Effect of lucerne phase duration in cropping systems in the high-rainfall zone

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Abstract

We used simulation models to investigate the impact of including a 3 or 6-year lucerne phase into a 9-year rotation sequence on raised beds within a mixed cropping / sheep enterprise in south-western Victoria. The results showed that inclusion of lucerne is likely to have a substantial negative impact on subsequent crop yields that may persist for 3 to 4 years (mean yield reduced by 0.2 to 1.2 t/ha). Soil water profile drying by lucerne was largely complete after 3 years and extending the duration of lucerne from 3 to 6 years reduced subsequent crop yields by an average of only 3%. Inclusion of lucerne reduced mean annual drainage under the lucerne-crop sequence by 11 to 54 mm/yr, depending on location and lucerne phase duration.

Key Words

Drainage, yield, crop rotation

Introduction

Lucerne phases have been grown in sequence with crop rotations in mid-rainfall cropping zones (400-550 mm) for many years. McCallum *et al.* (2001) found that annual crops following lucerne are at a greater risk of water limitation and their long-term simulation analysis in the Mallee region predicted a median yield penalty of 0.4 t/ha (a 15% reduction). In southern NSW, Verburg *et al.* (2007) found that while drainage risk was reduced by drier soils following a lucerne phase, there was a trade-off with grain yield. Inclusion of lucerne phases with crop sequences in the high rainfall zones are thought to present fewer tradeoffs, producing better NRM outcomes through reduced drainage, while filling pasture feed gaps with less impact on crop productivity.

Methods

We linked various APSIM crop and soil models and GRAZPLAN pasture and animal management models together to form a functioning mixed-farming-systems model, using the AusFarm software. A representative farming practice scenario was developed describing crop rotations, in-crop management, livestock enterprises and animal husbandry practices that would be followed by an expert farm manager in the Corangamite and Glenelg-Hopkins catchments.

Simulation analyses were carried out at three sites in western Victoria: Inverleigh (38?06’ S, 144?03’ E, average annual rainfall 592 mm), Lake Bolac (37?43’ S, 142?51’ E, average annual rainfall 574 mm) and Hamilton (37?50’ S, 142?04’ E, average annual rainfall 685 mm). Weather data were obtained as Patched Point datasets from the SILO data base for Winchelsea Post Office (near Inverleigh), Lake Bolac Post Office and Hamilton Research Station. Attributes of a Eutrophic Mottled-Subnatric Brown Sodosol were described based on measurements at Inverleigh (R Peries, *pers. comm.*). This soil had plant-available water content (PAWC) of 185 mm to 1.2 m and was used at all sites.

Crop and pasture management

The cropping paddocks were all assumed to be configured as raised beds of width 1.5 m and height 0.2 m, with furrows of width 0.5 m between the beds. Water above the drained upper limit in the uppermost 0.2 m of the soil was assumed to flow laterally across the beds at the same rate as it drained downward, and any water reaching the furrows was taken to be lost immediately as runoff. The beds were assumed to relieve any negative effects of waterlogging on plant growth. Paddock-scale crop yields were reduced by 5% (assuming that yield in the furrows was 80% of that on the beds due to the effects of waterlogging and compaction).

Crops were sown at the autumn break on a rainfall of at least 15 mm over 5 days, or dry sown on 15 June if no sowing opportunity occurred. Lucerne was sown from 1 April and wheat from 25 April (cv. Mackellar or cv. Chara after 25 May). Canola (cv. Thunder; mid-season, triazine-tolerant) and barley (cv. Gairdner) were sown from 1 May, although barley was not sown dry until 1 July. Nitrogen was applied as urea to lucerne (10 kg N/ha) at sowing and at the start of the growing season for second- and third-year lucerne stands. Because the focus of the investigation was on the effect of lucerne on the water balance, all crops received ample N to minimise differences in nitrogen status. 50 kg N/ha was applied at sowing, followed by 100 kg/ha N on 1 August for all crops in all simulations. Nitrogen was applied to the beds only; these rates are expressed per unit bed area.

Stubbles were grazed over summer and wheat and barley stubbles were burnt prior to sowing of barley and canola. Summer weeds in stubbles were not controlled. The lucerne stand was removed on 15 November of the final year of the lucerne phase. On that date, the lucerne stand was killed with herbicide (80% kill rate) and then cut and conserved as fodder. Surviving lucerne plants (and other weeds if any) were re-sprayed during March-April (100% kill rate) at a time when the lucerne was actively growing.

Permanent pastures were simulated as mixtures of perennial ryegrass, phalaris, annual ryegrass and subterranean clover. A moderate level of phosphorus fertility (Olsen P of 12-15) was assumed. Pastures were oversown whenever a constituent species fell to negligible levels. The simulations used a first-cross ewe breeding enterprise, with 9, 10 and 12 breeding ewes per pasture hectare at Inverleigh, Lake Bolac and Hamilton, respectively. A constant stocking rate was maintained from year to year and fluctuations in forage supply were managed through supplementary feeding. Pastures were grazed tactically by moving stock at 7-14 day intervals and assigning the best feed to the different livestock classes in an order of priority according to local management practice.

The simulated farm contained 500 ha of permanent pastures (divided into four paddocks to facilitate sheep/pasture management) and 500 ha of arable land (divided into nine paddocks phased by 1 year to average the effects of climatic variability across all phases of the rotation). At each location, three simulations were run, each with a different length of lucerne phase, to examine the effect of lucerne phases on crop yields. The treatments were: (1) continuous cropping, (2) 3-year lucerne/canola/wheat/barley/ canola/wheat/barley, and (3) 6-year lucerne/canola/wheat/barley. Each simulation was run from 1962 to 2005; however only the 35 years from 1971 to 2005 were included in the analysis of results, in order to prevent the initial conditions affecting the outcomes.

Results

Under continuous cropping mean crop yields increased with increasing rainfall, although barley yields were lower at Inverleigh than at Lake Bolac (Table 1).

Table 1: Impact of different lengths of lucerne phase on the long-term average (1971-2005) yield (t/ha) of subsequent crops at three locations in south-western Victoria. All yields are given on a paddock-area basis (i.e. averaged across raised beds and furrows).

	Continuous Crop	3 Years Lucerne		6 Years Lucerne
		Cycle 1	Cycle 2	

Lake Bolac	Canola	3.0	2.6	2.9	2.6
	Wheat	6.4	5.5	6.3	5.3
	Barley	6.9	6.3	6.8	6.0
Inverleigh	Canola	3.2	2.8	3.0	2.8
	Wheat	6.6	5.7	6.6	5.6
	Barley	6.5	5.6	6.5	5.4
Hamilton	Canola	3.2	3.0	3.1	2.9
	Wheat	7.0	6.0	7.0	5.8
	Barley	7.3	6.5	7.3	6.1

As expected, inclusion of lucerne phases in the rotations drew down soil water, resulting in drier profiles at the commencement of the cropping phase (Figure 1). At Lake Bolac, the 3-year lucerne system had an average of 74 mm less water than the continuous cropping system on 1 May of the first cropping year; at Inverleigh the corresponding water difference was 97 mm and at Hamilton it was 47 mm. Extending the lucerne phase to 6 years had little further effect on the water available to the first crop at sowing; indeed the draw-down of water by the lucerne was largely complete after 3 years.

At Lake Bolac and Inverleigh, differences in total soil water persisted until the sixth crop (Figure 1). At Hamilton, which was the highest-rainfall location, the differences in total soil water lasted for 3 years, and there was virtually no difference between the continuously-cropped system and the second cycle of cropping in the 3-year lucerne system.

Crop yields immediately following a lucerne phase were substantially lower than in a continuously-cropped system (Table 1). Averaged over the three locations, the yields of the first canola, wheat and barley crops were reduced by 0.30 t/ha (10%), 0.94 t/ha (14%) and 0.75 t/ha (11%) respectively. Mean yields were slightly lower (0-0.4 t/ha) following 6 years of lucerne compared to 3 years of lucerne, with this effect being greater at the wetter location of Hamilton (Table 1).

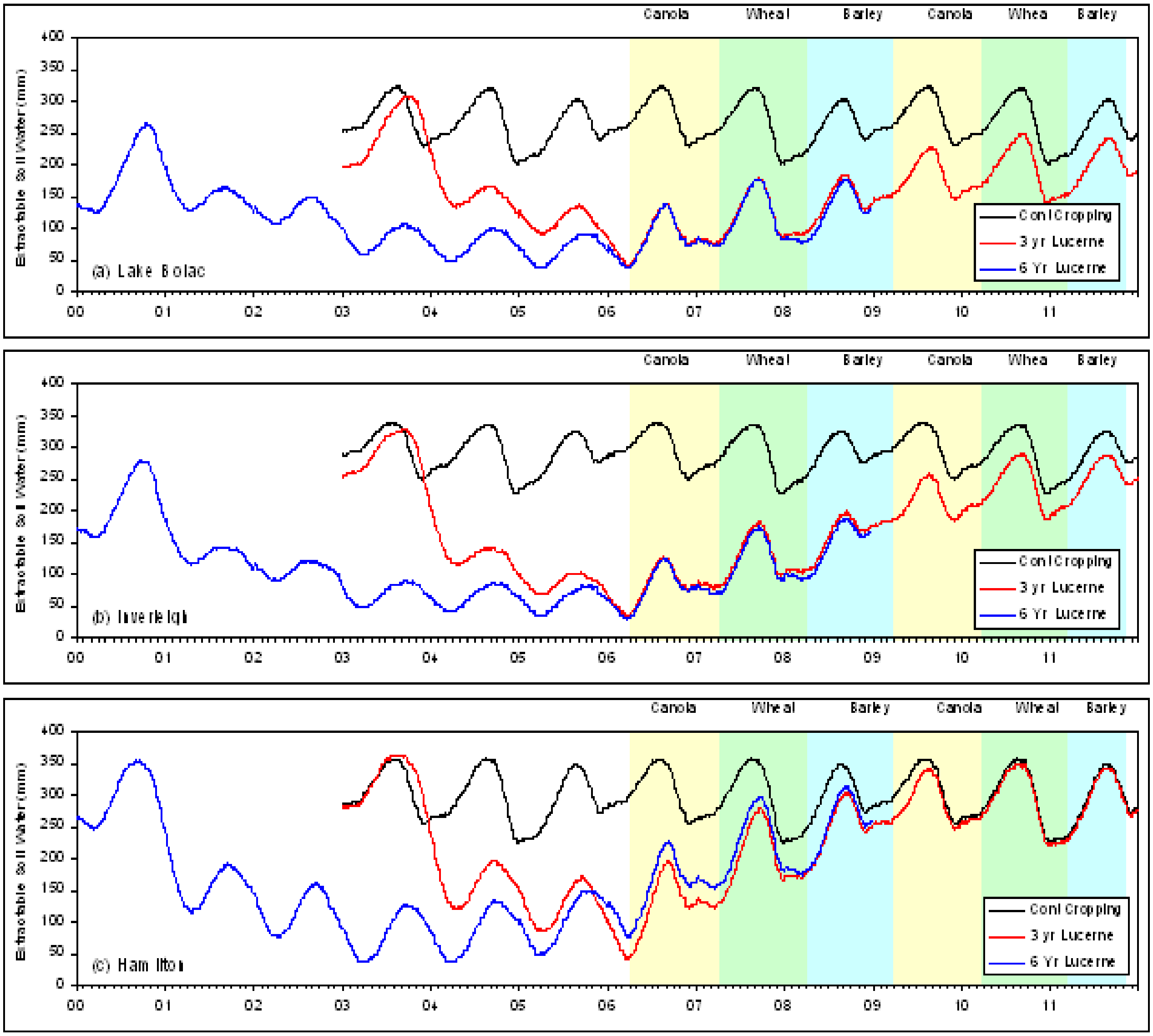

Figure 1: Simulated effect of different lengths of lucerne phase on long-term average (1971-2005) total extractable soil water over 0-2.2m. The soil water trajectories have been aligned so that the cropping years are shown together. Shaded bars show each cropping year (from the earliest sowing date on 25 April). For the continuous cropping simulations, the soil water trajectories have been repeated so that differences induced by the lucerne can be seen.

The effect of lucerne phases showed an interaction between sites and crops. For canola, the proportional reduction in mean yields was in the order Lake Bolac = Inverleigh > Hamilton. This trend – from driest to wettest location – also appeared between cropping seasons within each site. There was a strong relationship between growing-season rainfall (April-October) and the difference between canola yield after continuous cropping and canola yield in the first year after a lucerne phase (Figure 2). High growing-season rainfall counteracted the soil-drying effect of the lucerne and so reduced the yield differential.

In the second cycle of the 3-year lucerne phase system, there was a small (0.09-0.20 t/ha) reduction in the mean canola yields relative to continuous cropping. Mean yields in the second wheat and barley crops were similar to the continuously-cropped system, suggesting that the soil water differences under these crops at Inverleigh and Lake Bolac at this time in the rotation sequence were largely restricted to soil below the rooting zone of the cereals. As expected, mean annual drainage increased with site rainfall and decreased with extended duration of the lucerne phase. The further reduction in mean annual drainage when the lucerne phase was extended to 6 years was small, since drainage was more heavily dominated by wet years when large drainage events occurred.

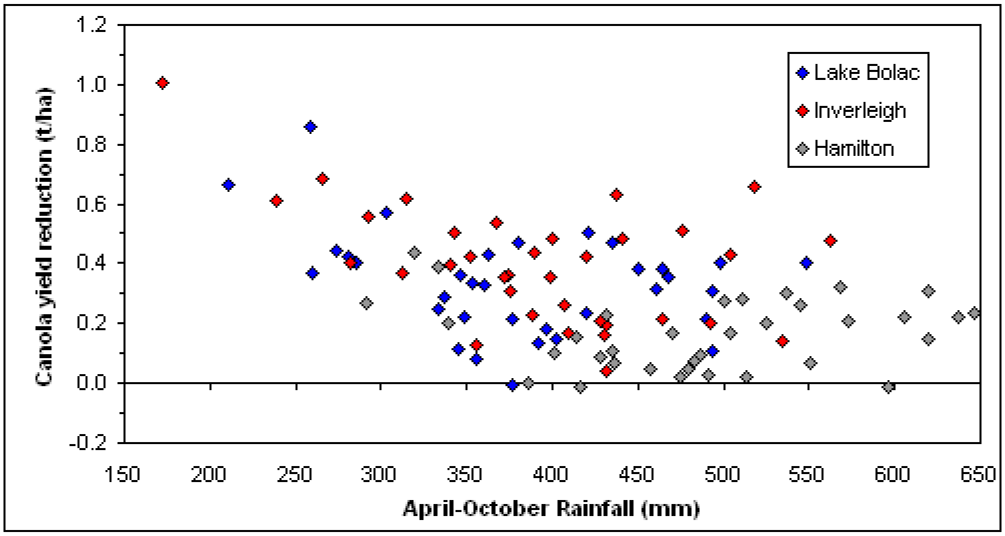

Figure 2: Relationship between growing-season rainfall and the difference in yields of canola grown under continuous cropping and immediately after a 3-year lucerne phase, for three sites in south-western Victoria. All sites lie on a common regression line.

Table 2: Mean annual drainage (mm) under crop rotation paddocks at three sites in south-western Victoria.

	Continuous Crop	3 Years Lucerne	6 Years Lucerne
Lake Bolac	18	7	4
Inverleigh	36	14	5
Hamilton	70	39	16

Conclusions

Introducing a lucerne phase into a raised-bed cropping system is likely to have a substantial impact (of order 0.2 to 1.2 t/ha/year) on following crop yields for up to three or four years, with the effect lasting longer at drier sites. This simulation analysis indicates that yield penalties from inclusion of lucerne in a cropping rotation are of a similar magnitude to those observed in lower rainfall regions of the Mallee and southern NSW (McCallum *et al.* 2001; Verburg *et al.* 2007). Extending the lucerne phase beyond three years appeared to have a small, but continuing trade-off between drainage and crop yield with a small benefit in further reduced drainage and slightly lower average crop yields. The reduction in area under crop at any given time as the length of the lucerne phase increases will also have impacts on management and profitability of the mixed farming enterprise.

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