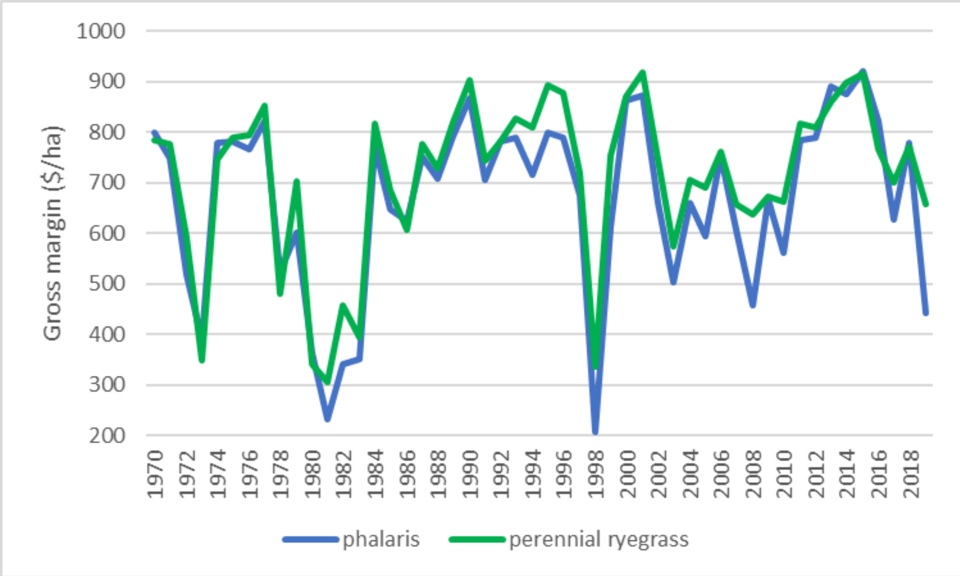


Figure 38 ***Annual gross margin ($/ha) for a self-replacing Merino enterprise grazing Phalaris or Perennial Ryegrass pasture at Bombala 1970-2019.***

Table 26 ***Mean gross margin and key income and cost variables in poor, average and good seasons for a self-replacing Merino enterprise grazing Phalaris or Perennial Ryegrass pasture at Bombala 1970-2019.***

Pasture	Season	Gross margin $/ha	Total income ($/ha)	Total Expense ($/ha)	Net Wool Income ($/ha)	Sheep sale income ($/ha)	Maintenance supplement ($/ha)	Production supplement ($/ha)
Phalaris	poor	386	961	622	559	405	122	150
	average	712	1115	390	618	501	36	0
	good	863	1219	346	649	568	0	0
Perennial Ryegrass	poor	451	1013	558	577	429	78	153
	average	750	1133	366	623	509	10	0
	good	880	1256	341	659	591	0	0

Table 27 ***Mean production from a self-replacing Merino enterprise grazing native pastures with low or high soil fertility in drought or other years.***

Pasture	Season	Lambs weaned/ewe joined (%)	Wether weight at weaning (kg)	Weaner growth Jan to May (g/day)*	Production supplement (kg/ewe)	Clean fleece weight (kg/ewe)	Fibre diameter ewes (μ)
Phalaris	drought	88	17.7	85	36	3.0	17.4
	other	90	22.8	95	5	3.5	17.8
Perennial Ryegrass	drought	89	18.7	85	33	3.2	17.5
	other	91	23.8	97	6	3.5	17.9

*Wether weaners

<u>Key Messages for species simulation: Phalaris vs Perennial Ryegrass</u>

- Perennial Ryegrass may produce higher pasture growth rates in autumn and summer than Phalaris and provide a higher quality diet for sheep in suitable regions, increasing sheep production.
- The persistence of sown pastures impacts on profitability. Pastures with lower persistence may become less productive and require more frequent re-sowing which increases costs. Persistence could not be modelled for perennial species in this analysis.
- Perennial species which increase autumn growth and the length of the growing season during drought years may reduce the need for supplementary feeding.
- Managing ewe nutrition to avoid large loss in condition score during late pregnancy is recommended to optimise lamb survival.
- Managing ewe nutrition to avoid large loss in condition in autumn or around lambing is recommended to minimise reductions in the staple strength of wool.

5. Limitations of the modelling

- The results represent grazing-only systems, without access to grazing of crop stubbles which can be a valuable source of feed in some regions during summer and autumn. The grazing of stubbles may allow higher stocking rates and lower quantities of supplementary feeding than that indicated in this analysis.
- The results represent a farm with a single type of pasture to enable the impact on the sheep enterprise to be clearly defined. Farms with a range of feed sources with differing patterns of supply throughout the year may increase resilience to drought, but were not considered in this analysis.
- The analysis considered stock sales at defined dates with no reduction in stocking rate in poor seasons. Flexibility in sale date to respond to seasonal conditions may reduce the risk of high feeding costs and improve sustainability measures.
- Stable price and costs were used, but feed costs are expected to increase during periods of drought. Pastures which attract lower feeding costs may therefore improve the resilience of the system to drought. The financial results presented reflect the prices and costs used, so the financial performance of different choices will vary if different values are used.
- The analysis used established pastures and did not consider the time nor cost required to establish sown pasture prior to grazing. Establishment reduces the effective grazing area of pasture, but the degree to which this occurs will depend upon the longevity of the pasture and the percentage re-sown each year. This establishment phase can make perennial pastures less productive than an annual pasture (Moore 2014). Well-managed pastures sown in suitable locations (soil type, environment) can remain productive for decades, reducing the cost of establishment.
- The analysis used single representation of both species types. All types of pasture may vary widely in their performance, altering the relative benefit or disadvantage of either pasture, but a large analysis was beyond the scope of this study.
- Barley Grass seeds are a risk to sheep welfare through damage to eyes and skin penetration. Contamination of wool and carcases will attract price penalties. Strategies to avoid grazing Barley Grass pastures during seeding are recommended, such as grazing alternative pastures, grazing only in short wool or grazing to keep pastures short. The simulation did not allow sheep access to other pasture types, and does not include potential penalties for wool and meat damage.
- The growth potential or increase in pasture growth in response to fertiliser and the cost of fertiliser may vary from those reported here, and may be much lower for pastures sown within cropping rotations.

- The cost to increase or vary stocking rates has not been considered in this analysis.
- The analysis assumes all pastures persist, as perennials are not removed by heavy grazing in GrassGro.
- The analysis used stocking rates suggested by the producer groups as representative of the region and considered production differences for different pastures at the same stocking rate. Optimal stocking rates were not determined, but are expected to vary with different pastures, different sheep management systems, and where a pasture species is part of a wider feed base.

6. General Recommendations

A wide choice of pasture species is available. The persistence of different species could not be evaluated in this study, but will be increased by selection of species and varieties that are adapted to a particular soil, climate and management system. The ability to withstand drought is increasingly important for choice of species as the climate in southern Australia becomes hotter, drier, with less reliable rainfall. Use of appropriate species and varieties for a specific situation is fundamental to the production and persistence of pastures to drive sheep production. The long-term resilience of sheep/pasture systems will be increased through use of grazing management which matches the needs of the pasture eg rest periods to promote the persistence of perennial species. However, the resilience of farming systems, particularly to drought, is also increased through practices which improve long-term financial performance. Cost-efficient methods to increase the growth potential of pastures, use of optimal stocking rates to increase performance per hectare, and timing sheep management (time of lambing, time of stock sales) to match feed supply will also assist in improving long-term productivity, financial performance and so resilience to drought.

7. Acknowledgements

Each farming systems group devised the comparisons to be simulated and provided comment on the results. Doug Alcock provided base GrassGro models for the Monaro region which were adapted for purpose, and provided helpful comment on the simulation outputs. Ms Emma Smith and Ms Steph Cowley from Holbrook Landcare Network facilitated meetings with each producer group to enable communications. Dr Alison Southwall, CEO of Holbrook Landcare Network, generated the project concept, lead the project and is gratefully acknowledged for supporting this work. Funding from the Future Drought Fund enabled the project.

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9. Appendices

Appendix 1. Description of key location details.

	Mangoplah	Bookham	Finley	Temora	Boorowa	Condobolin	Nimmitabel	Bombala
Weather station	Henty 35º31'S; 147º02'E	Yass 34º50'S; 148º55'E	Finley 35º39'S; 145º34'E	Temora 34º24'S; 147º32'E	Harden 34º45'S; 148º19'E	Condobolin 33º04'S; 147º14'E	Nimmitabel 36º36'S; 149º18'E	Bombala 36º55'S; 149º14'E
Annual rainfall (mm)*	598	680	443	536	613	446	656	655
Soil type	Dr2.32 (red duplex)	Dy3.42 (yellow-grey duplex)	Dr2.33 (red duplex)	Dr2.33 (red duplex)	Dy3.42 (yellow-grey duplex)	Apsoil 690	Red basalt	Dy2.21 (yellow kurosol)
Base soil fertility scalar	0.9	0.6	0.8	0.8	0.8	0.7	0.9	0.8

*1970-2019

Appendix 2. Description of key simulation parameters for each location.

		Mangoplah	Bookham	Finley	Temora	Boorowa	Condobolin	Nimmitabel	Bombala
Comparison		Phalaris vs Barley Grass	Base vs higher fertility	Set stocked vs rotational grazing Lucerne; Lucerne vs volunteer	Various species	Set stocked vs rotational grazing Phalaris	Various species; Pure Lucerne vs mixes	Lucerne vs Phalaris	Phalaris vs perennial ryegrass
Rooting depth (mm)	Phalaris	750*			600	600	-	740	400
	Perennial ryegrass	-	-	-	-	-	-	-	400
	Barley Grass	250			-	-	-	-	-
	Annual Ryegrass			320	350	-	-	-	-
	Subterranean Clover	250	250	320	350	-	250	-	-
	Annual Medic	-	-	-	-	-	250	-	-
	Microlaena	-	420	-	-	-	-	-	-
	Austrodanthonia	-	460	-	-	-	-	-	-
	Cocksfoot	-		-	560	-	800	-	-
	Lucerne	-		540	860	-	1000	450	-

*At Mangoplah Phalaris was modelled using a fixed 30% legume

Appendix 3. Pasture growth rates

Simulated and literature estimates[A] of average monthly pasture growth rates (kg DM/ha/day) 1970-2019 for each location.

Location	Pasture	Data	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mangoplah	Phalaris	simulated	0	0	0	6	22	23	24	23	43	57	14	0
		MLA SW slopes	5	7	16	25	24	17	16	26	47	64	43	12
	annual	simulated	3	3	5	12	19	18	17	29	50	32	2	1
		MLA SW slopes	3	4	10	23	24	14	10	25	45	64	35	7
Bookham	native high	simulated	17	5	9	15	16	12	7	13	29	29	37	18
	native low	simulated	14	3	7	12	12	10	5	11	23	24	31	14
		MLA SW slopes	16	14	10	8	7	5	5	6	15	30	24	18
Finley	Lucerne	simulated	10	8	6	12	18	13	10	17	34	16	24	11
		McDonald 2004	3	3	6	15	16	14	14	19	31	48	21	4
	annual	simulated	0	0	0	1	6	9	14	26	30	15	4	0
		McDonald 2004	0	0	0	1	10	18	19	32	46	40	0	0
Temora	Lucerne	simulated	22	24	13	17	24	13	8	16	40	62	39	23
		Moore 2014	10	10	11	12	12	8	6	14	26	34	28	14
	Subterranean Clover	simulated	0	0	0	4	13	16	14	30	55	40	8	0
		Moore 2014	2	4	8	10	12	11	11	18	34	38	25	5
	Phalaris	simulated	0	0	0	3	16	17	17	24	42	46	16	0
		Moore 2014	1	3	6	8	11	10	10	13	25	35	31	8
	Cocksfoot	simulated	0	0	0	4	17	18	18	27	53	34	1	0
		literature	-	-	-	-	-	-	-	-	-	-	-	-

Condobolin	Lucerne	simulated	12	13	10	4	15	10	10	17	23	19	23	14
		McDonald 2004	13	9	9	9	14	11	10	13	19	21	14	10
	Subterranean Clover	simulated	0	0	0	0	3	8	12	22	24	11	0	0
		McDonald 2004	0	0	0	2	5	9	14	20	22	5	0	0
	Annual Medic	simulated	0	0	0	0	7	8	12	21	24	4	0	0
		McDonald 2004	0	0	0	2	5	9	14	20	22	5	0	0
	Cocksfoot	simulated	0	0	0	0	9	13	17	22	24	1	0	0
		MLA	3	2	1	7	14	16	10	11	18	41	41	17
Nimmitabel	Phalaris	simulated	2	3	22	20	15	3	0	4	18	30	42	26
		MLA	10	80	20	26	20	12	10	15	45	75	55	20
	Lucerne	simulated	31	32	25	18	6	0	0	1	6	17	28	30
		literature	-	-	-	-	-	-	-	-	-	-	-	-
Bombala	Phalaris	simulated	1	4	28	27	18	9	5	14	25	42	54	7
		literature	-	-	-	-	-	-	-	-	-	-	-	-
	perennial ryegrass	simulated	3	1	29	36	24	9	3	14	27	43	61	38
		MLA	10	80	20	26	20	12	10	15	45	75	55	20

[A]Regional estimates sourced from:

https://mbfp.mla.com.au/pasture-utilisation/tool-33-pasture-growth-estimates/tool-33-nsw-feed-year-growth-rate-patterns/

https://www.evergraze.com.au/library-content/regional-pasture-growth-rates/index.html.

Agnote 501 (McDonald 2004)

Appendix 4. Key prices and costs used to calculate gross margins

Meat prices

Meat category	Light lamb < 18 kg	Trade lamb 18-22 kg	Heavy lamb 22+ kg	Merino lamb	Mutton
c/kg carcase weight*	730	781	763	667	520

*All stock sales used a dressing percentage of 45% and $0 for skin value.

Wool prices

Fibre diameter (micron)	16	17	18	19	20	21	22	23	24	25	26	28	30
c/kg clean*	3302	2660	2142	1680	1422	1339	1312	1095	986	877	674	400	331

*Wool income was calculated from fleece weights using an average 90% of fleece price to account for the lower value of oddments.

Sheep and husbandry costs

Variable	Value
Excess young ewes	$221/head
Replacement ewes	$281
Terminal rams	$1200
Merino rams	$2000
Shearing/sheep	$9.01
Husbandry/ewe	$9.02
Husbandry/Merino lamb	$10.00
Husbandry/XB lamb	$6.17
Commission for sheep sales	4.5%
Wool sale costs (wool levy; testing, cartage; commission)	16% (XB ewes) 5% (Merino ewes)
Supplementary feed (barley grain)	$330/t
Pasture maintenance for improved pastures	$73/ha (Finley, Temora, Boorowa, Condobolin) $80/ha (Nimmitabel) $60/ha (Bombala)
Pasture maintenance for volunteer/native pastures	$0/ha (Finley, Mangoplah) $26/ha low fertility Bookham $73/ha higher fertility Bookham