Grain & Graze National Feedbase Project

Production vs ground cover tradeoffs in the Murrumbidgee region

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If farm systems are managed to conform to ground cover targets, what productivity constraints result? How feasible are particular ground cover targets (expressed at paddock or property scales), and what are the tradeoffs with production? To address this question in the Murrumbidgee region, we have used the AusFarm simulation software to link various APSIM crop and soil models and GRAZPLAN pasture and animal management models together.

Methods

The approach taken to this question was to start from a “base” scenario built around representative farming practice, and then to modify the simulated management system in various ways that affect the ground cover/productivity tradeoff. 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 Murrumbidgee regional project. There were two main components to this part of the work:

- Linking of crop, soil, pasture and animal management models to function as a mixed-farming-systems model.
- Specifying “representative farming practice” so that it can be built into a simulation using the model. We focussed on Coolamon, the most central of the five focus farms in the Murrumbidgee regional project. The representative farm included two soil types, based on local soil data. The Dryland Farming Systems Survey carried out by the Murrumbidgee CMA was used, in conjunction with ABARE data and colleagues’ expertise, to draft a management system (crop rotations, in-crop management, livestock enterprises and animal husbandry) considered representative of the Coolamon area.

Weather and soils

Weather data were obtained as a Patched Point dataset from the SILO data base.

Table 1: Weather data from the SILO database, 074033 (Coolamon Post Office)

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Precipitation (mm)	40	35	35	36	45	40	45	45	43	51	41	38	494
Mean Max Temperature (°C)	31.6	30.9	27.7	22.7	17.5	14.0	13.0	14.8	17.9	21.8	25.9	29.7	22.3
Mean Min Temperature (°C)	16.4	16.5	13.6	9.6	6.2	3.9	2.9	3.7	5.5	8.3	11.2	14.3	9.3

Two soil types were included on the simulated farm, based on soil data from the region. Soil 1 (the better soil) had a plant available water content (PAWC) of 159 mm to 1.2 m, while Soil 2 (the poorer soil) had a PAWC of 117 mm to 1.2 m. For both soils, soil pH was around 5.3 in the surface and increased to 7.0 or greater below 1 m. Organic carbon was around 14 g/kg in the surface, declining to 7 g/kg in the 0.1-0.2 m layer and declining further with depth to 1.3 g/kg below 1 m.

Land Use and Rotations

The CMA survey provided local (postcode) scale information about the proportions of the cropping area under different crops, and the proportions of the pasture area under different pastures. The CMA survey did not give the ratio of cropping area to pasture area; this ratio was set at 2:3, based on ABARE data for the region. From this information we estimated the proportions of the broadacre farming area under different crops and pastures for Coolamon (Table 2). For our simulations, we included native/unimproved pasture with annual pasture, and pulses with oilseeds. Five crop and pasture types were therefore included in the simulations: annual pasture, permanent perennial-based pasture, lucerne pasture, cereals (wheat) and oilseeds (canola). Long fallow was omitted from the representative farming system (53% of survey respondents never use it).

Table 2: Proportions of farming area under different crops and pastures for Coolamon, based on a 2:3 ratio of crop to pasture area

Annual Pastures	Perennial Pastures	Native Pastures	Other Pastures	Cereals	Oilseeds	Pulses	Other Crops
33%	20%	5%	2%	27%	7%	5%	0%

In our simulation we allocated these crops and pastures into four rotations, each of which occupied a fixed proportion of the farm area. The areas allocated to each rotation in Table 3 were calculated to give areas of the five crop and pasture types that are consistent with Table 2. The permanent pastures were placed on soil 2 (the poorest) and the lucerne-cropping rotation on soil 1 (the best). Annual pasture-cropping paddocks are spread equally across both soil types.

Table 3: Allocation of crop and land area to different rotations for Coolamon

Rotation	Number of Paddocks	Area per Paddock (ha)	Total Area (ha)
3 years annual pasture/wheat/canola/wheat	6	90	540
3 years lucerne pasture/wheat/canola/wheat	6	40	240
Permanent perennial-grass based pasture	1	70	70
Permanent annual pasture	3	50	150
Total	16		1000

Crop & Pasture Management

Sowing rules. Spring wheat(cv Janz) was sown from 1 May to 15 June on a rainfall of totalling at least 15 mm over 5 days, or dry-sown on 15 June otherwise. Canola (cv Oscar) was sown from 20 April to 15 May on a rainfall of at least 15 mm over 5 days, or dry-sown on 15 May otherwise.

Cultivation. A majority of survey respondents stated that they do not cultivate, or only cultivate under "special circumstances"; however 70% of respondents cultivate a paddock that is changing from pasture into crop. The simulation analysis assumed no cultivation.

Fertilizer management. For wheat, 20 kg/ha N was applied at sowing. In mid-August, potential yield was estimated and the crop was topdressed according to the rule:

N applied (kg/ha) = 0.040 x yield potential (kg/ha) – (soil N test (0-0.6m) on 1 Apr) – (sowing N) – 70

(The 70 kg N/ha allows for in-season mineralization.) Total N application was capped at 50 kg/ha. For canola, 25 kg/ha was applied at sowing and a coefficient of 0.052 kg/kg was used in the topdressing rule. (~25% greater than wheat) and total N application was capped at 100 kgN/ha.

Stubble management. 69% of survey respondents graze their stubbles, 50% burn and 39% spray them to control weeds. The simulations allowed stubbles to be grazed over summer (either for 42 days or down to 1 t/ha, whichever occured sooner). Wheat stubble of the 1st wheat crop was burnt at the end of March in preparation for sowing of canola.

Lucerne. Respondents to CMA survey split their lucerne sowing times almost equally between autumn, winter and spring. In the simulations, lucerne was sown at the autumn break using the same rule as for crops. Volunteer annual grasses and clovers were simulated in the lucerne stands, but were controlled with herbicide during an establishment period in the first year of the lucerne phase (until 15 August) to ensure a lucerne-dominant stand.

Pasture removal. Lucerne and annual pastures in the pasture/crop rotation paddocks were removed in the spring prior to sowing of the wheat crop. The annual pasture was removed by a single herbicide application producing a 100% kill on 30 September. The lucerne stand was removed by two spray events, reflecting the difficulty of lucerne removal. An initial herbicide application on 30 September resulted in an 80% kill, and a second on 30 October killed the stand completely.

Weed management. All weeds were controlled in the crop establishment phase (from 1 April until 15 August for all crops and for 1st year lucerne). Weeds germinating in the summer fallow (between crop harvest or pasture removal and crop sowing) were also removed by herbicide when they reached 100kg/ha biomass. This is in keeping with regional fallow management practices, allowing a period of soil water accumulation and nitrogen mineralisation.

Animal Management

The CMA survey gives livestock numbers as an average over the whole CMA region. A rough calculation from these data in the survey gives an average of 5.4 dry sheep equivalents per farm hectare (i.e. 9 DSE per pasture hectare). About 45% of these DSEs are from ewe enterprises, 45% from beef cattle enterprises and 10% from wethers.

The simulation analysis represented a sheep enterprise (ewes and wethers) grazing the pastures and stubbles. The “base” simulation maintains a constant stocking rate from year to year and handles fluctuation in forage supply through supplementary feeding.

Genotypes and reproductive management. The sheep enterprise was based on medium-framed Merino ewes producing a mixture of Merino and first-cross lambs, with 20% of dry sheep equivalents devoted to a wether enterprise. The number of ewes mated to Merino rams was computed to ensure that sufficient replacement ewes and wethers would be available.

Joining commenced on 1 February and lasted for 30 days, so that lambs were born through July and August. Weaning was on 1 October, when the oldest lambs were about 12 weeks of age. Lambs were sold opportunistically depending on the availability of lucerne over the summer, as follows: on 15 December, the amount of lucerne on the simulated property was assessed and one lamb retained for every 40 kg of lucerne dry matter. Any excess lambs were sold. Retained lambs were grazed on the lucerne until the amount of lucerne on the property fell below 10 kg/lamb, or until 30 April

Grazing management. Over 90% of survey respondents graze their stock rotationally or use a combination of set-stocking and rotational grazing. In the simulations, livestock were moved around the pasture paddocks regularly (every 25 days), with the best feed being assigned in the following priority order: weaners, lactating ewes, ewes in late pregnancy, other ewes, wethers. Stubbles were grazed with sheep.

Supplementary feeding. Stock were fed grain to maintain their body condition above class-specific thresholds. Maintenance feeding was carried out in the paddocks, i.e. feedlotting is not be used.

Calculation of land cover

Cover has been estimated from light interception of various components of the vegetation. Cover (light interception) is estimated from a relationship between biomass and light interception using unique parameters for each species and for standing green biomass, standing dead biomass and litter components. Total cover is calculated daily for each paddock by aggregating the contribution of each species (including each of its components). Standing green biomass, standing dead biomass and litter components of the vegetation do not contribute equally to risk of erosion, and their contribution will depend on type of erosion (wind or water). For example, while litter lies flat on the surface, standing biomass is anchored in the soil and provides additional protection from soil erosion. These differences in ability of the various vegetation components to protect the land resource are not accounted for in our representation of cover. Further work is planned to develop an assessment of cover more relevant to erosion risk.

Simulation treatments to assess impact of farm management on land cover

Impact of modification of farm management practices was assessed by making the changes listed in Table 4 to the base simulation. The simulation was run from 1971 to 2005 for each treatment and impact of farm management was analysed.

Table 4: Modifications to farm management rules to assess impact on farm cover.

Practice	Level	Rule used in base simulation
Stubble burning	No burning	
	Stubble of 1st wheat crop in cropping phase burnt	✓
Stocking rate	4.5 DSE/ha	
	5.4 DSE/ha	✓
	6.5 DSE/ha	
Close any paddock to grazing when its cover falls below a threshold of:	0% (never)	✓
	50%	
	70%	
	90%	
Shift stock to a "sacrifice paddock" when whole-farm cover falls below a threshold of:	0% (never)	✓
	50%	
	70%	
	90%	

Results

Figure 1 shows a small part of the results of the simulation of the base scenario.

Mean wheat and canola yields were 4.3 and 2.4 t/ha respectively in the base scenario (Table 5). Refraining from stubble burning increased mean annual cover slightly (Figure 1a) and also increased storage of soil water, increasing yield of the subsequent canola crop slightly. All other cover management practices simulated had negligible impact on crop yield. In the base scenario, mean annual clean fleece weight (CFW) was 15.4 kg/ha, and lamb live weight (LW) sold was 57 kg/ha. Stubble burning had no impact on these figures, while altering stocking rate by 1 DSE altered CFW by about 3 kg/ha and lamb LW sold by 7 kg/ha. As expected, supplementary feed requirements increased with increasing stocking rate. Closing paddocks below a cover threshold of 70 or 50% or destocking when mean farm cover was below 50 or 70% had little impact on livestock production. However, closing paddocks with less than 90% cover increased requirements for supplementary feeding of stock, and shifting stock to a sacrifice paddock when whole farm cover fell below 90% reduced lamb productivity and increased supplementary feed requirement of stock by 80 kg/ha.

Figure 1: Time courses from 1971-2005 of a small subset of the state variables simulated for a representative mixed farming system at Coolamon.

(a) Shoot dry matter (kg/ha) in one of three annual pasture paddocks.

(b) Shoot dry matter (kg/ha) in one of six paddocks in a lucerne-wheat-canola-wheat rotation.

(c) Numbers in different classes of sheep.

(d) Average live weight of the breeding ewe flock.

(e & f) Total potentially-extractable soil water in the (0-2400mm soil horizon) for four of the sixteen paddocks (perennial pasture, annual pasture, annual pasture-wheat-canola-wheat rotation and lucerne-wheat-canola-wheat rotation).

(a)

(b)

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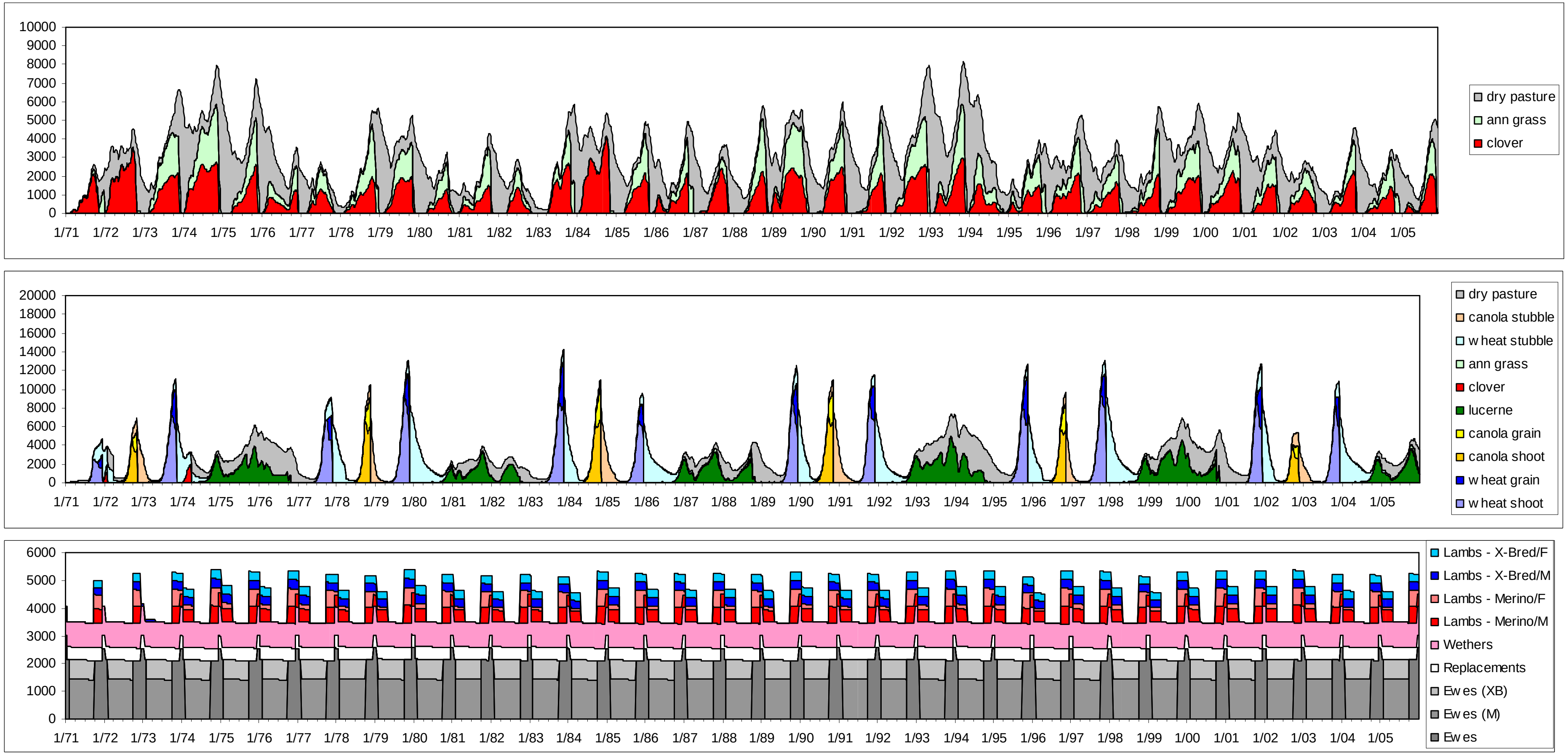

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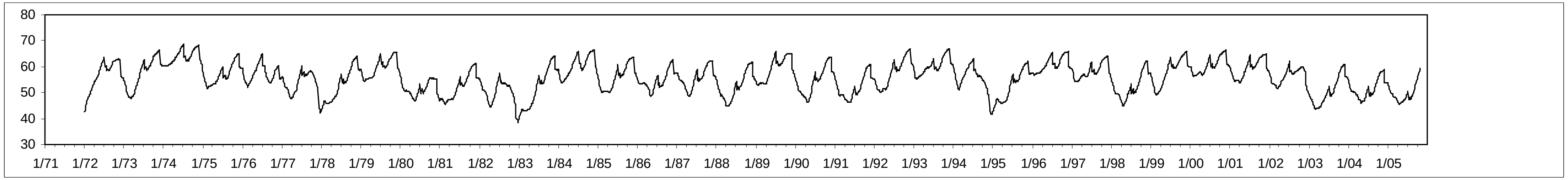
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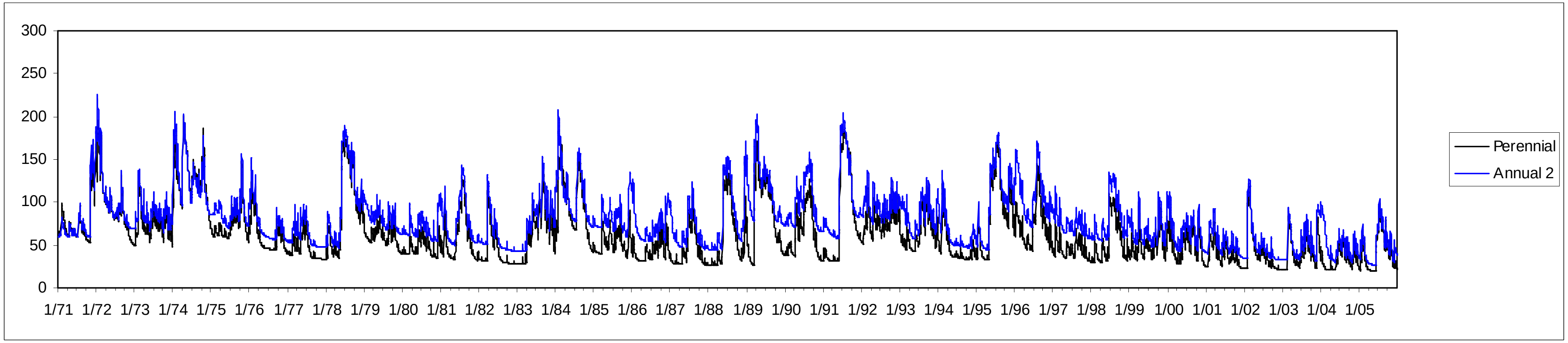
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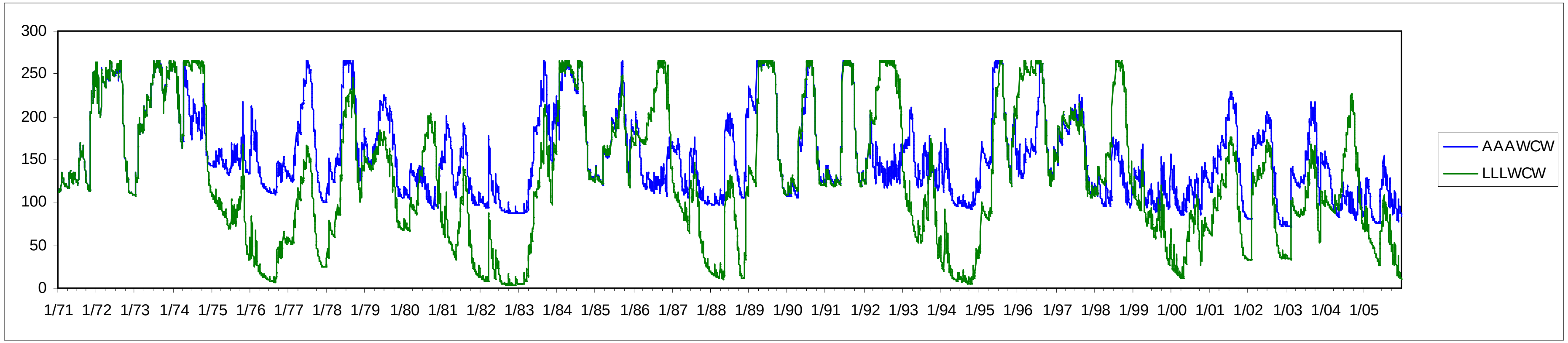
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Table 5: Impact of modifications to farm management rules on crop yields, animal productivity and supplement fed, proportion of time when paddock cover was less than a given threshold, mean farm cover and difference in gross margin from the base simulation.

Management option	Wheat yield	Canola yield	CFW kg/ha	Lamb LW sold	Supple-ment fed	Area-weighted proportion of days when cover is below			Mean farm cover	Gross margin difference
	t/ha	t/ha			kg/ha	50%	70%	90%		$/ha
Base	4.3	2.4	15.4	57	35	0.05	0.14	0.37	0.88	
No burning	4.3	2.5	15.4	57	32	0.03	0.10	0.34	0.90	7
SR=4.5 DSE/ha	4.3	2.4	13.0	50	17	0.04	0.11	0.32	0.90	-27
SR=6.5 DSE/ha	4.2	2.4	18.3	63	63	0.07	0.18	0.43	0.85	28
Paddock cover=50%	4.3	2.4	15.4	56	34	0.05	0.14	0.37	0.88	-1
Paddock cover=70%	4.3	2.4	15.4	56	31	0.05	0.14	0.38	0.87	-1
Paddock cover=90%	4.3	2.4	15.2	55	54	0.05	0.14	0.37	0.88	-10
Farm cover=50%	4.3	2.4	15.4	56	35	0.05	0.14	0.37	0.87	-1
Farm cover=70%	4.3	2.4	15.5	56	40	0.05	0.14	0.37	0.88	0
Farm cover=90%	4.3	2.4	15.0	46	120	0.04	0.12	0.34	0.89	-37

Figure 2: Mean farm cover of the base simulation over a 35 year period.

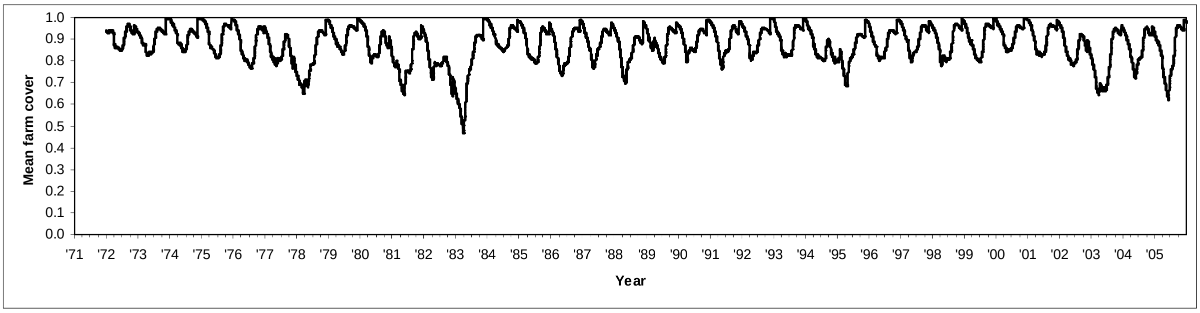

Figure 2 shows that the average cover estimated at the farm scale follows an annual cycle, with the mean farm cover falling from late summer through autumn, as stubbles and pasture become scarce and cropping paddocks are kept fallow in preparation for sowing of the subsequent crop. The long-term mean of farm cover in the base simulation over the 35 year period was 88%. More severe reductions in cover levels were observed in the summer/autumn period following the drought years of 1982, 2002 and 2004.

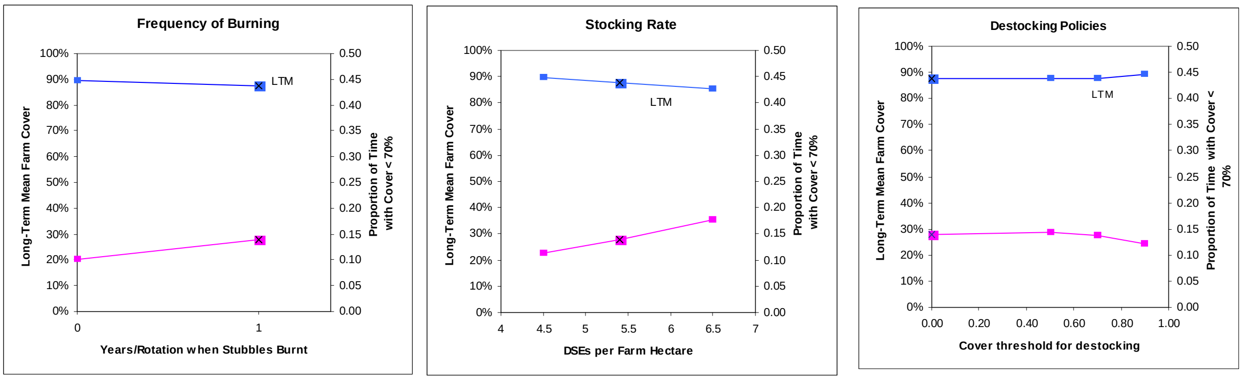

Figure 3: Impact of modifications to farm management rules on long-term mean farm cover, and proportion of time when mean farm cover was less than 70%.

Data presented in Figure 3 show that changes in farm management had little impact on overall mean farm cover across 35 years. Changing stocking rate from 4.5 to 6.5 DSE decreased mean farm cover by 5%, while other management strategies had much less impact. Proportion of time when cover was below a threshold of 70% was altered by management change, but the mean impact over the long-term was small. Careful analysis of individual years indicates that in any year environmental conditions dominate farm cover. In drought years, environmental conditions were so severe that cover was reduced under any management policy, although the proportion of time cover was < 50% was less when stock were moved when whole farm cover fell below 70%. It appears that seasonal variation in cover level and year to year variation in cover level dominate the management effect in this simulation analysis. In this simulation analysis, modification of stock movement rules probably cause little change in allocation of stock to particular paddocks, since in the base simulation stock are moved every 25 days to paddocks with the best feed supply (somewhat equivalent to moving stock out of paddocks with poor cover). In addition movement of stock to a "sacrifice" paddock severely depletes cover in that particular paddock and continues to impact on whole farm cover. The option of removing stock from the property was not considered in this anlaysis.

To measure the tradeoff between farm productivity and farm cover we conducted a partial budgeting analysis comparing the imposed cover management strategies. Commodity prices were set using April 2007 values (wheat $224/tonne; canola $480/tonne; N fertiliser $0.72/kg N; lamb $1.60/kg LW, wool $9.40/kg clean fleece), and long-term average differences in gross margins (GM) between the base scenario and the alternative management options were computed. The largest impact on gross margin occurred when stocking rate was changed by 1DSE. Increasing stocking rate increased GM by $28/ha at the environmental risk of an average 4% more days when paddock cover was below the 70% threshold. Reducing stocking rate by 1 DSE had the direct opposite effect with a reduction in GM of $27/ha, but 3% fewer days when paddock cover was below 70%.

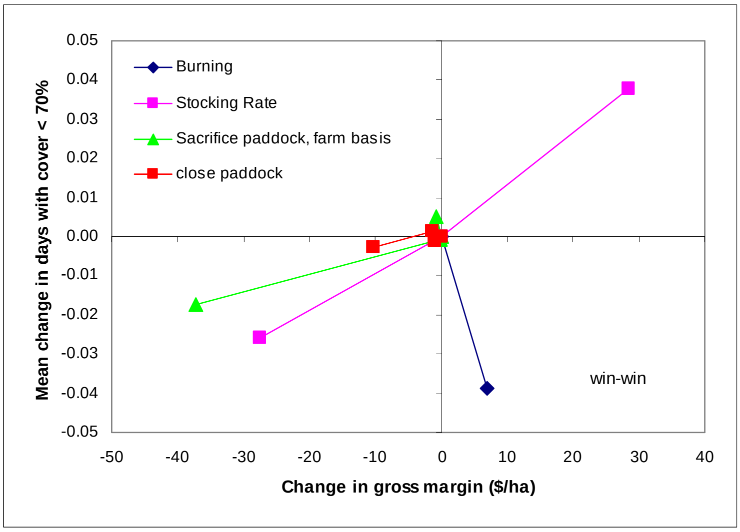

Figure 4: Simulated impact of modifications to farm management rules on gross margin and the mean number of days per year when mean farm cover was less than 70% relative to the base simulation.

Closing paddocks at a threshold of 50, 70 or 90% cover had little impact on GM or time below the cover threshold, while moving stock based on a whole farm cover rule only changed from the base simulation when the threshold was 90%. Shifting stock when whole farm cover fell to 90% increased the days above the 70% cover target by 2% per year, but decreased mean GM by $37/ha.

In this simulation analysis, omitting stubble burning following the 1st wheat crop was estimated to decrease the proportion of paddocks cover below the 70% threshold by 4% per year, and increase gross margin by $7/ha. This is an apparent “win-win” result, reducing environmental risk and increasing farm profitability. However, the increased difficulty of sowing and establishing the subsequent canola crop into a large stubble load was not accounted for in our analysis.

Conclusion

In this simulation analysis, changing stocking rate had the largest impact on mean farm cover and the proportion of time land was below the 70% cover threshold. However there was always a tradeoff between productivity of the enterprise and environemental risk as measured by cover. The only win-win management change identified was that of reduced stubble burning; however the impact of stubble load on sowing operations and crop establishment was not accounted for. Further investigation of the contribution of different vegetation components to cover, with particular reference to erosion risk, may lead to a shift in prediction of cover and may alter this analysis.