The whole-farm impact of including dual-purpose winter wheat and forage brassica crops in a grazing system: a simulation analysis

Andrew D. Moore, Libby Salmon and Hugh Dove

[1] CSIRO Plant Industry, GPO Box 1600, Canberra ACT 2601. www.csiro.au Email
Andrew.Moore@csiro.au

Abstract

An exploratory simulation analysis is presented of four management options for using pasture, dual-purpose winter wheats and forage brassica in a lamb production system at two sites in south-eastern Australia (Canberra and Wagga Wagga). The GRAZPLAN process models were combined with a rule-based representation of management to produce a simulation model of the complex interactions within mixed cropping/grazing systems. At the Canberra site, allocation of 20% of land area to a winter wheat-fallow-pasture rotation resulted in an increase of $23/ha in whole-farm gross margin compared with a pasture-only system. The response at the Wagga Wagga site was smaller ($12/ha). At both sites, inclusion of a forage brassica in the rotation gave a further increase of about $30/ha in whole-farm gross margins but this was accompanied by increased year-to-year variability in gross margin, especially at Wagga Wagga. The inclusion of forage brassica also reduced deep drainage of water compared with a pasture-wheat system, though differences were small. The simulations suggest the need to explore the use of other livestock enterprises for utilising winter wheat forage, and have also highlighted areas in need of further research.

Media summary

A simulation analysis indicates that increases in whole-farm gross margin are likely from incorporating winter wheat and brassica forage crop into pasture-based prime lamb systems.

Key Words

Mixed farming, winter wheat, brassica forage crop, simulation, GRAZPLAN

Introduction

Dual-purpose (grain and grazing) wheats are now available for the High Rainfall Zone in southern Australia, and sowings have increased dramatically over the last decade (Kelman et al. 2004). The incorporation of such wheats into grazing systems can provide extra income by providing high-quality forage, to help overcome the winter feed gap which commonly occurs within pasture-only systems. They also provide the opportunity to incorporate and pay for lime to ameliorate the effects of low soil pH.

Several issues must be resolved if dual-purpose winter wheats are to be optimally integrated into farming systems. Grazing the winter wheat may reduce wheat yields, particularly in years of low spring rainfall. Moreover, devoting land to wheat production will result in a reduction in forage supply and thus increased grazing pressure during the period between removal of pasture and the time when the wheat is grazed. One option to minimise this “crop penalty” is to grow a forage brassica in between removal of the pasture and sowing of the wheat. This will increase the total supply of high-quality forage, but the brassica crop will use water that would otherwise be available for wheat growth (Kelman et al. 2004). Conversely, leaving the area in fallow over the summer may result in increased deep drainage, and hence increased salinity risk (Hatton and Nulson 1999). A multi-way trade-off must therefore be made between water use by the wheat, water use by the brassica, deep drainage from the soil profile, and the supply of high-quality forage for livestock. The long-term impact of these trade-offs on profitability is best assessed at the whole-farm level.

Given the complexity of the interactions involved in a system based on pasture, livestock, cereal and forage crop, and the impact of rainfall variability upon the outcomes, a modelling approach is probably the only viable approach to evaluating the trade-offs described above. This paper reports an exploratory simulation analysis of various options for using pasture, dual-purpose winter wheats and forage brassica in a grain/lamb production system at two sites in south-eastern Australia. The simulations have been conducted as part of a GRDC-funded research project; they use and extend the data reported at this Congress by Kelman et al. (2004), and allow a comparison of economic outcomes at the whole-farm level.

Methods

Dynamics of the soil-crop-pasture-livestock-management systems were simulated with the GRAZPLAN models of ruminant biology (Freer et al. 1997) and of soil water and pasture (Moore et al. 1997). In order to model a dual-purpose wheat, either a pasture model must be adapted to represent grain production, or else a cereal model must be adapted to represent grazing interactions. The former approach was used; an existing parameter set for an annual grass was adapted to approximate a winter wheat cultivar, including wheat stubble. A parameter set for a forage brassica was developed similarly, based on a dicot herb.

Two locations were simulated: a perennial pasture-based system at Canberra and an annual pasture-based system at Wagga Wagga (Table 1). While total annual rainfall is similar at the two sites, rainfall at Wagga Wagga is more winter-dominant while Canberra has colder winters. Wagga Wagga is presently viewed as a marginal environment for winter wheat and especially for forage brassicas. All systems were simulated using historical daily weather data from 1 January 1972 to 31 July 2002.

Table 1. Biophysical summaries of the two locations used in the simulation study.

	Canberra	Wagga Wagga
Location	35? 19' S, 149? 12' E	35? 10' S, 147? 27' E
Average annual rainfall	630 mm	595 mm
Proportion of rainfall in Apr-Oct	0.55	0.64
Average July temperature	5.8 ?C	7.7 ?C
Soil type	Yellow Chromosol	Red Kandosol
Pasture species	Phalaris, subterranean clover, annual grass	Annual grass, subterranean clover

Studies of dual-purpose winter wheats have focussed on their use for lamb production (e.g. Dove et al. 2002). All management systems were therefore based on a first-cross ewe flock with lamb production as the main source of income. Border Leicester X Merino ewes were kept for four years and replaced in December each year. The flock was joined with Dorset rams for 6 weeks from 1 February each year; lambs were castrated on 1 September and weaned on 31 October. Conception rates and perinatal lamb mortalities each year were predicted by the model. The pasture area was divided into four equally-sized paddocks; livestock were moved at regular intervals, with weaned lambs (when present) allocated to the paddock with the best available forage and ewes to the next-best paddock. Livestock were supplemented with wheat grain sufficient to maintain their weight whenever their condition score fell below a class-specific threshold.

At each location, four management systems were considered. Each system added an element of management to the previous one:

- “P-sell”: pasture only, all lambs sold on 15 December each year. This is the base scenario.
- “P-retain”: pasture only, 50% of lambs sold in December and the remainder held over summer and sold on 31 July the following year. The heaviest lambs at weaning were allocated for early sale.
- “P-F-W”: 25% of lambs were sold in December and the remainder held until 31 July. 20% of the enterprise area was allocated to a pasture-winter wheat rotation (i.e. 5% to each of four paddocks). Each rotation paddock contained a different phase of the four-year rotation. Pasture in each rotation paddock was killed with herbicide on 1 August of the first year. The paddock was left fallow until February the following year, and winter wheat was then sown on the first occasion that 25 mm of rain fell within a five-day period, or dry sown on 15 March. The wheat crop was grazed by the retained lambs in June and July; it was opened to grazing once it reached a mass that provided an allowance of 1.5 kg/lamb/day with a residual of 1000 kg/ha. After the wheat harvest, stubbles were grazed by the next cohort of lambs until 15 February of the third year; phalaris (at Canberra) or annual grass (at Wagga) was then sown on the first occasion that 25 mm of rain fell within a five-day period, or dry sown on 30 April. Clover was simulated as regenerating from its seed bank. Finally, the rotation paddock was re-opened to grazing once it reached a herbage mass of 1500 kg/ha.
- “P-B-W”: as for the “P-F-W” system, except that a forage brassica crop was sown on 15 August of the first year and grazed from 1 November by the lambs allocated for sale on 15 December.

Representing management systems of this complexity was only practicable through the use of the rule-based management language developed for the FarmWi$e decision support tool (Moore 2001). Current (early 2004) costs and prices for the various inputs and outputs were used to compute gross margins for each system. It should be noted that current lamb prices of $A3.50/kg dressed weight (DW) are very high by historical standards.

Because the different management systems were expected to result in different rates of pasture utilization, the management systems were compared at their optimal stocking rates (the optimal stocking rate for each site x system is given in Table 2). Each system was simulated over a range of stocking rates from 7.0 to 10.0 ewes per hectare and the rate that produced the highest gross margin was selected for presentation.

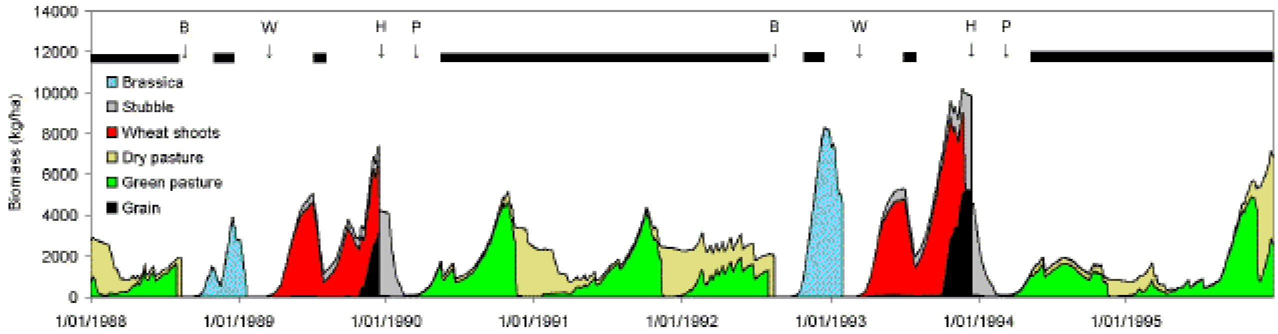

Figure 1. Herbage mass and grain production over two rotation cycles of the “P-B-W” management system at Canberra. Bars at the top of the figure show periods when the simulated paddock is open for grazing. Symbols denote: B – sowing of forage brassica, W – sowing of wheat, H – wheat harvest, P - sowing of pasture.

Results

The optimal stocking rates for the different management systems ranged from 7.5 to 9.0 ewes/ha. (Table 2). Average gross margin values are also given in Table 2 for a common, near-optimal stocking rate of 8.0 ewes/ha. At both sites, retention of half the lambs to twelve months of age (the “P-retain” system) increased the total weight of lamb turned off but did not greatly improve gross margins owing to increased supplementary feeding costs (data not shown).

Table 2. Long-term mean production data for four simulated management systems at two locations in south-eastern Australia. NPP=shoot net primary production. Pasture, forage brassica and wheat yields are expressed on a paddock area basis; lamb turned off, wool cut and gross margins are expressed on an enterprise area basis.

Location	Canberra				Wagga Wagga			
Management system	P-sell	P-retain	P-F-W	P-B-W	P-sell	P-retain	P-F-W	P-B-W
Optimal stocking rate (ewes/ha)	8.0	7.5	8.5	9.0	8.0	8.0	8.5	9.0
Proportion of lambs retained	0.00	0.50	0.75	0.73	0.00	0.50	0.75	0.54
Pasture NPP (t/ha/year)	9.1	9.2	9.2	9.2	8.8	8.6	8.8	8.8
Brassica yield at 1 Nov (t/ha)				1.97				2.88
Wheat yield (t/ha)			4.14	3.84			4.89	4.62
Lamb LW gain on wheat (g/d)			196	190			212	216
Lamb LW gain on brassica (g/d)				220				163
Lamb turned off (kg DW/ha/year)	134	146	144	157	129	151	135	144
Wool cut (kg greasy/ha/year)	43	40	37	39	42	42	36	38
Enterprise gross margin ($/ha)	347	355	370	399	326	335	338	370
Std deviation of enterprise G.M. ($/ha)	179	178	176	222	115	131	120	228
Enterprise G.M. at 8.0 ewes/ha	347	358	365	386	326	335	329	358

Simulated winter wheat yields averaged about 4 t/ha at Canberra and 5 t/ha at Wagga, which was within the expected range given that disease effects were not modelled. Retention of lambs coupled with a fallow-winter wheat rotation (the “P-F-W” system) produced a $23 /ha increase in gross margin at Canberra compared with the base system, but only a $12 /ha increase at Wagga Wagga; These differences may be too conservative, however, as the simulated average lamb weight gains on the winter wheat were lower than expected from the results of Dove et al. (2002). Variability in gross margin changed very little between the base and “P-F-W’ systems. Inclusion of forage brassicas into the management system reduced average wheat yields by approximately 0.3 t/ha at both sites; this was compensated for by a sharp rise in the average weight of lamb turned off, especially at Canberra. The “P-B-W” system was therefore predicted to have higher gross margins at both locations. Introduction of forage brassica also increased the variability in annual gross margins, especially at Wagga Wagga where the standard deviation of the gross margin increased by 90%.

Simulated long-term average deep drainage amounts from the pasture systems were generally consistent with the predictive equations of Zhang et al. (2001), given that the pastures at Canberra were based on perennial rather than annual grasses. In the P-F-W system, the rotation paddocks were predicted to drain much larger quantities of water in three out of four years of the rotation. Including forage brassica into the management system reduced drainage from the rotation paddock in both the brassica and the wheat years. Differences between the management systems were small in magnitude; the 80% of enterprise area under permanent pasture diluted the differences between management systems operating on the remaining 20% of the area.

Table 3. Long-term mean deep drainage (mm/year) for four simulated management systems at two locations in south-eastern Australia.

Location	Canberra				Wagga Wagga			
Management system	P-sell	P-retain	P-F-W	P-B-W	P-sell	P-retain	P-F-W	P-B-W
Pasture paddocks	37	37	38	38	117	120	119	119
Rotation paddocks:								
fallow/brassica year			79	54			152	122
wheat year			83	45			140	90
pasture year 1			79	80			142	133
pasture year 2			44	45			121	116
Enterprise average	37	37	44	42	117	120	123	118

Discussion and Conclusions

These exploratory simulations have clarified some key questions for the management of dual-purpose winter wheat. At least for environments similar to Canberra, the inclusion of brassicas in winter wheat rotation systems seems likely to deliver both economic and environmental benefits. Keeping the majority of lambs over summer and autumn may not be the best strategy for utilizing winter wheat forage; to fully exploit the value of winter wheat, the proportion of lambs retained and the area sown to wheat need to be optimized and the sensitivity of this optimum to lamb and grain prices understood.

Our approach of using existing, published simulation models and a rule-based management system has meant that we have been able to construct a working model efficiently at the start of our programme of experimental research, despite the highly complex nature of the agricultural system we are studying. As a result, the modelling work has already influenced research plans. A need for quantitative data on winter wheat forage growth and on the depth and rate of water extraction by both winter wheat and forage brassicas were identified as the simulations were constructed. Discrepancies between simulated and measured lamb live weight gains for both winter wheat and forage brassicas – possibly a consequence of very high forage digestibility – also point to an area of future research.

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