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What is the optimum wool–meat enterprise mix?

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Abstract

The GrassGro™ model was used to simulate profitability of 14 sheep enterprises at four locations in south-eastern Australia. The simulated enterprises were: Merino wethers (superfine and fine wool); self-replacing Merino ewes (fine and medium wool); dual-purpose Merino ewes (fine and medium wool) joined to terminal sires; prime lamb first-cross ewes joined to terminal sires. A sheep model was also used to compare a self-replacing Merino enterprise with dual-purpose and prime lamb enterprises. GrassGro simulations highlighted that the fine-wool dual-purpose enterprise was the most profitable, followed by the prime lamb, self-replacing Merino and Merino wether systems. From 1999–2003, when a large premium existed for superfine-wool, Merino yearlings with superfine wool were as profitable as the fine-wool dual-purpose enterprise. The sheep model analysis showed that Merino yearlings had slightly greater gross margins than other enterprises when mean wool and meat prices for 1994–2004 were used, but not when prices for meat were high in relation to those of wool (June 2003-May 2004). In the sheep model comparisons, spring lambing resulted in greater gross margins than winter lambing and production of yearlings was more profitable than production of weaners. The dual-purpose Merino meat–wool enterprise is resilient against changes in commodity prices, but the genetic merit (wool production, fibre diameter and liveweight) of ewes purchased or bred should be considered. A prime lamb enterprise, using first-cross ewes, will not necessarily be more profitable than systems using a Merino ewe base, particularly when prices for first-cross ewes are high or when weaning percentages are low.

Introduction

The size and composition of the Australian sheep flock has changed over the past decade because of the combined effects of drought and the high price of meat relative to that of wool (Barrett et al., 2003; ABARE, 2004). There has been a trend among wool producers to change from pure Merino flocks to dual-purpose Merino flocks as a hedge against price fluctuations. The increased interest in meat production resulted in practices such as joining Merino ewes to terminal sires, early lambing (autumn or early winter) to produce heavier lambs, selection for large-frame Merino ewes, infusion of South African Mutton Merino or Dohne Merino genes and increased number of lambs weaned per ewe. This study was conducted to elucidate key profit drivers and risks associated with various types of enterprises.

Materials and Methods

The profitability of 14 sheep enterprises was modelled using a computer program (GrassGro version 2.4.3; Moore et al., 1997). Simulations were conducted for Mortlake (south-western Victoria), Rutherglen (north-eastern Victoria), Cowra (central-west New South Wales) and Naracoorte (south-eastern South Australia). Historical weather data from 1965–2002 was used, and soil types typical of

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the regions and well fertilised, improved pasture species were assumed to be present.

The following enterprises were modelled: Merino wethers (superfine [17.5 µm], and fine wool [19.0 µm]); self-replacing Merino ewes (fine [19.0 µm] and medium wool [21µm]) turning off store Merino lambs (4 months old) or yearlings (12 months old); dual-purpose Merino ewes (fine and medium wool) turning off first-cross store lambs (4 months old) or lambs finished to 44 kg liveweight with grain (up to 6 months of age); prime lamb first-cross ewes turning off second-cross store lambs (4 months old), or lambs kept up to 6 months of age and finished on grain to reach 44 kg or 53 kg liveweight. The assumptions used for the simulations are summarized in Table 1. Full details of assumptions are given by Warn et al. (2005). An optimum stocking rate, which took into account production and environmental risks, was selected for each enterprise. Time of lambing was also optimised prior to comparison of systems. Mean prices for meat, wool and replacement ewes over two periods were used: 1999–2003, during which lamb prices and premiums for wools 19 µm and finer were relatively high and 2003–2004, during which fine-wool premiums were less than the mean for 1999–2003 and meat prices were higher than the mean for 1999–2003. The effects on gross margins of breed, genotype, time of lambing, stocking rate, time of sale and type of finishing system were simulated.

A second analysis was done using a gross-margin sheep model (McEachern, 2004). The following enterprises were compared: a self-replacing Merino flock, a dual-purpose flock and prime lamb production. It was assumed that all enterprises turned off weaners or yearlings, and three- or five-year-old wethers were sold in the case of the self-replacing Merino flock (Table 1). A uniform winter stocking rate of 15 dry sheep equivalents per ha (DSE/ha) was used. Winter (July/August) lambing was compared with spring lambing (September). Merino meat prices were 75% of 2003–2004 prime lamb prices. Gross margins per ha were calculated using both 10-year mean (1994–2004) and 2003–2004 meat and wool prices.

Results and discussion

Which enterprise was most profitable?

GrassGro simulations

When meat and wool prices for 1999–2003 were used to simulate mean gross margins for the period 1966–2002, the dual-purpose (first-cross lambs) enterprise was most profitable, followed by prime lambs (second-cross lambs). With the exception of superfine-wool (17.5 µm) yearlings, the self-replacing flocks (lambs and yearlings) were least profitable. Fine-wool (19.0 µm), wethers were less profitable than ewes, but the superfine-wool wethers compared favourably with the fine-wool Merino lamb enterprise (Table 2). The relative profitability of each enterprise at the four locations was similar. An effect of micron premiums was apparent for the Merino enterprises. These results are consistent with benchmarking studies, which indicate that dual-purpose flocks performed better than wool (Merino) or prime lamb flocks over the past few years (Holmes, Sackett and Associates, 2002). Although the Victorian Farm Monitor Project does not differentiate between dual-purpose Merino flocks and cross-bred ewe flocks, data from this project also confirms the superior profitability of prime lamb flocks relative to wool flocks since 2001 (Department of Primary Industries Victoria, 2005).

When the mean price for 1999–2003 was used, there was no advantage in keeping Merino lambs to shear and sell as yearlings (Table 2). About 6 kg/ha (18%) additional wool was produced in the yearling system, and a similar amount of meat was produced per ha. The price discount for yearling meat relative to that of lamb (30%) limited the income from meat in the yearling system. If the price for meat from lambs was the same as that from yearlings, the yearling enterprise would be marginally more profitable than the Merino lamb enterprise.

Table 1. Assumptions used in the GrassGro[A] and sheep models to simulate profitability of various sheep enterprises.

Breed	Fibre diameter of ewe (μm)	Greasy fleece weight of ewe (kg)	Weight of ewe in average condition (kg)	Weaner weight (kg)	Yearling weight (kg)	Wether weight (kg)	[B]Ewes lambing (%)	Lambs weaned per ewe (%)	Weaner growth rate (g/d)	Yearling growth rate (g/d)
GrassGro model										
Superfine wool Merino	17.5	3.6	45							
Fine wool Merino	19.0	4.1	50							
Medium wool Merino	21.0	4.5	55							
Cross-bred	29.0	4.0	60							
Sheep model										
Merino	20.0	4.0		30	45	60	43–80	80	170	40
Dual-purpose Merino	21.0	4.0		43	56		69–99	96	190	60
Prime lamb Cross-bred	29.0	4.0		49	65		65–99	120	220	75

[A]Lamb turn-off weights, growth rates and weaning percentages are outputs from GrassGro simulations, not inputs to the model, and vary between sites and years; [B]Expressed as a percentage of ewes present in the flock at mid-winter.

Finishing first-cross lambs to 44 kg liveweight was less profitable than store lambs, and this was most pronounced for the Cowra location. The length of the growing season and the extent of the spring peak in pasture supply affected the relative value of finishing lambs. Finishing first-cross lambs (medium-wool ewes) to a liveweight of 44 kg was less profitable than lambing later, retaining more ewes and turning off store lambs: a loss of $6–$7/ha resulted for Mortlake, Rutherglen and Naracoorte, and a loss of $77/ha resulted for Cowra. The mean sale weight of first-cross store lambs ranged from 39 kg (Cowra) to 41 kg (Rutherglen). Grain-feeding reduced production risk by adding an additional 4–6 kg liveweight to the lambs. However, this small gain in meat production per ha was associated with a decrease in the number of ewes per ha and wool production per ha. Compared with turning off stores, finishing second-cross lambs to a liveweight of 44 kg with grain costing $150/t increased gross margin by $26/ha for Mortlake, $6/ha for Rutherglen, $3/ha for Naracoorte, and decreased gross margin by $20/ha at Cowra. Compared with turning off stores, finishing second-cross lambs to 53 kg liveweight would have increased gross margin by $87/ha at Mortlake, $64/ha at Naracoorte, $45/ha at Cowra and $34/ha at Rutherglen.

Table 2. Simulated[A] mean gross margins (1966–2002) for sheep enterprises at Mortlake, Rutherglen, Naracoorte and Cowra. Mean wool and meat prices for 1999–2003 were used.

Enterprise [B]	Ewe fibre diameter (μm)	Lamb turn-off [C]	Mean gross margin ($/ha)			
			Mortlake	Rutherglen	Naracoorte	Cowra
Wethers	17.5	-	797	459	488	347
Wethers	19.0	-	496	282	288	214
SRM	17.5	yearlings	1021	569	582	496
SRM	19.0	yearlings	720	398	406	345
SRM	21.0	yearlings	537	311	298	266
SRM	19.0	store lambs (4 months)	759	422	433	402
SRM	21.0	store lambs (4 months)	669	373	378	354
DP	19.0	store lambs (4 months)	1042	584	579	561
DP	21.0	store lambs (4 months)	893	514	496	479
DP	19.0	44 kg lambs	1061	583	586	462
DP	21.0	44 kg lambs	883	508	489	402
PL	29.0	store lambs (4 months)	844	481	446	463
PL	29.0	44 kg lambs	870	487	449	443
PL	29.0	53 kg lambs	931	515	510	508

[A] GrassGro simulations.
[B] SRM = self-replacing Merino flock, DP = dual-purpose flock, Merino ewes joined to terminal sires, PL = prime lamb flock, first-cross ewes joined to terminal sires.
[C] Lambs are finished on grain to achieve a target live weight of 44kg or 53 kg, and are kept up to 6 months of age.

With the exception of the superfine- and fine-wool ewe enterprises, the advantage of which was negated by the demise of micron premiums during 2003/2004, relative rankings of the enterprises for the two price scenarios were similar for each location. The mean gross margins for the Merino yearling and Merino lamb enterprises were similar because of a smaller price differential between yearling and lamb prices in 2003/04. The mean gross margins for the dual-purpose and prime lamb enterprises increased with the increase in meat income (data not shown).

The dual-purpose enterprise appeared to be relatively resilient to price changes, as it was the most profitable enterprise under both price scenarios. The dual-purpose and prime lamb enterprises produced more meat per ha than the self-replacing Merino enterprises and consequently delivered a greater income per ha from meat (Table 3). As all ewe replacements were purchased, not bred, in the dual-purpose and prime lamb enterprises, more joined ewes were run per ha and thus more meat was produced per ha than in the self-replacing Merino enterprises. The fine- and medium-wool dual-purpose enterprises delivered higher wool incomes than the prime lamb enterprises because of the slightly higher wool production per ha and the higher value of the wool. The wether enterprises produced slightly more wool per ha but substantially less meat per ha than the ewe enterprises, which

resulted in the lowest profitability under both price scenarios.

Table 3. Comparison of liveweight per ha (meat production) and the proportion of income from wool for GrassGro simulated sheep enterprises located at Rutherglen.

Enterprise	Ewe fibre diameter (μm)	Lamb turn-off	Time of peak lambing[A]	Stocking rate[B] (wethers/ ha or ewes/ha)	Clean wool (kg/ha)	Liveweight (kg/ha)	Proportion of income from wool (%)	
							1999–2003 prices	2003–2004 prices
Wethers	17.5		-	13	40	154	86	75
Wethers	19.0		-	12	42	158	81	74
SRM	17.5	yearlings	October	9.5	38	334	67	50
SRM	19.0	yearlings	October	8.5	38	333	58	48
SRM	21.0	yearlings	October	8.0	39	344	50	45
SRM	19.0	store lambs	August	10.5	32	325	44	40
SRM	21.0	store lambs	August	10.0	33	339	37	39
DP	19.0	store lambs	August	10.5	33	489	32	25
DP	21.0	store lambs	August	10.0	34	492	26	24
DP	19.0	44 kg lambs	July	9.5	30	503	29	22
DP	21.0	44 kg lambs	July	9.0	31	487	24	22
PL	29.0	store lambs	August	8.5	26	537	14	11
PL	29.0	44 kg lambs	July	8.0	24	543	13	10
PL	29.0	53 kg lambs	July	7.0	21	552	11	9

[A] Time of lambing refers to the date on which the majority of the lambs were born.

[B] The stocking rate was selected using risk criteria for pasture mass and feeding of supplements.

Sheep model simulations

Merino yearlings had similar gross margins to the dual-purpose and prime lamb yearling enterprises under the 1994–2004 mean price scenario. Prime lamb and dual-purpose enterprises were more profitable than Merino yearlings when meat prices were high in relation to wool prices (June 2003 to May 2004). Using mean prices for 1994–2004, spring lambing, Merino yearlings had the highest gross margins, which were 9% and 16% higher than those of spring lambing, dual-purpose yearlings and prime lamb yearlings, respectively (Table 4). However, with June 2003-May 2004 prices, gross

margins for Merino yearlings were 12% and 5% lower than those of spring lambing, dual-purpose yearlings and prime lamb yearlings, respectively. Mean gross margins were 7% higher for yearlings than for weaners, and Merino yearling gross margins were 14% (June 2003 to May 2004 prices) to 40% (1994–2004 mean price) higher than for wethers. Results from an analysis by Thompson and Young (2002) using the MIDAS computer model also showed that a self-replacing Merino flock producing pure Merino lambs for slaughter at 6–7 months of age was more profitable than a Merino flock in which wethers were retained to 3.5 years of age.

Under both price scenarios, the gross margins for spring lambing exceeded those for winter lambing by 10% for the dual-purpose and prime lambs and by 24%–30% for Merino weaners and yearlings.

Table 4. Simulated (sheep model) effect of age at which lambs are sold and prices for wool and meat on gross margins ($/ha) for six sheep enterprises.

Enterprise	Time of lambing	Weaner	Yearling	3-year-old wether	5-year-old wether
		10 year (1994–2004) mean prices			
Merino	winter	325	352	325	315
Merino	spring	424	448	380	
Dual P	winter	350	375		
Dual P	spring		410		
Prime L	winter	305	352		
Prime L	spring		385		
		June 2003-May 2004 prices			
Merino	winter	455	490	455	425
Merino	spring	590	610	530	
Dual P	winter	580	615		
Dual P	spring		680		
Prime L	winter	510	575		
Prime L	spring		640		

The results of the GrassGro analysis of the profitability of Merino weaners and yearlings differed slightly from those of the sheep model analysis. This was because of slight differences in price discounts assumed for Merino yearling meat and Merino lamb, and differences in the criteria used to select stocking rate and time of lambing. This illustrates the sensitivity of gross margins to price and management factors. However, both sets of results indicated that there were relatively small differences between the gross margins of Merino weaner and yearling enterprises. Both analyses indicated that the dual-purpose fine-wool Merino enterprise was more profitable than self-replacing fine-wool Merino enterprises or prime lamb enterprises when recent (2003–2004) price scenarios were used.

Which management factors had the greatest effect on gross margin?

Quantity of product per ha and weaning percentage

Within an enterprise, the amount of meat and wool produced per ha had the greatest effect on income and gross margin (Table 3). Stocking rate had the greatest effect on meat and wool produced

per ha (Fig, 1). It was critical to optimise time of lambing before optimising stocking rate. The sale weight of lambs was not a key profit driver. Keeping lambs longer or lambing earlier in autumn or winter to increase sale weights reduced the number of ewes that could be kept per ha and the amount of meat and wool produced per ha. Increasing lamb liveweight by feeding grain could be profitable, particularly for the prime lamb enterprises, when grain costs $150/t.

With the GrassGro model, the effects of weaning percentage on meat produced per ha was less important than that of stocking rate. An increase in the number of lambs weaned per ewe of 10% increased gross margin by approximately 10% ($3.50–$5.00/ewe when the 1999–2003 prices were used) for the dual-purpose and prime lamb enterprises (Fig. 1). Enterprises that are understocked would derive greater benefit from increasing the number of ewes per ha than by increasing weaning percentage. In instances in which the stocking rate is optimum, an increase in weaning percentage would be profitable, even allowing for a small decrease in the number of ewes/ha. A producer could not afford to spend more than $1.80–$2.50 per ewe on increasing weaning percentage. It is unlikely that this could be achieved by feeding ewes grain to increase liveweight and ovulation rate; improvement of lamb survival and flock genetics are more economical ways of improving weaning percentage.

Weaning percentage was more important for the prime lamb (second-cross lamb) enterprise than for the dual-purpose (first-cross lamb) enterprise. For example, at Mortlake, the dual-purpose flock and the prime lamb flock had mean weaning rates of 85% and 120%, respectively. For the prime lamb flock to generate a similar gross margin to the dual-purpose flock, weaning percentage would have had to increase to 135–145%, depending on the price scenario.

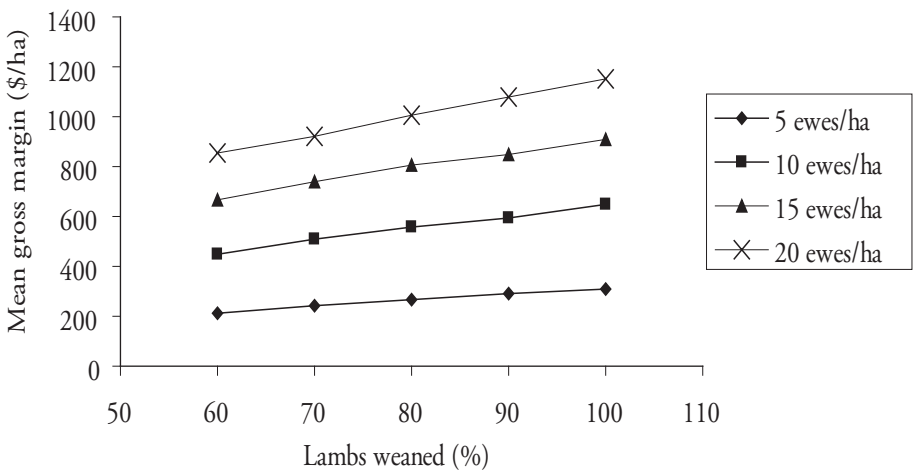

Fig. 1. Simulated effect of weaning percentage and stocking rate on gross margins for a first-cross store lamb enterprise in which fine-wool Merino ewes lambed in early September at Mortlake. Mean wool and meat prices for 1999–2003 were used and data were analysed using GrassGro.

Price of product

For the Merino enterprises, the price paid for wool was an important profit driver under the mean 1999–2003 price scenario, when there were large premiums for wool less than 19 μm in diameter. Even though the price premiums in 2003–04 were smaller, there was still a small benefit of producing finer wool because the greasy wool of all Merino genotypes was equivalent to 8% of liveweight.

For meat enterprises, price premiums for time of sale or heavier carcass weights did not have significant effects on gross margins (Table 5). Other than low prices for lamb in early spring, there was no consistent trend for lamb prices. Therefore, it was more profitable to lamb at the optimum

time (viz., late winter or spring, depending on the location), run more ewes and turn off store lambs at the end of the growing season than (a) lamb in autumn/early winter and sell at the end of the growing season to obtain a higher price per kg, or (b) lamb at the optimum time but retain lambs over summer/autumn and sell in winter to get a higher price. To justify reductions in stocking rate associated with option (a) and return the same meat income per ha, prices for heavier lambs (20–22 kg carcass weight) would have to be 1.4 times higher than the five-year mean of 303 c/kg for December (viz., 424 c/kg). For option (b), lamb prices would have to be 1.3 times higher than the five-year mean of 292 c/kg for June for carcasses weighing 16–18 kg (viz., 380c/kg). These price premiums do not account for the loss in wool income incurred from maintaining less ewes per ha.

Table 5. Simulated effect of time of lambing and sale of lambs on stocking rate and gross margins for a dual-purpose first-cross lamb enterprise (fine-wool ewes) at Mortlake.

System		Stocking rate[A] (ewes/ha)	Gross margin[B] ($/ha)	Mean sale weight of lambs (kg)	Wool income ($/ha)	Meat income ($/ha)	Maintenance supplement cost ($/ha)
Lambing	Lamb sale						
June	End December	12.0	695	44	323	788	71
September	Mid June	14.5	782	42	431	856	105
September	End December	20.0	1032	38	593	1075	100

[A] Stocking rate was adjusted using pasture mass and the supplementary feeding recommendations of Warn et al. (2005).
[B] Mean wool prices for 1999–2003 were used; Relevant, mean 1999–2003 monthly meat price was used to correspond to each time of sale.

Variable Costs

Supplementary feed was the major variable cost per ha when stocking rate was increased (GrassGro analysis). Time of lambing was critical for minimising costs of supplements and optimising stocking rate. The effect of time of lambing on gross margin was also demonstrated by the sheep model (Table 4).

Risk of changing enterprises (break-even times)

The price paid for ewes had a large effect on gross margins and the risk associated with changing enterprises. Changing from a self-replacing Merino flock to a first-cross ewe flock was investigated assuming 2003–2004 prices and that the market value of a fine-wool Merino ewe was $80. Although the gross margin of the first-cross ewe enterprise was higher than that of self-replacing Merinos for a range of ewe prices, a price of more than $150 for a first-cross ewe would increase risk because it would prolong the time taken to break even. The break-even time for first-cross ewe purchase prices of $100, $130 and $150 was 1, 2 and 5 years respectively.

Which combination of enterprises is most profitable?

GrassGro was used to determine the most profitable use for a land with a particular soil type and pasture for a given environment. However, optimisation of whole farm profit from combinations of enterprises could not be simulated using GrassGro. Despite this, it is possible to extrapolate from results for individual enterprises to estimate the most profitable combination of enterprises. The dual-purpose flock (fine-wool Merino ewes turning off first-cross store lambs) was the most profitable enterprise for all locations. However, if the risks of purchasing replacement Merino ewes such as disease, genetics and price are of concern, a self-replacing Merino flock in which the surplus ewes are "sold" to the dual-purpose enterprise may be considered. The number of ewes available for the dual-purpose enterprise will depend on weaning percentage. These calculations can be done using

the "Merino versus terminal sire" model, which is available from the Sheep CRC website (www.sheepcrc.org.au/flock_structure.php#model).Within a farm, variation in soil type, pasture specie and soil fertility can also affect the optimum combination of enterprises, although the biggest effect of these variables will be on stocking rate.

Conclusions

A dual-purpose Merino enterprise (Merino × terminal sire) affords a measure of resilience against price variations, but the genetic merit of purchased ewes (wool production, fibre diameter in relation to liveweight) and the breed of terminal sire should be considered to reap the full benefits of this system. The results of this study support the feasibility of the option that many producers with self-replacing Merino flocks have chosen, viz., joining a portion of ewes to terminal sires and maintaining fewer wethers. It is more profitable to sell Merino wethers as lambs or yearlings than to retain them until 3 or 5 years of age.

Opportunities to improve the performance of an existing enterprise should be considered before changing the system. Merino enterprises can be as profitable as first-cross ewe or prime lamb enterprises. Stocking rate and time of lambing have major effects on gross margins and profit. Weaning percentage plays a lesser role in determining the amount of meat produced per ha than stocking rate, but it is worth increasing weaning rate if the cost per ewe is low. Merino producers contemplating changing over to first-cross ewe systems need to exercise caution because profitability may not necessarily be increased, particularly if high prices are paid for ewes or if ewes do not achieve high weaning percentages. Under the price scenarios modelled, self-replacing flocks were not as profitable as enterprises in which replacement ewes were purchased, but the purchase of ewes is associated with the risk of introducing disease, an altered gene pool and potentially high ewe prices.

The results from these simulations can be used to determine which combination of enterprises would achieve the highest gross margin and profit on a farm. The various classes of land and pasture species on individual properties will ultimately dictate the optimum combination of enterprises, flock structure and stocking rates.

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References

Australian Bureau of Agricultural and Resource Economics, 2004. Australian prime lamb industry. ABARE research report 4.3. (http://abareonlineshop.com/product.asp?prodid=12895).

Barrett, D., Ashton, D., Shafron, W., 2003. Australian Wool Industry. ABARE research report 03.5.

Department of Primary Industries, Victoria, 2005. Farm Monitor Project, Summary of Results 2003/2004 (www.dpi.vic.gov.au/DPI/nrenfa.nsf/childdocs).

Holmes, Sackett and Associates, 2002. AgInsights 2002 – Opportunities for broadacre agriculture. Holmes, Sackett and Associates Pty. Ltd., 112 Fitzmaurice St.,Wagga Wagga, NSW, 2650.

Holmes, Sackett and Associates, 2004. Analysis and discussion of yearling Merino sheep production systems. Australian Sheep Industry CRC, Armidale, NSW.

Moore, A. D., Donnelly, J. R., Freer, M., 1997. GRAZPLAN: Decision support systems for Australian grazing enterprises. III. Pasture growth and soil moisture submodels and the GrassGro DSS. Agricultural Systems 55, 535–582.

Thompson, A. N., Young, J. M., 2002. A comparison of the profitability of farming systems using the wool and wool/meat sheep genotypes in south-west Victoria. Wool Technology and Sheep Breeding 50, 615–621.

Warn, L.K., Webb Ware, J., Salmon, L., Donnelly, J., Alcock, D., 2005. Analysis of the profitability of sheep wool and meat enterprises. Report to the Australian Sheep Industry CRC, Armidale, NSW.