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Grain & Graze National Feedbase Project

Effect of lucerne phases in cropping rotations in the Corangamite/Glenelg-Hopkins region

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The Corangamite/Glenelg-Hopkins regional project is exploring a number of strategies to improve productivity and NRM outcomes in mixed farming systems. One of these strategies is the introduction of lucerne into rotations on raised bed systems.

Since the introduction of raised bed technology into south-western Victoria, the beds have mainly been used for continuous cropping. Lucerne phases are now being proposed as part of raised-bed farming systems, primarily to act as a disease break.

A set of related questions arise once lucerne is introduced into the farming system, relating to its impacts on the rest of the cropping system and also to the way that it will shift the forage resources on which the livestock enterprises are based. In this report we address two specific questions:

- What effect will soil drying by lucerne have on subsequent grain yields?
- Does this effect impact the optimum length of the lucerne phase?

To address these questions, we have used a whole-farm system simulation model based on the APSIM crop and soil models and GRAZPLAN pasture and animal management models.

Methods

The approach taken to this question was similar to that used in section 5; a “base” scenario was built around representative farming practice and modified to represent lucerne phases of different lengths. Much of the effort has gone into developing a robust simulation of the base scenario, as it will be re-used to address other questions relevant to the Corangamite/Glenelg-Hopkins regional project (for example the best means to utilize lucerne, or the possibility of intercropping forage wheat in a first-year lucerne stand).

Simulations were carried out for three sites in western Victoria:

- Lake Bolac (37°43’ S, 142°51’ E, average annual rainfall 574 mm)
- Inverleigh (38°06’ S, 144°03’ E, average annual rainfall 592 mm)
- Hamilton (37°50’ S, 142°04’ E, average annual rainfall 685 mm).

A representative management scenario was developed in consultation with the Corangamite/Glenelg-Hopkins project team (Cam Nicholson, David Watson and Simon Falkiner). Crop rotations, in-crop management, livestock enterprises and animal husbandry practices that would be followed by an expert farm manager were described and then implemented (with some simplification) using the rule-based management facility of CSIRO’s AusFarm software.

Weather and soils

Weather data were obtained as Patched Point datasets from the SILO data base for stations 090167 (Winchelsea Post Office), 089016 (Lake Bolac Post Office) and 090103 (Hamilton Research Station).

Table 1: Weather data from the SILO database for Winchelsea (averages over 1971-2005)

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Precipitation (mm)	41	34	35	40	52	52	56	59	64	69	49	40	592
Mean Max Temperature (°C)	24.3	24.9	22.7	19.6	16.5	13.8	13.2	14.3	16.0	18.1	20.2	22.6	18.8
Mean Min Temperature (°C)	13.0	13.6	12.4	10.3	8.6	6.6	5.8	6.3	7.2	8.4	10.0	11.5	9.5

A single soil type was included on the simulated farm, based on soil data provided by Renick Peries (DPI Victoria) for a Eutrophic Mottled-Subnatric Brown Sodosol. This soil had a plant available water content (PAWC) of 185 mm to 1.2 m. Organic carbon was around 25 g/kg in the surface, declining to 15 g/kg in the 0.1-0.2 m layer and declining further with depth to 2 g/kg at 0.6 m. The soil was configured to exhibit restricted drainage.

Land Use and Rotations

The “base” simulation is one in which permanent pastures based on perennial ryegrass are combined with a cropping system based on phases of lucerne & wheat. A farm of 1000ha is simulated.

Permanent pastures, crops and lucerne pastures each occupy a fixed proportion of the farming area in each year. The areas allocated to permanent pastures and to the cropping rotation are given in Table 2:

Table 2: Allocation of crop and land area to different rotations for Coolamon

Rotation	Number of Paddocks	Area per Paddock (ha)	Total Area (ha)
Permanent ryegrass-based pasture	4	125.0	500
3 years lucerne/canola/wheat/barley/canola/wheat/barley	9	55.5	500
Total	13		1000

Crop & Pasture Management

Raised beds. The cropping paddocks were all assumed to be configured as raised beds of width 1.7m and height 0.2m, with furrows of width 0.5m between the beds. Water above the drained upper limit in the uppermost 0.2m 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.

The simulation models were used to simulate growth and yield within the raised beds, and paddock-scale crop yields were then computed by assuming (arbitrarily) that yield in the furrows was 50% of that on the beds.

Crop sowing rules. Crops were sown from 1 May to 14 June on a rainfall of at least 15mm over 5 days, or dry sown on 15 June if no sowing opportunity occurs. For canola, cv Thunder (mid-season, triazine-tolerant) was sown. For wheat, cv Mackellar was used unless the crop was dry-sown, in which case cv Silverstar was used. For barley, cv Gairdner was sown.

Cultivation. The crop rotation paddocks were cultivated (and raised beds formed) prior to each canola crop, i.e. twice per rotation cycle. This operation was carried out on 30 April to ensure that it was complete before the earliest possible sowing.

Fertilizer management. Nitrogen was applied as urea. In the base system, the following amounts of N fertilizer were applied at sowing (or at the start of the growing season for second- and third-year lucerne crops): lucerne and canola 25 kg N/ha, wheat and barley 20 kg N/ha. Only the second round of crops, i.e. years 7-9 of the above rotation, was topdressed in the base system. A fixed rate of 50 kg N/ha was applied. Nitrogen was assumed to be applied to the beds only, and these rates are expressed per unit bed area.

Stubble management. The simulations assumed that stubbles were grazed over summer (see the grazing management schedule below). Stubbles were burnt after each wheat crop. Summer weeds in stubbles were not controlled, except after the final year of lucerne (i.e. prior to the first canola crop) when they were controlled as part of killing the lucerne stand (see below).

Lucerne. Lucerne was sown at the autumn break using the same rule as for crops, except that the sowing period began on 1 April. 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. Permanent pastures were simulated as mixtures of perennial ryegrass, phalaris and subterranean clover. (It was assumed that annual grasses were controlled to negligible levels). A moderate level of phosphorus fertility (Olsen P of 12-15) was assumed. Pastures were oversown whenever a constituent species fell to negligible levels.

Animal Management

The simulations use a first-cross ewe breeding enterprise, with 4.5 breeding ewes per pasture hectare at Winchelsea, 5.0 breeding ewes per pasture hectare at Lake Bolac and 6.0 breeding ewes per pasture hectare at Hamilton. A further cohort of replacement (non-breeding) ewes was also held on the simulated farm. A constant stocking rate was maintained from year to year and fluctuations in forage supply were managed through supplementary feeding.

Genotypes and reproductive management. The ewe enterprise was based on Border Leicester x Merino cross ewes (breed standard reference weight = 60kg) producing second-cross lambs. The ewes were mated to Dorset rams (breed standard reference weight = 65kg). Joining commenced on 8 February and weaning occurred when the oldest lambs were 12 weeks of age (~8 October). A cohort of replacement ewes was purchased each year in January at 6 months of age and joined the breeding flock at 18 months of age.

Ewes were scanned 12 weeks after the start of joining; empty ewes were culled at scanning. Ewes were also be cast for age at 6½ years.

Lamb sales. Lambs were sold according to the following schedule:

- The heaviest 10% of lambs (batch 1) were sold at weaning.
- The next heaviest 15% of lambs (batch 2) were identified at weaning and sold when they reached a carcass weight of 20 kg.
- Once the lambs in batch 2 were sold, the next heaviest 50% (batch 3) were placed on lucerne and targeted for sale at 20 kg carcass weight. These lambs were be supplemented with grain if required to reach the target weight by 28 February.
- The remainder of the lambs (batch 4, 25% of the initial flock) were grazed on permanent pastures until 28 February, and supplemented if necessary to achieve growth rates of 80 g/d. On 1 March, these animals were allocated the best available pastures (including lucerne if available) and sold when they reached 20 kg carcass weight. If necessary, they were supplemented to achieve growth rates of 80 g/d from 1 March until 15 April, and then fed to reach their target weight by 15 May.

Shearing was on 1 December. Weaners were shorn.

Grazing management. Tactical grazing was used. Livestock were moved around the pasture paddocks at regular intervals (14 days during winter, 7 days at other times).

At each movement date, the best feed was assigned to livestock in an order of priority. The priority of different classes of livestock changed over the course of the year, as follows:

Table 3: Grazing management: priorities accorded to each livestock class over the course of the year

Start of period	Priority order
1 March	Batch 4 lambs (if any), breeding ewes, replacement ewes
One month prior to start of lambing	Twin-bearing ewes, single-bearing ewes, replacement ewes
Weaning	Batch 2 lambs, batch 3 & 4 lambs, replacement ewes, dry ewes
Sale of batch 2 lambs	Batch 3 lambs (if any), replacement ewes, dry ewes, batch 4 lambs

Once the first crops were harvested each year, replacement ewes were moved to a cereal stubble paddock to graze it. Four weeks after the first crop harvest, the breeding ewe flock was also moved to the current stubble paddock. All stock grazing stubbles occupied a single paddock. Animals were moved from one stubble paddock to the next when the replacement ewes ceased to gain weight. Stubble grazing ended once all cereal stubble paddocks had been grazed, or on 1 April. Note that canola stubbles were not grazed.

From weaning until the sale of the last lambs, lucerne paddocks were available to the heaviest batch of lambs still in the system. The lucerne paddocks were then closed until one month prior to the start of lambing, when they were made available to the ewes until weaning.

Supplementary feeding. Breeding ewes and replacements were fed lucerne hay (where available) and wheat grain to maintain their body condition above a score of 3 at all times. Weaners were fed to maintain the live weight gain schedules set out in the section on lamb sales.

Supplementary feeding was carried out in the paddocks, i.e. feedlotting was not used.

Simulation treatments to examine the effect of lucerne phases on crop yields

At each of the three locations (Winchelsea, Lake Bolac and Hamilton), three simulations were run, each with a different length of lucerne phase (0, 3 or 6 years; Table 4).

Table 4: Modifications to farm management rules to assess the impact of lucerne phase length on crop yields.

Phase Length	Description	Rule used in base simulation
Continuous cropping	No lucerne sown; all rotation paddocks cropped with a canola/wheat/barley sequence	
3 years of lucerne	Rotation paddocks managed according to the 3 year lucerne/canola/wheat/barley/canola/wheat/barley sequence described above	✓
6 years of lucerne	Rotation paddocks managed according to a 6 year lucerne/canola/wheat/barley sequence	

Because the focus of the investigation was on the effect of lucerne on the water balance, all crops were fertilized at higher rates than in the base scenario so as 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.

Each simulation was run from 1971 to 2005; only the 30 years from 1976 to 2005 were included in the analysis of results, in order to prevent the initial conditions from affecting the outcomes.

Results

Figure 1 shows a small part of the results of one of the simulations (the 3-year lucerne phase at Winchelsea.)

Despite the substantial rainfall differences between sites, the canola yields under continuous cropping were similar at about 2.5 tonnes/ha (Table 5). Wheat yields were lower at Lake Bolac than at the other two sites, while barley yields were higher.

Figure 1: Time courses from 1971-2005 of a small subset of the state variables simulated for a mixed farming system at Winchelsea.
(a) Shoot dry matter (kg/ha) in one of four permanent pasture paddocks.
(b) Shoot dry matter (kg/ha) in one of nine paddocks in a lucerne- lucerne- lucerne-wheat-canola-barley-wheat-canola-barley rotation.
(c) Total potentially-extractable soil water (in the 0-2200 mm soil horizon) for the crop rotation paddock shown in panel (b).

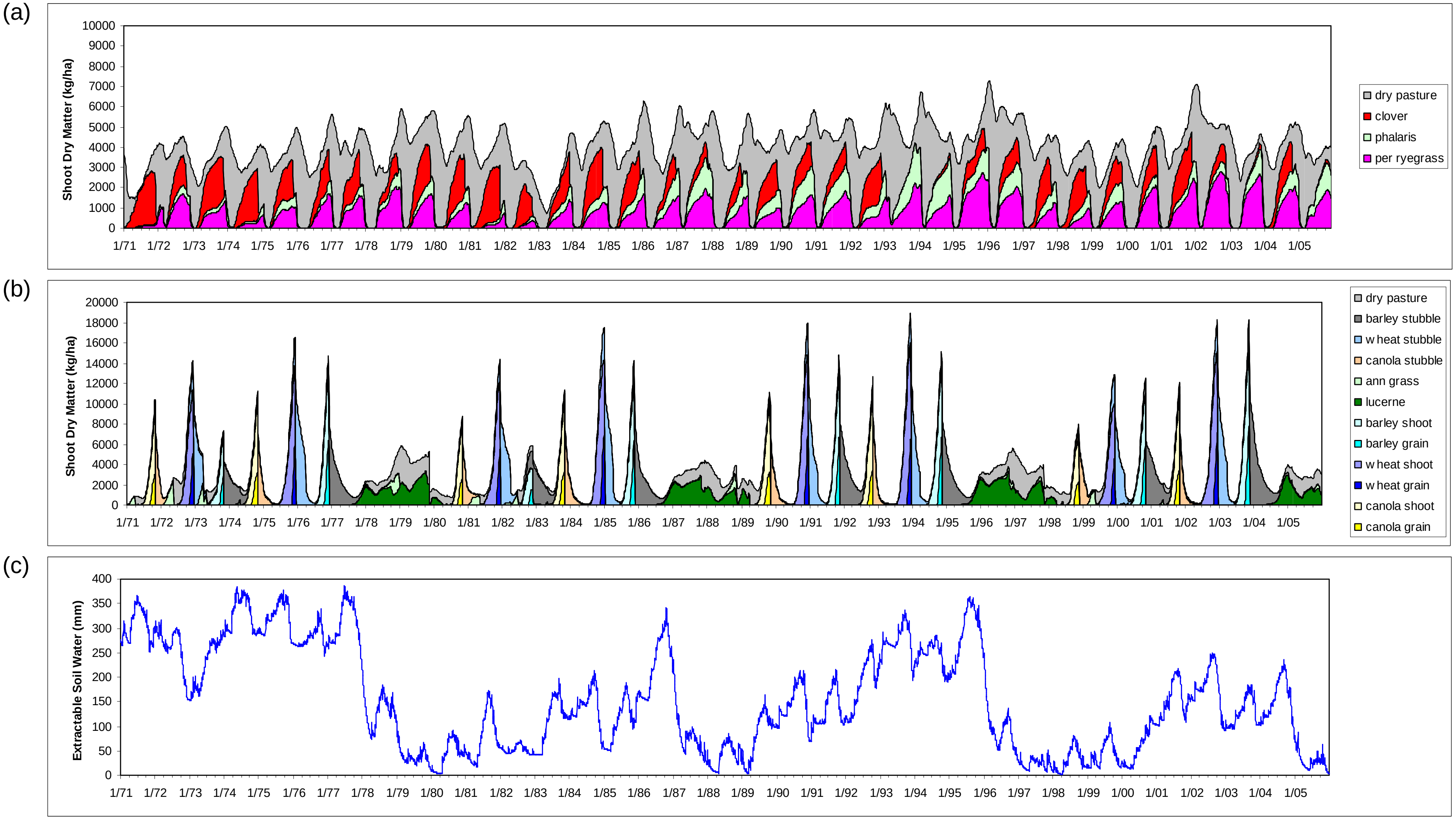
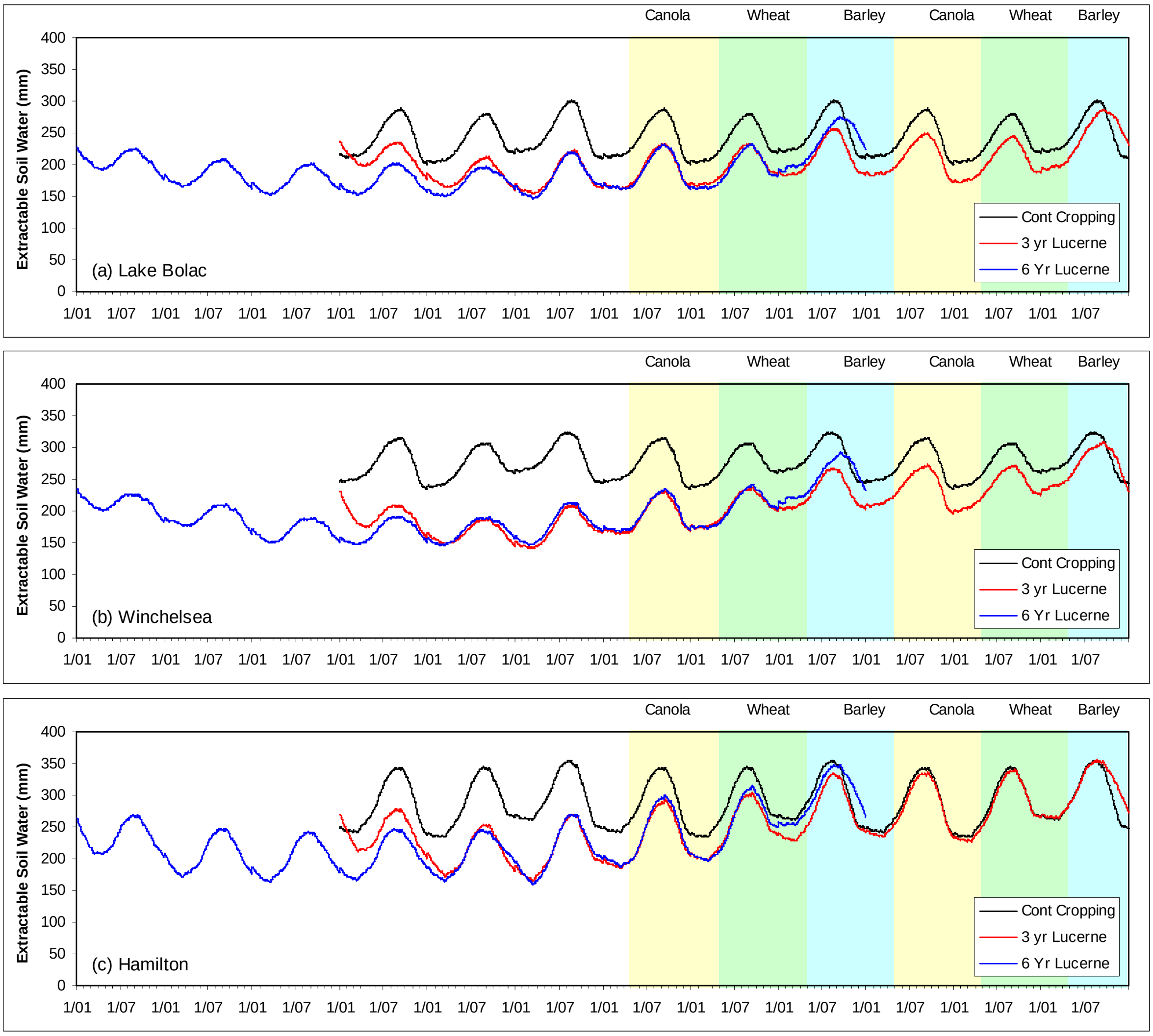


Figure 2: Simulated effect of different lengths of lucerne phase on long-term average (1976-2005) total extractable soil water over 0-2200mm. The soil water trajectories have been aligned so that the cropping years are shown together. Shaded bars show each cropping year (from the earliest sowing date on 1 May). For the continuous cropping simulations, the soil water trajectories have been repeated so that differences induced by the lucerne can be seen.



As expected, inclusion of lucerne phases in the rotations drew down soil water, resulting in drier profiles at the commencement of the cropping phase. At Lake Bolac, the 3-year lucerne system had an average of 42 mm less water than the continuous cropping system on 1 May of the first cropping year; at Winchelsea the corresponding water difference was 74 mm and at Hamilton it was 43mm. 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 2-2.5 years.

At Winchelsea and Lake Bolac, differences in total soil water persisted until the sixth crop. At Hamilton, which was the highest-rainfall location, the differences in total soil water lasted for less than 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.

Table 5: Impact of different lengths of lucerne phase on subsequent crop yields 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	2.51	2.03	2.34	2.07
	Wheat	3.36	2.81	3.19	2.75
	Barley	4.72	4.05	4.63	3.93
Winchelsea	Canola	2.45	2.10	2.30	2.07
	Wheat	3.98	3.56	4.03	3.49
	Barley	4.05	3.39	4.12	3.08
Hamilton	Canola	2.59	2.37	2.48	2.27
	Wheat	4.19	3.55	4.19	3.59
	Barley	4.76	3.92	4.77	3.81

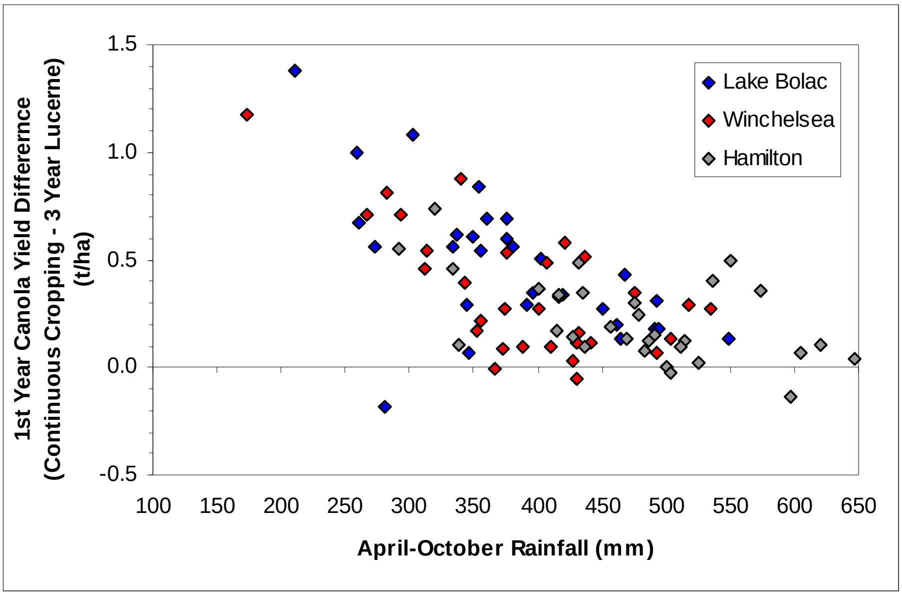


Figure 3: Relationship between growing-season rainfall and the difference in yields of canola grown under continuous cropping and immediately after a 3-year lucerne phase, for three sites in south-western Victoria. All site lie on a common regression line.

Crop yields immediately following a lucerne phase were substantially lower than in a continuously-cropped system. Averaged over the three locations, the yields of the first canola, wheat and barley crops were reduced by 0.35 t/ha (14%), 0.54 t/ha (14%) and 0.72 t/ha (16%) respectively. The yields of the first barley crops were reduced to a somewhat greater extent than those of canola or wheat, even though the total profile soil water values were generally less different at this stage of the rotation (the third crop after lucerne).

The effect of lucerne phases showed an interaction between sites and crops. For canola, the proportional reduction in yields was in the order Lake Bolac > Winchelsea > 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 3). High growing-season rainfall counteracted the soil-drying effect of the lucerne and so reduced the yield differential. A corresponding relationship with sowing date could not be found, however.

Reductions in barley yield due to lucerne followed an opposite trend across the locations: the proportional reduction in barley yield was smaller at Lake Bolac than at the other two sites.

Differences between crop yields following 3 years or 6 years of lucerne were minor, consistent with the lack of differences in soil water between these scenarios (Table 5; Figure 4).

Figure 4: Simulated frequency distributions of crop yields under different lengths of lucerne phase at three locations in south-western Victoria. All yields are given on a paddock-area basis (i.e. averaged across raised beds and furrows).

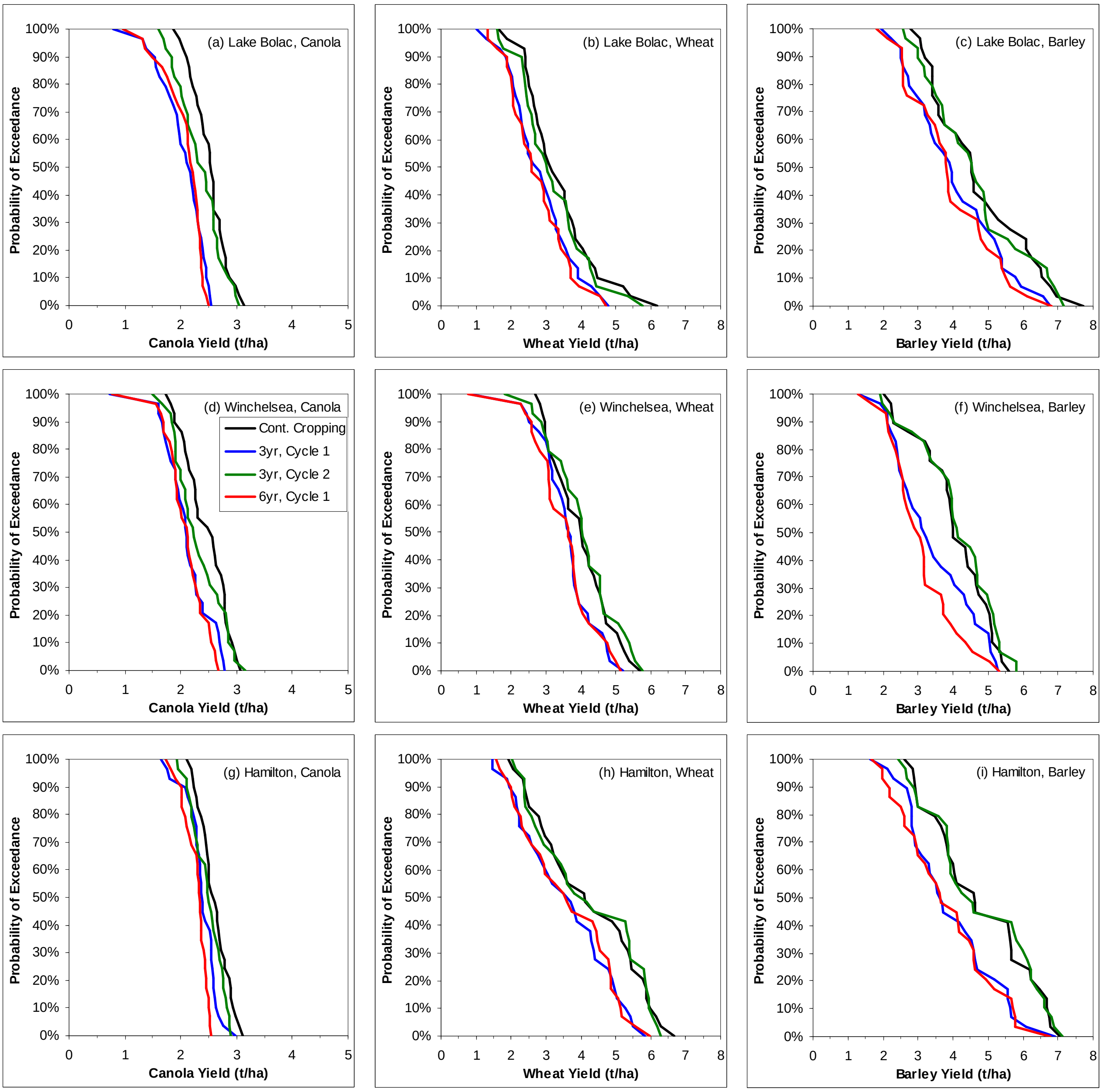
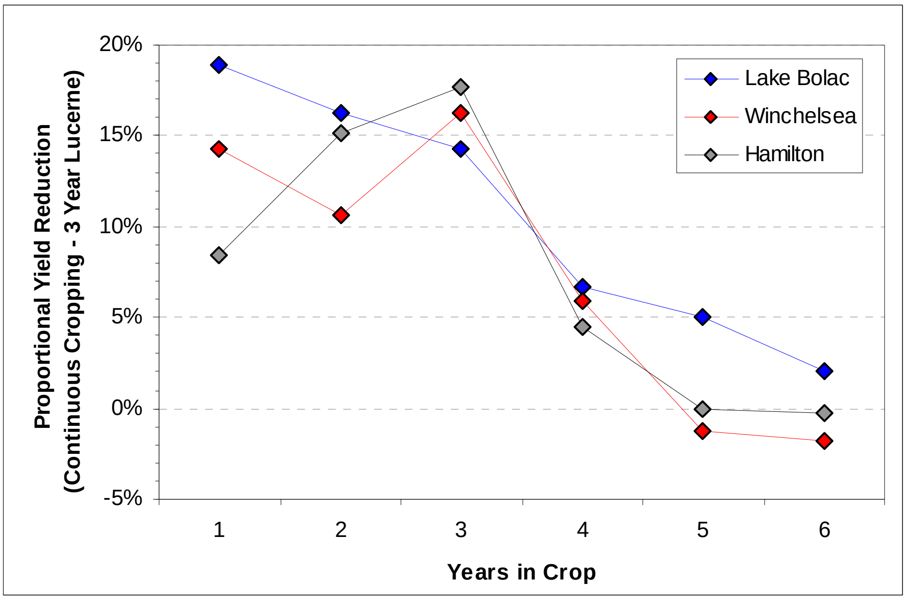


Figure 5: Simulated long-term average proportional reductions in crop yields (relative to continuous cropping) after a 3-year lucerne phase, at three locations in south-western Victoria.



In the second cycle of the 3-year lucerne phase system, there was a small (0.08-0.15 t/ha) reduction in the canola yields relative to continuous cropping. Apart from wheat at Lake Bolac, the mean and distribution of yields in the second wheat and barley crops were very similar to the continuously-cropped system (Figures 4 & 5), suggesting that the soil water differences under these crops at Winchelsea and Lake Bolac at this time in the rotation sequence were largely restricted to soil below the rooting zone of the cereals.

Conclusions

Introducing a lucerne phase into a raised-bed cropping system is likely to have a substantial impact (of order 0.5 t/ha//year) on following crop yields for up to three or four years, with the effect lasting longer at drier sites. Barley crops in the third year appear to be particularly vulnerable, perhaps because they were simulated as reaching maturity earlier than the wheat crops and so were less able to access deep water.

Extending the lucerne phase beyond three years will have little additional effect on following crop yields (although it will, of course, reduce the area under crop at any given time).

Simulated lucerne production in the first winter and spring of the lucerne phase tended to be low but lucerne growth continued into the following summer (Figure 1(b)). This suggests that the Cornagamite/Glenelg-Hopkins regional team are likely to be correct in their hypothesis that overall forage yields can be boosted by intercropping the lucerne with a forage cereal. (This point will be the subject of further analysis during 2007-08.)