MEAT & LIVESTOCK AUSTRALIA

finalreport

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Australian Sheep Industry CRC

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Improved Sheep Meat and Wool Production and Income

Abstract

With increasing importance of meat production in the Australian sheep industry this project investigated ways in which both meat and wool production could be improved simultaneously. Approaches included (a) monitoring meat and wool traits in 27 co-operating Merino breeder flocks, to estimate genetic parameters (b) GrassGro biophysical modelling to compare profitability of different sheep enterprises, (c) combined Grassgro and MIDAS modelling to validate profitable turnoff of Merino lambs, and (d) development of improved economic and statistical profit indicators from sheep farm benchmarking datasets.

Genetic parameters showed moderate to high heritabilities for meat and wool traits and despite some weak antagonisms this dataset indicated in a similar way to the wider SGA dataset that genetic improvement for meat and wool could occur together. Two new wool traits relating to crimp frequency and resistance to compression were developed as additional tools for wool producers. The widely varying environments were characterized using satellite and climate data to help develop management guidelines for flatter fibre diameter profiles and improved staple strength.

The GrassGro modelling based on four sites in southern NSW and Vic found that lamb production in dual purpose and prime lamb enterprises was generally more profitable than self replacing Merino enterprises. However turnoff of yearling Merino wethers in fine wool flocks was very competitive. It was concluded there was big variation in profitability across sites within these enterprise groupings and that attention to key management factors such as stocking rate and lambing date were important within existing enterprises. Some fine tuning of enterprise mix could be warranted in many cases.

Complementary biophysical (GrassGro) and income optimization (MIDAS) modelling investigated potential to diversify to meat production from Merinos based on Merinotech case study properties in South West WA. Grain finishing a high proportion of wether lambs to 7 months of age was more profitable than selling wether lambs as stores, yearlings or shippers.

The farm benchmarking project developed bioeconomic estimates of technical efficiency (outputs/inputs), total factor productivity (total outputs/inputs including new technologies and scale effects) and scope economies (synergies between enterprises). Statistical analysis aimed to identify key performance indicators of profit as indicated by gross margins. There was big variation in technical efficiency among benchmarked farmer groups. Annual productivity improvement in wool and lamb enterprises ranged from 2-5%, and there were synergies between wool, lamb, live sheep trading, beef and cropping enterprises. Analysis of production factors showed that producers in benchmarking schemes need to improve several factors as none stood out.

Executive Summary

The project objectives embraced sheep meat and wool productivity improvement, identification of sheep enterprise profit drivers, development of sheep farm economic production indices and comparisons of sheep enterprise profitability.

Positive genetic parameters found for meat and wool traits in the 27 Merino flocks monitored mean both traits can be improved simultaneously. Body weight was highly heritable and eye muscle depth moderately. The meat traits were moderately positively correlated. There were moderate to high correlations between body weight and both wool and meat traits. However there were some unfavourable correlations between eye muscle depth and both fleece weight and fibre diameter. Use of a weighted selection index can allow eye muscle depth and fleece weight to be increased while fibre diameter is held or decreased.

Wool traits were highly heritable, particularly fibe diameter at 0.71. There was a strong negative genetic correlation between CV of fibre diameter and staple strength meaning lower CVs indicated greater staple strength. Unfavourable genetic correlations existed between fleece weight and fibre diameter, and between fibre diameter and staple strength. The 0.31 correlation for the latter means selection for reduced fibre diameter will also cause staple strength to decline. These unfavourable correlations can be overcome by including the traits in a weighted selection index. For the new wool traits curvature was highly correlated with crimp frequency and resistance to compression while both crimp frequency and resistance to compression had moderately high heritabilities. Therefore curvature measurements from OFDA2000 can be used to predict and select for crimp frequency and resistance to compression.

The genetic correlations and heritabilities discussed above are similar to wider based SGA estimates for standard traits.

Sheep enterprise comparisons based on GrassGro modelling over four sites in southern NSW and Vic was completed early in 2006. The main findings were that lamb production in dual purpose and prime lamb enterprises was generally more profitable than self replacing Merino enterprises. However turnoff of yearling Merino wethers in fine wool flocks was very competitive. It was concluded that there was big variation in profitability across sites within these enterprise groupings and that attention to key management factors such as stocking rate and lambing date were important within existing enterprises. Some fine tuning of enterprise mix could be warranted in many cases.

These results complement the earlier Holmes-Sackett modelling work done as part of this project which showed that turnoff of yearling Merino wethers for meat was competitive with other sheep enterprises and allowed diversification into dual meat-wool production using the existing Merino flock base.

Combined GrassGro-MIDAS work involved complementary biophysical (GrassGro) and income optimization (MIDAS) modelling. The project investigated potential to diversify to grain finished meat production from Merinos based on Merinotech case study properties in South West WA. Main findings were:

- At standard prices, finishing a high proportion of wether lambs at 7 months of age is more profitable than selling wether lambs as stores, yearlings or shippers.
- The average amount of grain (wheat) required to finish 90% of Merino lambs is 76kg per head. Approximately 54kg is required to finish 10% of Merino lambs.
- Seasonal conditions before and after weaning impacts on the amount of supplement to finish lambs. Producers need to retain up to 85kg/lamb in a poor season to finish 90% of their Merino lambs.
- When grain prices are high or when sheep prices are low, it is more profitable to sell wether lambs as stores or yearlings than to finish Merino prime lambs.
- High quality paddock feed is better utilised by finishing lambs than by ewes to improve reproductive rate.
- Very little difference in profit is generated from selecting lambs for finishing by weight compared with a random draft.

The farm benchmarking work aimed to develop new methodologies to add value to benchmarking data sets. Included was bioeconomic estimates of technical efficiency (outputs/inputs), total factor productivity (total outputs/inputs including new technologies and scale effects) and scope economies (synergies between enterprises). Statistical analysis aimed to identify key performance indicators of profit as indicated by gross margins.

Main points from this work were:

- Technical efficiency showed large variation among benchmarked farmer groups
- While stocking rate was a key factor for greater output there was evidence of lower technical efficiencies at higher stocking rates
- Mean annual productivity increase in wool and lamb enterprises ranged from 2% to 5% with no evidence of productivity change in dual purpose enterprises
- Analysis of benchmarking data across regions was of marginal use due to variable environmental influences
- Scope economies showed synergies between wool, lamb, live sheep trading, beef, and cropping
- Training of three benchmarking providers in the above analytical methodologies was successful.
- Different statistical approaches have included multiple regressions, principal components and development of a cause and effect process model with general linear mixed models
- Using the latter model 19 key performance indicators relating to gross margins were identified out of 49 performance indicators
- It was hypothesised that the benchmarking producers studied need to improve several aspects of their enterprises simultaneously i.e. no individual indicators stood out
- It is recommended that the sheep production process model be incorporated into a computer aided expert system for producers to identify areas for improvement.

The impacts of genetic improvement for meat and wool traits will be almost immediate as SGA currently has both meat and wool as well as dual purpose ASBV options including selection indices. Results from this project will provide material to SGA for fine tuning of ASBVs while general extension from the project will be a catalyst to meat and wool improvement. In five years time it is estimated that this project will have stimulated a 10% improvement in genetic merit for meat and wool traits across 20% of the Australian sheep industry.

Most progress from sheep enterprise comparisons will come from improvement in key management factors of stocking rate and lambing date. In addition there will be fine tuning of enterprise mixes and a probable increase in turnoff of Merino prime lambs and yearlings for meat. With the widespread extension by the project team and industry partners it is projected that improved meat and wool production will range from 5% immediately to 10% across 20% of sheep producers in five years time.

Industry impact from the benchmarking work will be through more effective and increased farm benchmarking and from general industry messages. It is estimated that 3% of producers will improve their production by 5% annually within five years as a result of the farm benchmarking work.

The genetic parameters from the Merino meat-wool interface work should be considered by SGA in terms of possible segmentation of Merino flocks by region for estimation of ASBVs, Development of the new wool ASBVs including trueness to type and resistance to compression (RTC) should proceed once the crimp frequency and RTC measurements are available commercially. Ongoing work as part of a PhD from this project on mapping of G*E risk for meat and wool traits will be reported to MLA later this year.

Increased meat from purebred Merinos will receive a boost from the Merino prime lamb and yearling results being included in ongoing MLA and sheep industry extension

Sheep enterprise comparisons will focus attention more on improvement within existing enterprises through key management factors like lambing date and stocking rate rather than opting for change. Attention should be drawn to the large variation in profitability within enterprises and the scope for improvement.

Ongoing training of consultants in the new farm benchmarking methodologies developed including technical efficiency, total factor productivity and identification of key performance indicators, should be encouraged. Key industry messages coming from this benchmarking project such as productivity trends should continue to be part of MLA and sheep industry extension.

Contents

1 Background

Recent changes in the Australian sheep industry have seen an increasing proportion of income from meat and hence more importance on improving meat and wool production simultaneously. Improvement of both wool and meat ensures a dual product income and helps insulate producers against reduced income due to commodity price fluctuations.

Improved meat and wool productivity can be approached at various levels including individual sheep, sheep enterprises and the whole farm. Improvements in each of these areas can be complementary and offer a range of opportunities to producers.

The Sheep Genetics Australia service has offered producers good opportunities through their ram breeders for genetic improvement in meat and wool traits. However there has been a lack of information on the meat-wool interface or the interrelationships between the various traits. Similarly the significance of contrasting environments for genetic improvement in meat and wool, and management implications have not been well understood.

With the swing to more emphasis on meat production there has been a trend towards a greater proportion of breeding ewes in sheep flocks at the expense of wethers for specialist wool production. At the same time there has been much debate on the pros and cons of dual purpose meat and wool from Merinos as opposed to use of specialist meat sires crossed with Merinos or crossbred ewes. The general belief has been that there are good opportunities for all these sheep enterprises but that producers lack comparative information on which to base their choice of enterprise or balance of different enterprises within their farm.

Sheep farm benchmarking has shown quite spectacular differences in profitability between the top 20% of producers and the average within client based datasets. Despite the large gap in productivity it has not been easy to lift the average producers performance due to confounding effects of different environments, cost-price variability and other factors. Similarly it has been difficult to identify the main profit drivers due to the complex interrelationships between them.

Note: as more detailed reports on all aspects of the project are appended this report is brief.

2 Project Objectives

The project objectives were to:

- Establish relationships between meat and wool traits in yearling Merinos in a range of environments
- Identify the relative importance of different profit drivers for various sheep enterprises
- Complete desktop studies to compare the profitability of various Merino meat and wool production systems
- Model various sheep enterprises to develop biological and economic guidelines to optimize profit and minimise risk in various environments

An overriding objective was for effective dissemination of results and recommendations. This was to involve regular presentations and publications by the project team, four major regional forums at the conclusion of the project and use of extension networks of partner organizations.

3 Methodology

3.1 Merino meat - wool interface

Mid side wool samples were collected from approximately 300 ewe and ram yearlings/hoggets from each of the 27 co-operating Merino breeder flocks during 2004-05 and 2005-06. Measurements on these wool samples included length, strength, yield and Laserscan at AWTA, OFDA2000 at IWG and wool style at CSIRO Chiswick. In addition ultrasound fat and eye muscle depth were available via SGA as were live weights and fleece weights.

The location of breeder properties and grouping according to climatic regions is shown in Fig. 1.

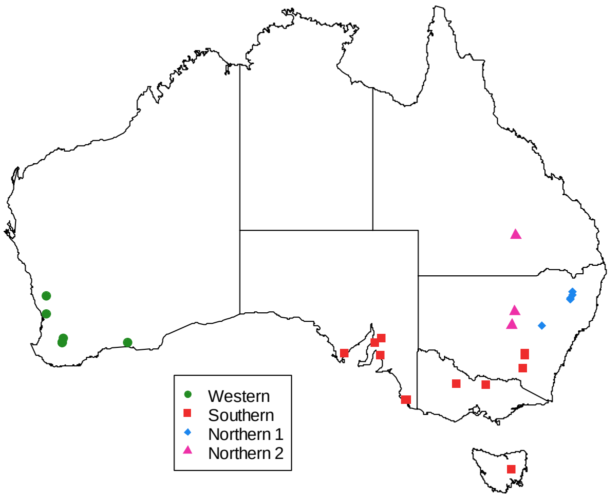

Fig. 1: Location of co-operating Merino breeder flocks and regional groupings

3.2 Sheep enterprise comparisons

Profitability of a range of sheep enterprises was modelled using GrassGro over four case study locations. These locations included Cowra in central-west NSW, Rutherglen in north-eastern Vic, Mortlake in south-western Vic and Naracoorte in south-eastern SA. Gross margins were compared over a wide range of sheep enterprises including Merino, first cross and prime lamb with different lamb finishing scenarios. In addition some joint Grassgro and MIDAS modelling was done to evaluate the profitability of Merino prime lamb production in south-west WA.

A sophisticated gross margin model was used by Holmes Sackett and Associates to compare self replacing Merinos, terminal sire x Merino (first cross) and terminal sire x crossbred ewe (prime lamb). Within each enterprise scenarios of either selling weaners or yearlings were compared in addition to selling adult wethers with self replacing Merinos.

3.3 Sheep farm benchmarking

New data processing methodology was developed with the co-operation of three sheep farm benchmarking schemes including Holmes Sackett and Assoc., JRL Hall and Co., and the Victorian Farm Monitor Project. New methodologies were developed to add value to benchmarking data sets. Included has been bioeconomic estimates of technical efficiency (outputs/inputs), total factor productivity (total outputs/inputs including new technologies and scale effects) and scope economies (synergies between enterprises). Statistical analysis aimed to identify key performance indicators of profit as indicated by gross margins.

4 Results and Discussion

4.1 Merino meat – wool interface

Collection and measurement of wool samples from some 16,000 ewe and ram yearlings/hoggets has been completed with the 27 co-operating Merino breeders over two years. This comprehensive dataset includes all standard SGA wool traits as well as new wool traits including resistance to compression and crimp frequency. In addition standard wool style measurements include greasy colour, crimp frequency, dust content and colour, and staple definition. Live weights and muscle and fat scan data on the same animals in the 27 flocks were available from SGA.

Genetic correlations between core meat and wool traits as in SGA, and the new wool traits including curvature, crimp frequency and resistance to compression, are given in the following table with heritabilities shown in bold.

Table 1: Genetic correlations and heritabilites for meat and wool traits.

	GFW	CFW	FD	FDCV	SS	CUR	CR	RTC	WT	EMD	FAT
GFW	**0.41**										
CFW	0.90	**0.30**									
FD	0.28	0.25	**0.73**								
FDCV	0.07	-0.06	-0.06	**0.52**							
SS	0.13	0.30	0.31	-0.50	**0.44**						
CUR	-0.28	-0.33	0.11	0.06	0.11	**0.27**					
CR	-0.38	-0.49	-0.15	-0.12	0.13	0.83	**0.41**				
RTC	-0.12	-0.14	0.35	0.23	0.03	0.77	0.49	**0.41**			
WT	0.46	0.43	0.17	-0.30	0.21	0.15	0.15	0.13	**0.47**		
EMD	-0.20	-0.12	0.13	-0.09	0.20	0.20	0.14	0.22	0.54	**0.23**	
FAT	-0.36	-0.15	0.20	0.02	0.16	0.09	0.13	0.16	0.45	0.54	**0.10**

GFW-greasy fleece weight; CFW-clean fleece weight; FD-fibre diameter; FDCV-CV of fibre diameter; SL-staple length; SS-staple strength; CUR-curvature; CR-crimp frequency; RTC-resistance to compression; WT-live weight; EMD-eye muscle depth; FAT- fat depth.

Body weight was highly heritable and eye muscle depth moderately. The meat traits were moderately positively correlated. There were moderate to high correlations between body weight and both wool and meat traits. However there were some unfavourable correlations between eye muscle depth and both fleece weight and fibre diameter. Use of a weighted selection index can allow eye muscle depth and fleece weight to be increased while fibre diameter is held or decreased.

Wool traits were highly heritable, particularly fibe diameter at 0.71. There was a strong negative genetic correlation between CV of fibre diameter and staple strength meaning lower CVs indicated greater staple strength. Unfavourable genetic correlations existed between fleece weight and fibre diameter, and between fibre diameter and staple strength. The 0.31 correlation for the latter means selection for reduced fibre diameter will also cause staple strength to decline. These unfavourable correlations can be overcome by considering the traits in a weighted selection index. For the new wool traits curvature was highly correlated with crimp and resistance to compression while both crimp and resistance to compression had moderately high heritabilities. Therefore curvature measurements from OFDA2000 can be used to predict and select for crimp frequency and resistance to compression.

These results indicate that simultaneous genetic improvement in meat and wool traits is possible in Merinos.

The genetic correlations and heritabilities discussed above are similar to SGA estimates for their standard traits. Alignment with the SGA dataset will subsequently allow inclusion of meat, wool, reproduction and disease traits in a broader analysis.

Genetic means for wool and meat traits.

Average breeding values (EBVs) have been calculated for key wool and meat traits in each flock. These EBVs are derived from the actual heritabilities and phenotypic values from this dataset as well as background pedigree information from the wider SGA database. Average EBVs for each region are given in Table 2.

Table 2: Average estimated breeding values for the flocks in each region

	Meat			wool			new wool		
Region	**WT**	**EMD**	**FAT**	**GFW**	**FD**	**SS**	**RTC**	**CUR**	**CR**
Northern1	-1.14	-0.16	-0.02	-0.08	-0.18	-0.27	-0.07	0.37	0.00
Northern2	0.32	-0.01	-0.04	0.05	-0.22	0.43	-0.05	-0.43	-0.02
Southern	0.29	-0.02	-0.01	0.08	-0.15	0.13	-0.11	-0.65	-0.05
Western	0.08	-0.05	-0.01	0.02	-0.06	0.31	0.00	0.34	0.05

Comparisons of average EBVs between regions indicate more variation in meat than wool traits with the exception of curvature. The Northern1 flocks (Northern Tablelands) appear on average to have less genetic potential for improved meat traits than their western and southern counterparts but have similar fleece weight genetics with a tendency to lower micron and higher crimp frequency than the other regions.

Further detail is given in Geenty *et al.*, Appendix 1.

Three conference papers have been completed (Geenty *et al. 2006;* Geenty *et al. 2007;* Brown *et al.* 2007) on genetic parameters for meat and wool traits from this project. In addition environmental data including satellite remote imaging of vegetation and rainfall has been obtained for all 27 breeder sites over the two years. Benchmarking reports have been provided to all 27 co-operating Merino breeders. Four New Century Tools for Merino forums have been successfully completed during May-June 2007 at Armidale, Rutherglen, Turretfield and Katanning with between 45 and 155 attendees at each and very favourable evaluations.

4.2 Sheep enterprise comparisons

The GrassGro modelling based on four sites in southern NSW and Vic was completed early in 2006 (see *Warn et al*., 2005, Appendix 2). The main findings were that lamb production in dual purpose and prime lamb enterprises was generally more profitable than self replacing Merino enterprises. However turnoff of yearling Merino wethers in fine wool flocks was very competitive. It was concluded that there was big variation in profitability across sites within these enterprise groupings and that attention to key management factors such as stocking rate and lambing date were important within existing enterprises. Some fine tuning of enterprise mix could be warranted in many cases.

These results complement the earlier Holmes-Sackett modelling work done as part of this project (see McEachern, 2004, Appendix 3) which showed that turnoff of yearling Merino wethers for meat was competitive with other sheep enterprises and allowed diversification into dual meat-wool production using the existing Merino flock base.

Combined Grassgro-MIDAS work involved complementary biophysical (GrassGro) and income optimization (MIDAS) modelling (see Kopke *et al.*, 2007, Appendix4). The project investigated potential to diversify to meat production from Merinos based on Merinotech case study properties in south-west WA. The report covers profitability of finishing Merino wether lambs as prime lambs, and identifies how profit is influenced by age of turnoff and the proportion of wether lambs finished. Also covered is the level of feed for various turn-off target weights over a range of seasons. Main findings were:

- At standard prices, finishing a high proportion of wether lambs at 7 months of age is more profitable than selling wether lambs as stores, yearlings or shippers.
- The average amount of grain (wheat) required to finish 90% of Merino lambs is 76kg per head. Approximately 54kg is required to finish 10% of Merino lambs.
- Seasonal conditions before and after weaning impacts on the amount of supplement to finish lambs. Producers need to retain up to 85kg/lamb in a poor season to finish 90% of their Merino lambs.
- When grain prices are high or when sheep prices are low, it is more profitable to sell wether lambs as stores or yearlings than to finish Merino prime lambs.
- High quality paddock feed is better utilised by finishing lambs than by ewes to improve reproductive rate.
- Very little difference in profit is generated from selecting lambs for finishing by weight compared with a random draft.

4.3 Sheep farm benchmarking

This project aimed to develop new methodologies to add value to benchmarking data sets. Included has been bioeconomic estimates of technical efficiency (outputs/inputs), total factor productivity (total outputs/inputs including new technologies and scale effects) and scope economies (synergies between enterprises) (see Fleming *et al.*, Appendix 5). Statistical analysis aimed to identify key performance indicators of profit as indicated by gross margins (see Rutley, 2007, Appendix 6).

Main points from this work were:

- Technical efficiency showed large variation among benchmarked farmer groups
- While stocking rate was a key factor for greater output there was evidence of lower technical efficiencies at higher stocking rates
- Mean annual productivity increase in wool and lamb enterprises ranged from 2% to 5% with no evidence of productivity change in dual purpose enterprises
- Analysis of benchmarking data across regions was of marginal use due to variable environmental influences
- Scope economies showed synergies between wool, lamb, live sheep trading, beef, and cropping
- Training of three benchmarking providers in the above analytical methodologies was successful.
- Different statistical approaches have included multiple regressions, principal components and development of a cause and effect process model with general linear mixed models
- Using the latter model 19 key performance indicators relating to gross margins were identified out of 49 performance indicators
- It was hypothesised that the benchmarking producers studied need to improve several aspects of their enterprises simultaneously i.e. no individual indicators stood out
- It is recommended that the sheep production process model be incorporated into a computer aided expert system for producers to identify areas for improvement.

Workshops have been successfully completed to teach three of the participating benchmarkers (Holmes Sackett, JRL Hall and Farm Monitor Project) methodology for estimating technical efficiency and total factor productivity.

5 Success in Achieving Objectives

5.1 Merino meat-wool interface

Preliminary estimation of genetic and phenotypic parameters have provided new information on the positive relationships between meat and wool traits in this dataset. In addition genetic parameters for new wool traits have provided the opportunity for MLA to develop new wool ASBVs. Further work is planned with the dataset in Sheep CRC2 including relationships of meat and wool traits with reproductive and disease traits as well as environmental interactions with genetic parameters.

5.2 Sheep enterprise comparisons

The modelling work has provided guidelines for achievement of the highest gross margins with regard to different enterprises or combinations and key management factors. The work has relevance to different environments in south east Australia. The desktop study and combined GrassGro-MIDAS modelling has shown production of Merino prime lambs and yearlings for meat can compare favourably financially with other sheep enterprises.

5.3 Sheep farm benchmarking

Identification of key profit drivers has been difficult in the benchmarking datasets studied with the conclusion that small improvements across a number of production factors are needed. Lack of obvious profit drivers is probably due to client consultancy and is in contrast to the modelling work which identified stocking rate and lambing date as two key management factors. Valuable methodologies for economic analyses of farm benchmarking datasets were developed.

6 Impact on Meat and Livestock Industry – now & in five years time

6.1 Genetic improvement

The impacts of genetic improvement for meat and wool traits will be almost immediate as SGA currently has both meat and wool as well as dual purpose ASBV options including selection indices. Results from this project will provide material to SGA for fine tuning of ASBVs while general extension from the project will be a catalyst to meat and wool improvement. In five years time it is estimated that this project will have stimulated a 10% improvement in genetic merit for meat and wool traits across 20% of the Australian sheep industry.

6.2 Sheep enterprise improvements

Most progress from sheep enterprise comparisons will come from improvement in key management factors of stocking rate and lambing date. In addition there will be fine tuning of enterprise mixes and a probable increase in turnoff of Merino prime lambs and yearlings for meat. With the widespread extension by the project team and industry partners it is projected that improved meat and wool production will range from 5% immediately to 10% across 20% of sheep producers in five years time.

6.3 Sheep farm benchmarking

Industry impact from the benchmarking work will be through more effective and increased farm benchmarking and from general industry messages. It is estimated that 3% of producers will improve their production by 5% annually within five years as a result of the farm benchmarking work allied with sound farm consultancy advice.

7 Conclusions and Recommendations

The genetic parameters from the Merino meat-wool interface work should be considered by SGA in terms of possible segmentation of Merino flocks by region for estimation of ASBVs. Development of the new wool ASBVs including trueness to type and resistance to compression (RTC) should proceed once the crimp frequency and RTC measurements are available commercially. Ongoing work as part of a PhD study from this project on mapping of G*E risk for meat and wool traits will be reported to MLA later this year.

Increased meat from purebred Merinos will receive a boost from the Merino prime lamb and yearling results being included in ongoing MLA and sheep industry extension

Sheep enterprise comparisons will focus attention more on improvement within existing enterprises through key management factors like lambing date and stocking rate rather than opting for change. Attention should be drawn to the large variation in profitability within enterprises and the scope for improvement.

Ongoing training of consultants to use the new farm benchmarking methodologies developed including technical efficiency, total factor productivity and identification of key performance indicators, should be encouraged. Key industry messages coming from this benchmarking project such as productivity trends should continue to be part of MLA and sheep industry extension.

8 Bibliography

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9 Appendices

9.1 Appendix 1

Merino wool-meat interface (Geenty *et al.* 2007). *Also contains other papers from New Century Tools for Merino forums.*

9.2 Appendix 2

Profitability of sheep wool and meat enterprises (Warn *et al.* 2005).

9.3 Appendix 3

Yearling Merino sheep production systems (McEachern, 2004).

9.4 Appendix 4

Merino prime lamb finishing systems (Kopke *et al.* 2007).

9.5 Appendix 5

Efficiency and productivity of wool production (Fleming *et al.* 2007).

9.6 Appendix 6

Farm enterprise benchmarking (Rutley, 2007)

SHEEP CRC

NEW CENTURY TOOLS FOR MERINOS

ARMIDALE	MAY 31, 2007
RUTHERGLEN	JUNE 19, 2007
ROSEDALE	JUNE 22, 2007
KATANNING	JUNE 25, 2007

CSIRO
australian wool innovation limited
mla MEAT & LIVESTOCK AUSTRALIA
AWTA
THE UNIVERSITY OF MELBOURNE
AGBU ANIMAL GENETICS AND BREEDING UNIT A joint unit of NSW DPI and UNE
NSW DEPARTMENT OF PRIMARY INDUSTRIES
InteractiveWoolGroup "The OFDA People"
MERINOSELECT

CRC AUSTRALIA

PARTICPANTS: Allflex Pty Ltd • Australian Meat Processor Corporation Ltd • Australian Wool Innovation Limited • Australian Wool Testing Authority Limited • Commonwealth Scientific and Industrial Research Organisation • Hall Family Trust and Ritchie Family Trust trading as JRL Hall & Co • Holmes, Sackett and Associates Pty Limited • Mike Stephens & Associates • Meat & Livestock Australia Limited • Murdoch University • NSW Department of Primary Industries for and on behalf of the State of New South Wales • Ridley Agriproducts Pty Ltd • Sheepmeat Council of Australia • State of Queensland acting through the Department of Primary Industries and Fisheries • State of South Australia acting through the Department for Primary Industries and Resources (SA) trading as SARDI • State of Victoria acting through the Department of Primary Industries • State of Western Australia represented by the Director General of Agriculture • University of New England • University of Tasmania • University of Western Australia • WoolProducers Australia Limited

THE SHEEP CRC LTD IS A JOINT VENTURE ESTABLISHED AND SUPPORTED UNDER THE AUSTRALIAN GOVERNMENT'S COOPERATIVE RESEARCH CENTRES PROGRAM

CONTENTS

Sheep Genetics Australia information materials are provided in the forum bags.

Merino wool-meat interface

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Summary

Information on wool and meat traits was collected from some 16,000 Merino ewe and ram hoggets over two years in 27 co-operating breeders' flocks across Australia. Environmental information including rainfall and pasture growth rates was also recorded. There were no major genetic antagonisms between wool and meat traits, which mean they can be improved concurrently. Regional variation in estimated breeding values means breeders and producers can consider sourcing improved genetics from other regions according to their breeding objectives. OFDA2000 measurements allow use of coefficient of variation in fibre diameter to improve staple strength and curvature to predict crimp frequency and resistance to compression for new wool traits. Pasture growth data and fibre diameter profiles provide a retrospective means of improved feeding for better staple strength.

Introduction

The sheep industry in Australia has responded over the last three years to increased income from meat relative to wool. Up to 40% of Merino ewes have been mated to specialist meat breeds and a large proportion of wethers previously run for wool production have been replaced by breeding stock. Therefore, sheep producers are seeking ways to improve their income from both wool and meat simultaneously.

Improving both meat and wool production in Merinos has potential advantages from improved meat characteristics in Merino cross lambs. About 90% of lambs turned off for meat in Australia contain varying proportions of Merino genes.

An added advantage of having income from both wool and meat is the insulation against income vulnerability as commodity price swings for these products are cyclical and unrelated.

Aims

Our project had the primary aim of measuring relationships between wool and meat traits including some wool traits not currently part of the Sheep Genetics Australia (SGA) program. In addition, we obtained detailed information on the large range of environments to help develop improved breeding and management guidelines.

Project outline

Wool and meat traits were recorded over two years on some 16,000 2003 and 2004 born ewe and ram yearlings/hoggets with 27 co-operating Merino ram breeders across Australia (see Fig. 1 below). All flocks were recorded on SGA including standard wool and meat traits and ultrasound muscle and fat depths. In addition we collected mid side wool samples for (a) length, strength, yield, crimp frequency, laserscan and resistance to compression tests by the Australian Wool Testing Authority; (b) OFDA2000 testing by the Interactive Wool Group; and (c) visual and measured wool style by CSIRO at Chiswick. In addition, satellite data for each of the 27 sites obtained through CSIRO's Pastures from Space project gave pasture growth rates.

The location of breeder properties and grouping according to climatic regions is shown in Figure 1.

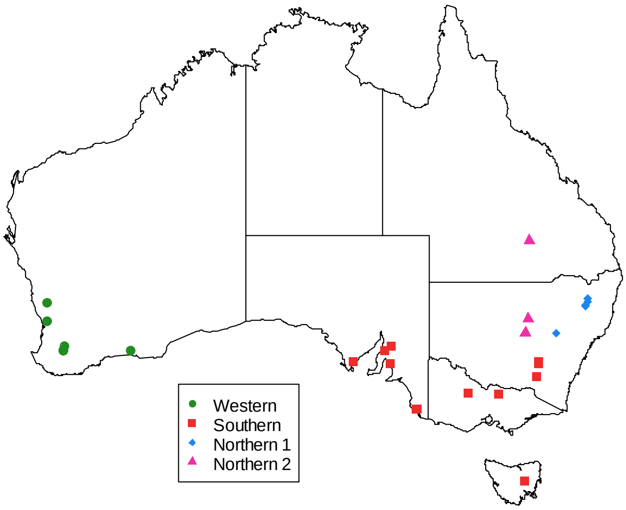


Figure 1: Location of co-operating Merino breeder flocks and regional groupings

Results and discussion

The results are presented as regional averages as outlined in Figure 1 under the following headings –

- Phenotypic means for wool and meat traits
- Genetic variability and associations between wool and meat traits
- Genetic means for wool and meat traits
- Fibre diameter profiles and pasture information

Phenotypic means.
Average phenotypic means for wool and meat traits are given by region in Table 1.

Table 1: Phenotypic means for wool and meat traits by regions and years

Region	Year	Yearling or Hogget wt (kg)	Greasy fleece wt (kg)	Wool micron	Staple strength (N/ktex)	Eye muscle depth (mm)	Fat depth (mm)
Western	1	45.4	4.0	17.4	31.1	21.2	2.5
	2	47.8	4.0	17.7	37.2	21.0	1.0
Southern	1	47.6	3.8	17.3	33.6	23.0	2.7
	2	47.8	3.6	17.8	32.2	21.9	2.7
Northern1	1	52.4	4.9	16.8	45.4	22.0	2.5
	2	48.1	4.0	15.7	46.4	23.3	2.8
Northern2	1	46.3	4.0	18.2	39.8	23.4	2.4
	2	36.0	2.8	17.7	31.3		

The above means represent environmental differences, independent of genetic differences, including climate, pasture and management. There are few obvious trends in the data though Northern1 (Northern Table Lands) appear to have comparatively heavier body weights and

fleece weights, despite lower wool micron, probably due to later weighing and shearing when animals are comparatively older.

Genetic variability and associations.

Heritabilities and genetic correlations describe the amount of genetic variability and associations between traits. A heritability of 0.30 or 30% means that 30% of the variability between animals is under genetic control through their breeding values. Genetic correlations describe how closely two traits are genetically related with values between -1 and 1. The nearer the values are to zero the weaker the relationship between traits.

Genetic correlations between core wool traits as in SGA, and the new wool traits including curvature, crimp frequency and resistance to compression, are given in the following table with heritabilities shown in bold.

Table 2: Genetic correlations and heritabilities for wool and meat traits.

	GFW	CFW	FD	FDCV	SS	CUR	CR	RTC	WT	EMD	FAT
GFW	**0.41**										
CFW	0.90	**0.30**									
FD	0.28	0.25	**0.73**								
FDCV	0.07	-0.06	-0.06	**0.52**							
SS	0.13	0.30	0.31	-0.50	**0.44**						
CUR	-0.28	-0.33	0.11	0.06	0.11	**0.27**					
CR	-0.38	-0.49	-0.15	-0.12	0.13	0.83	**0.41**				
RTC	-0.12	-0.14	0.35	0.23	0.03	0.77	0.49	**0.41**			
WT	0.46	0.43	0.17	-0.30	0.21	0.15	0.15	0.13	**0.47**		
EMD	-0.20	-0.12	0.13	-0.09	0.20	0.20	0.14	0.22	0.54	**0.23**	
FAT	-0.36	-0.15	0.20	0.02	0.16	0.09	0.13	0.16	0.45	0.54	**0.10**

GFW-greasy fleece weight; CFW-clean fleece weight; FD-fibre diameter; FDCV-CV of fibre diameter; SL-staple length; SS-staple strength; CUR-curvature; CR-crimp frequency; RTC-resistance to compression; WT-live weight; EMD-eye muscle depth; FAT- fat depth.

Wool traits were highly heritable, particularly fibre diameter at 0.71. There was a strong negative genetic correlation between CV of fibre diameter and staple strength meaning lower CVs indicated greater staple strength. Unfavourable genetic correlations existed between fleece weight and fibre diameter, and between fibre diameter and staple strength. The 0.31 correlation for the latter means selection for reduced fibre diameter will also cause staple strength to decline. These unfavourable correlations can be overcome by considering the traits in a weighted selection index. For the new wool traits, curvature was highly correlated with crimp and resistance to compression while both crimp and resistance to compression had moderately high heritabilities. Therefore, curvature measurements from OFDA2000 can be used to predict and select for crimp frequency and resistance to compression.

Body weight was highly heritable and eye muscle depth moderately. The meat traits were moderately positively correlated. There were moderate to high correlations between body weight and both wool and meat traits. However, there were some unfavourable correlations between eye muscle depth and both fleece weight and fibre diameter. Use of an appropriate selection index can allow eye muscle depth and fleece weight to be increased while fibre diameter is decreased.

The genetic correlations and heritabilities discussed above are similar to SGA estimates for their standard traits.

Genetic means for wool and meat traits.
Average breeding values (EBVs) have been calculated for key wool and meat traits in each flock. These EBVs are derived from the actual heritabilities and phenotypic values from this dataset as well as background pedigree information from the wider SGA database. Average EBVs for each region are given in Table 3 and ranges are in Fig. 1.

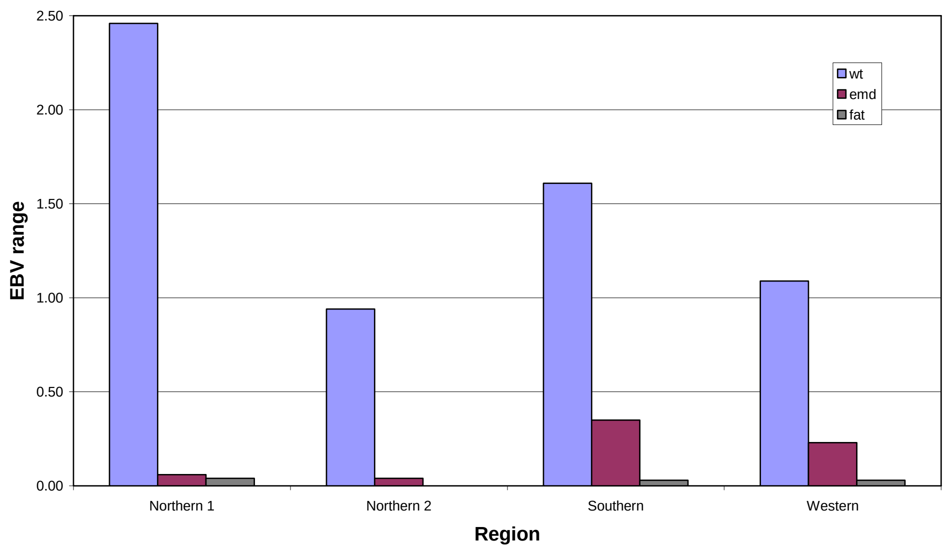
Table 3: Average estimated breeding values for the flocks in each region

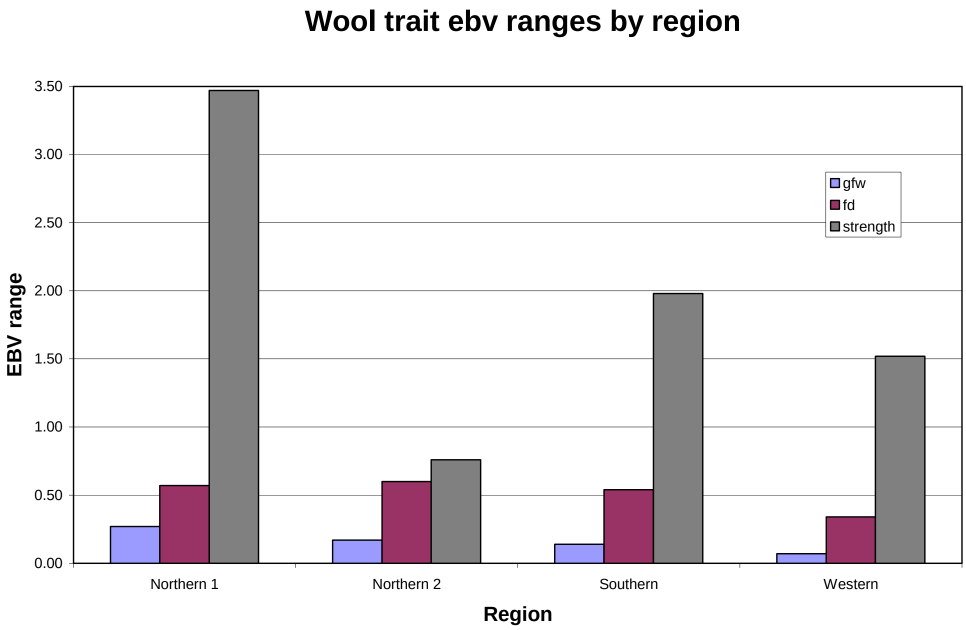
		Meat			wool			new wool	
Region WT	**EMD**	**FAT**	**GFW**	**FD**	**SS**	**RTC**	**CUR**	**CR**	
Northern1	-1.14	-0.16	-0.02	-0.08	-0.18	-0.27	-0.07	0.37	0.00
Northern2	0.32	-0.01	-0.04	0.05	-0.22	0.43	-0.05	-0.43	-0.02
Southern	0.29	-0.02	-0.01	0.08	-0.15	0.13	-0.11	-0.65	-0.05
Western	0.08	-0.05	-0.01	0.02	-0.06	0.31	0.00	0.34	0.05

Comparisons of average EBVs between regions indicate more variation in meat than wool traits. The Northern1 flocks (Northern Tablelands) appear on average to have less genetic potential for improved meat traits than their western and southern counterparts, however all four regions still have significant opportunity for selection. While the four regions have similar fleece weight genetics, the northern region has a tendency to lower micron and higher crimp frequency.

Ranges in meat and wool trait EBVs, relating to averages in Table 3 for each region are given in Figure 1 below. Note that these values can be positive and/or negative.

Meat trait ebv ranges by region





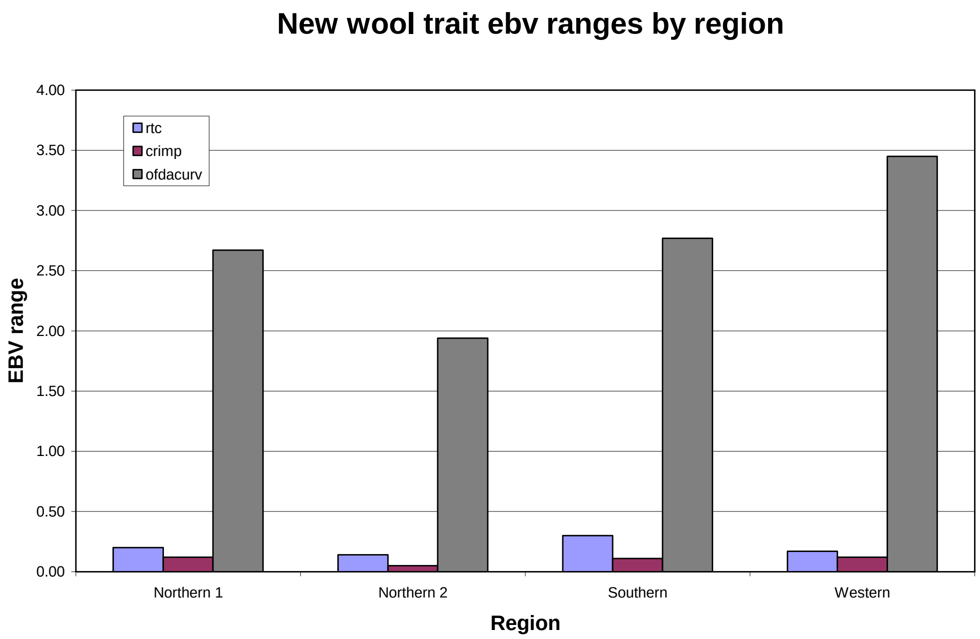


Figure 1: Ranges in average flock EBVs meat and wool traits in each region.

Note that the above graphs contain standardised EBV ranges.. The ranges for average flock breeding values showed that breeding flocks in the Northern1 region had comparatively greater variation in live weight and wool staple strength while western region flocks had the most variation in wool curvature. These results indicate comparatively greater potential for genetic improvement in live weight and staple strength in the Northern1 region than indicated by the average values in Table 4. The new wool traits, curvature in particular, had greatest variation in the western region. This provides opportunities for both breeders and commercial producers to explore these regional differences by sourcing genetic material to better match their breeding objectives.

Pasture information

Pasture growth information averaged over properties in the two contrasting Western and Northern1 regions for the two years of the project is given in Figure 2 below.

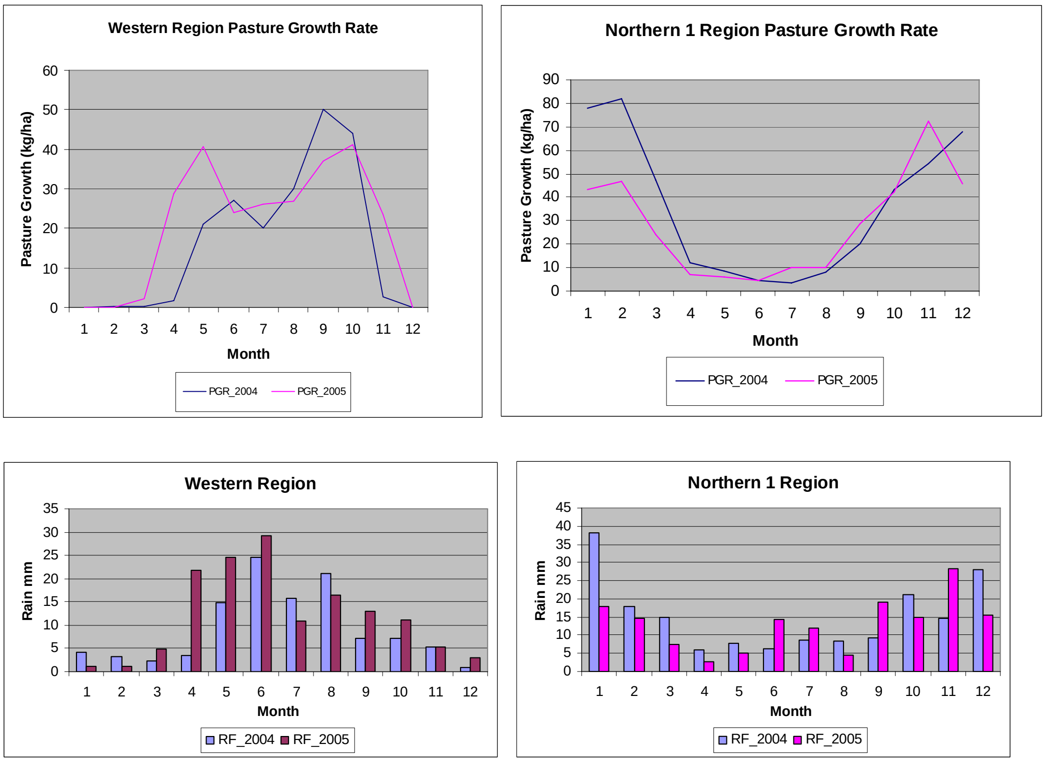
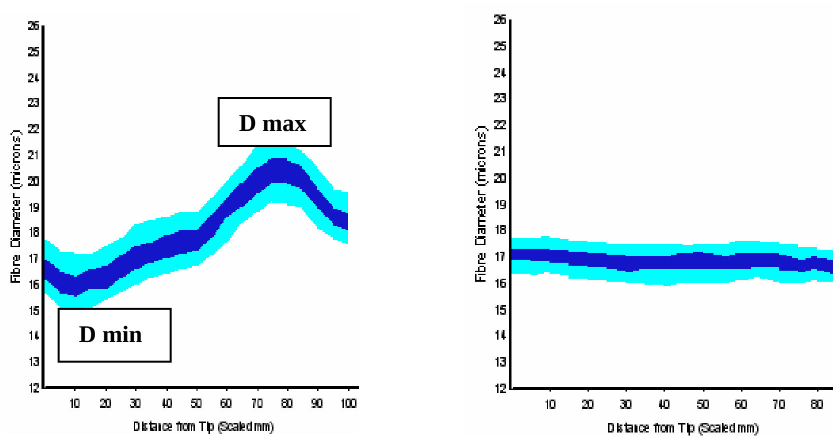


Figure 2: Average pasture growth rates and rainfall for the Western and Northern1 regions.

The pasture growth information in Fig. 2 above has been obtained from satellite data kindly supplied by CSIRO's Pastures from Space project. The two contrasting regions show winter (Western) and summer (Northern1) dominant pasture growth aligned with the rainfall data in the lower graphs. Within each of these regions, there was considerable variation among the various breeder properties in rainfall and pasture growth variation.

Fibre diameter profiles

The OFDA2000 measures fibre diameter profiles, which give changes in fibre diameter along the wool staple. Results from our project show there is much greater variation in fibre diameter in the southern and western regions with Mediterranean type climates with hot dry summers than in the more temperate northern climates with more equitable rainfall. Typical fibre diameter profiles from these contrasting regions are shown in Figure 3.



Mediterranean **Temperate**

Figure 3: Typical fibre diameter profiles from Mediterranean and temperate climates

Average flock differences between maximum (Dmax) and minimum (Dmin) fibre diameter are plotted against average staple strength for 18 of the co-operating flocks during year one of the project in Fig. 4.

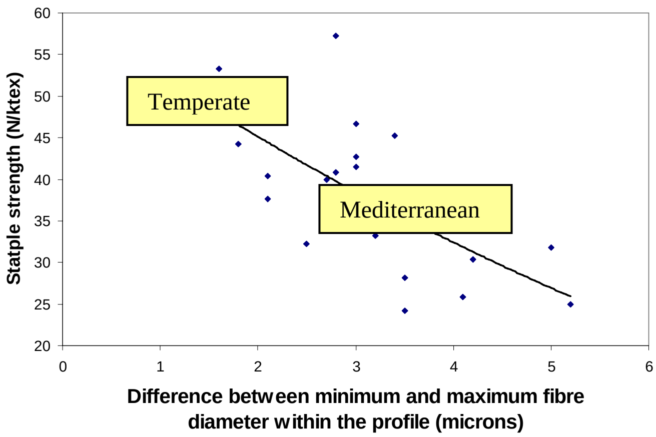


Fig. 4: Relationship between flocks with low fibre diameter profile variation in temperate regions in contrast with higher variation in Mediterranean climates.

The average flock differences between Dmax and Dmin gave a good indication of average staple strength as shown in Fig. 4 above.

For improved staple strength management, breeders should aim to flatten the profiles with most emphasis on preferential feeding during the time period of minimum fibre diameter. The example in Fig. 3 above indicates that under Mediterranean conditions with shearing in late spring preferential feeding over the summer would have improved staple strength. However, the cost effectiveness of this strategy would need to be assessed. This same principle applies in temperate conditions where there are low staple strength wools due to nutritional stress. Use of OFDA2000 and pasture growth rate data can define periods for preferential feeding.

Conclusions

The results from this project on wool and meat traits give breeders and commercial producers guidelines for genetic improvement in wool and meat production. There is also information

about use of pasture growth rates and fibre diameter profiles to improve wool staple strength. The main take home messages for breeders and producers are –

- The genetic parameters for standard SGA traits in this study did not vary greatly (with a few exceptions) from SGA values
- There are no major antagonisms between wool and meat traits in Merinos so breeders and their ram buyer clients can genetically improve both wool and meat production at the same time
- The unfavourable genetic correlations between fleece weight and fibre diameter, fibre diameter and staple strength, and eye muscle depth and greasy fleece weight/fibre diameter, can be overcome with use of appropriate selection indexes
- Regional variation in wool and meat trait EBVs provides opportunities for breeders and producers to source improved genetics
- Selection for lower coefficient of variation in fibre diameter from OFDA2000 profiles is the best tool to use for improvement in staple strength
- Values for the new wool trait curvature from OFDA2000 can be used to predict the other new wool traits of crimp frequency and resistance to compression.
- Pasture growth data and fibre diameter profiles can be used retrospectively for improved feeding during periods of pasture shortage to improve staple strength

Acknowledgements

Grateful acknowledgement is made to the following: the 27 co-operating Merino breeders; MLA and AWI for financial and technical support; AWTA and IWG for in-kind laboratory support; provision of Pastures from Space data by Graham Donald, CSIRO Chiswick; skilled technical input from Grant Uphill, Christine Dennis, Judi Kenny and Heather Brewer, CSIRO Chiswick.

Novel Merino Wool Quality Traits

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Summary

The project was conducted in conjunction with Sheep CRC Project 1.2.6, in which wool samples representing some 29 Sheep Genetics Australia (SGA) flocks were tested for a range of novel traits including resistance to compression, crimp frequency and measured and assessed style traits.

Genetic variation in novel traits:

- The novel traits of crimp frequency, resistance to compression, crimp definition, wool colour and staple size were moderately to highly heritable and therefore could be easily improved through selection.
- The genetic correlation between mean fibre curvature and crimp frequency was 0.84 to 0.93 suggesting that there is little need to measure crimp frequency to change it genetically.

Trueness to Type:

- The results also indicate that there is significant variation between Merino strains / flocks in their diameter and crimp relationships. That is some flocks have a measured fibre diameter consistently different to that predicted from their crimp frequency.
- A "Trueness to Type" score was calculated for each sheep which indicated its FD relative to that expected based on its crimp frequency.
- Given the strong genetic relationships between crimp frequency and fibre curvature it is also possible to predict a crimp frequency measurement from the standard fibre curvature measurement. This predicted crimp frequency measurement can also be used to calculate a Trueness to Type score. Trueness to Type classification could be made available in the near future following industry consultation and validation.

Prediction of resistance to compression:

- Measurements of resistance to compression can be predicted with moderate accuracy from the other wool measurements made in this study.
- At the genetic level, resistance to compression was significantly related to fibre diameter (0.36), fibre diameter coefficient of variation (0.21), fibre curvature (0.79), crimp frequency (0.52), variation in crimp frequency (0.96) and staple size (0.41). Therefore resistance to compression could easily be included in the breeding objective without the need for direct measurements.

Introduction

The focus of this project is to extend the scope of traits measured for SGA across-flock genetic evaluation, by developing the basis for trait definitions for several traits presently considered important to sheep classer and wool buyers – namely those relating to the visual 'style' and the tactile appeal of wool.

"Trueness to type" is a term used is the wool industry to define whether a fleece's crimp frequency matches its fibre diameter. Across flocks there is a strong relationship between these traits, with finer wools displaying a much higher crimp frequency and curvature than broader wools. Nevertheless, at any given fibre diameter, flocks are often under or over crimped, and therefore not "true to type".

Novel wool traits

Historically, trueness to type has been used by the wool trade as an integral component of a system allowing the prediction of processing performance to the yarn stage of greasy wool, using a system of "quality numbers". In assigning a quality number, trueness to type was combined with assessment of handle, colour, length and strength to estimate the number of 560 yard hanks of yarn able to be spun from per imperial pound of scoured wool. While the prediction of processing performance based on objective raw wool measures has advanced substantially over the years, trueness to type is still an important price determinant in some wool markets.
The compression characteristics of wool represent an important aspect of wool quality with requirements depending upon end use and processing conditions. Resistance to compression has also been shown to be significantly related to fibre curvature and crimp frequency.

This study will develop the preliminary basis for the estimation of breeding values for:

- Crimp frequency: new measurement technology has been used which enables a routine and objective measurement of crimp frequency.
- Trueness to type: the relativity of fibre curvature and crimp frequency with fibre diameter.
- Compressibility: as estimated using the measurement of resistance to compression and other raw wool traits.

The Data Used

This project was conducted in conjunction with Sheep CRC Project 1.2.6, whereby wool samples representing some 29 client flocks of Sheep Genetic Australia were tested for a range of wool parameters by IWG using OFDA2000 and AWTA using Laserscan and other measurement technology. Samples were also measures for style traits using the Style Machine and the same samples were visual assessed/scored for a similar range of style related traits.

The data set contained 12,085 animals (7,130 females and 4,951 males) with data and 22,397 animals in the pedigree. There were 374 sires and 6,000 dams with recorded progeny. The data originated from 29 SGA flocks and all animals measured were born in 2003, 2004 and 2005. All animals were measured at either at yearling or hogget ages. Some flocks also shore / tipped their sheep as lambs where others did not.

Genetic variation in novel traits

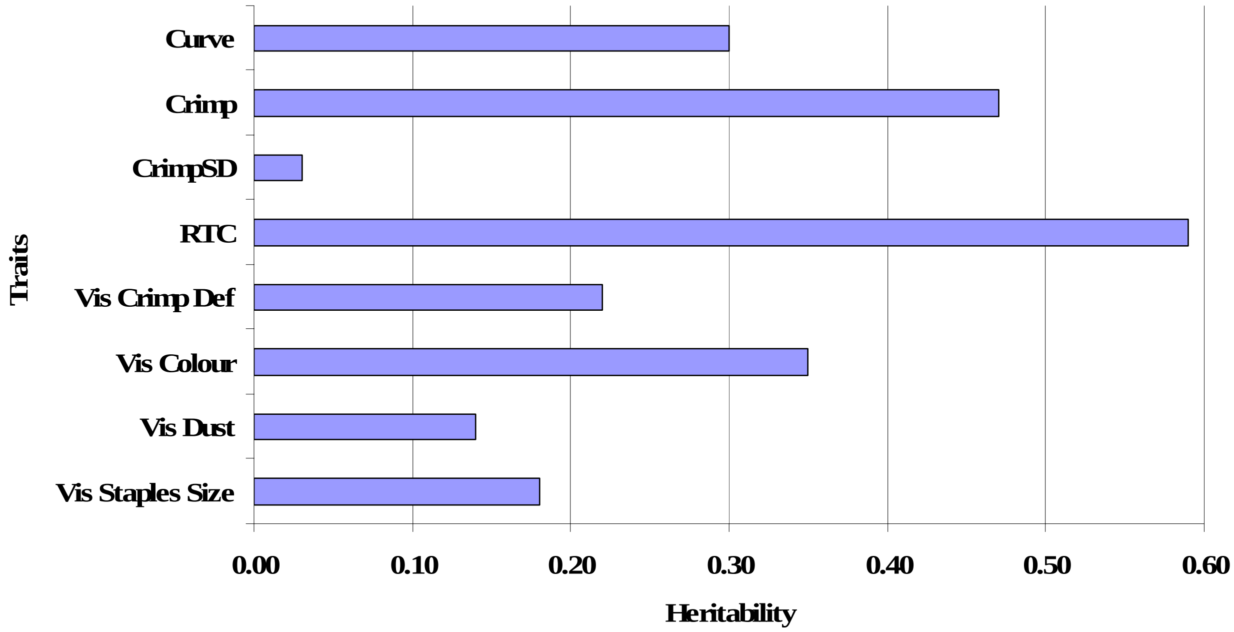
- The heritabilities of the standard wool traits agree with previous estimates from SGA data.
- As shown in Figure 1 below, the heritabilities for the novel traits were generally moderate to high except variation in crimp (CrimpSD) and dust penetration (Vis Dust).
- Visually assessed colour, crimp definition and dust were more highly heritable than the equivalent Style Machine traits.
- Fibre diameter measurements from Laserscan and OFDA were genetically and phenotypically the same traits, with genetic and phenotypic correlations of 0.98 and 0.89 respectively.
- Laserscan and OFDA fibre curvature had a high genetic correlation of 0.92, although the phenotypic correlation was only 0.53.
- Crimp frequency from AWTA was also genetically correlated with;
  - ✓ Greasy fleece weight -0.37
  - ✓ Staple length -0.43
  - ✓ Fibre diameter -0.15
  - ✓ Laserscan curvature 0.84
  - ✓ OFDA curvature 0.93

  The high genetic correlation between crimp frequency and curvature indicates that there is little need to measure crimp frequency directly in breeding programs. To put this in context, the genetic correlation between the traits of around 0.9 is much higher than the genetic correlation between CV of fibre diameter and staple strength (-0.5). CV of fibre diameter is regularly used as a proxy trait for staple strength.
- Some other interesting genetic correlations were;
  - ✓ Smaller staple size is associated with better crimp definition (0.83)

Novel wool traits

- ✓ Smaller staple size is associated with greater staple length (0.43)
- ✓ Higher crimp frequency was associated with short staple length (-0.44)

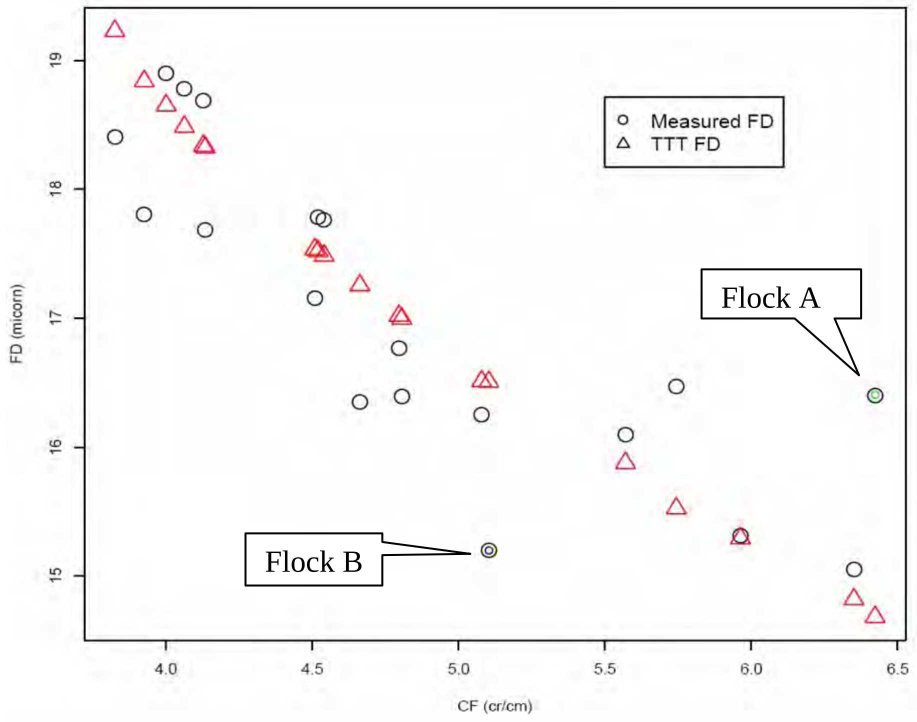
Figure 1: Heritabilities for selected novel wool traits



Trueness to Type

Trueness to type fibre diameter (TTT FD) was derived for each animal using crimp frequency and a modified version of published formulae. The deviation of each of these from the measured Laserscan FD was taken as the TTT score. Furthermore given the strong genetic relationship between crimp frequency and fibre curvature it is also possible to predict a crimp frequency measurement from the standard fibre curvature measurement and then derive TTT FD. Because breeding values for fibre diameter and curvature are currently available from SGA, the TTT classification could be implemented using current information, without the need to directly measure crimp frequency. Delivery could occur quite rapidly following industry consultation and validation.

Figure 2 Average Laserscan fibre diameter (AWTA FD), predicted "trueness to type" fibre diameter (TTT FD) and Crimp Frequency (CF) for each flock



The relationship between crimp frequency and fibre diameter in Figure 2 shows the effects we were trying to model. For example Flock A in figure 2 has an observed mean fibre diameter much higher than expected from its crimp frequency. Alternatively Flock B has a much low measured fibre diameter than expected from its crimp frequency.

Across all the animals there is a moderate negative relationship between fibre diameter and crimp frequency (correlation of -0.51). However, within flocks there are variable correlations ranging from low negative to low positive, hence the small genetic correlation between fibre diameter and crimp shown above. Other results suggest that the prediction function fits the data well at low to moderate crimp frequencies, but not so well at high crimp frequencies (>6 cr/cm).

The data set used in this study only contained animals with mean fibre diameters from approximately 14 microns to 19 microns. As this is not representative of wider industry the results need to be tested more with a data set which included more broader wools.

The results also demonstrated that the practice of tip/even-up shearing of lambs/weaners also affected the relationship between fibre diameter with crimp and curvature measurements.

Prediction of resistance to compression

Phenotypic Prediction

The ability to phenotypically predict RTC from the other measured traits was examined using both the Laserscan and OFDA data separately. The table below shows how much variation in RTC each trait explained.

	Laserscan	**OFDA**
Mean fibre curvature	33%	21%
Mean fibre diameter	8%	19%
Crimp frequency	7%	1%
Fibre diameter coefficient of variation	1%	1%
Variation in crimp frequency	1%	1%

Novel wool traits		
Total	**50%**	**43%**

Previous research has also demonstrated that the function of $D^2 * R^{-1.5}$ explained 91.2% of the variation in RTC where D is fibre diameter and R is the radius of fibre curvature. In the current study this prediction equation explained 41% and 38% of the variation in RTC based on Laserscan and OFDA measurements respectively. The accuracy of this prediction was also variable across each flock.

Genetic Prediction

Genetically resistance to compression was significantly related to fibre diameter (0.36 ± 0.05), fibre diameter coefficient of variation (0.21 ± 0.06), fibre curvature (0.79 ± 0.03), crimp frequency (0.52 ± 0.07), variation in crimp frequency (0.96 ± 0.25) and staple size (0.41 ± 0.09). Thus resistance to compression could easily be included in the breeding objective without the need for direct measurements.

Conclusions

- The novel traits of crimp frequency, crimp definition, wool colour and resistance to compression were moderately to highly heritable and therefore could be improved through selection.
- Curvature is significantly genetically and phenotypically related to crimp frequency such that there is little need for direct measurement of crimp frequency.
- The results also indicate that there is significant variation between Merino flocks in their diameter and crimp relationships. That is, some flocks have a measured fibre diameter consistently different to that predicted from their crimp frequency.
- A trueness to type score was able to be derived for each sheep which indicates its fibre diameter relative to that expected based on crimp frequency.
- As curvature and crimp frequency were significantly correlated a TTT score was also generated using fibre curvature rather than measured crimp frequency.
- This scoring system requires further consultation and validation by industry but could be implemented using existing information from SGA.
- Phenotypically, resistance to compression could be predicted with moderate accuracy from the other wool measurements made in this study.
- Genetically, resistance to compression was significantly related to many traits, therefore resistance to compression could be included in the breeding objective without the need for direct measurements.

Acknowledgements

This project involved the successful collaboration of several organisation including, AWI, AWTA, AGBU, CSIRO, Sheep CRC and IWG. The author would like to thank all parties for the valuable contributions but in particular Dr Paul Swan, Dr Trevor Mahar and David Crowe.

More Information

To obtain additional information about this project please contact Daniel Brown on email at dbrown2@une.edu.au or phone 02 6773 2160.

Sheep Enterprise Comparisons – Using the GrassGro DSS to compare sheep enterprises run under optimal management.

Doug Alcock
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Summary

GrassGro was used to compare the economic output of a range of sheep enterprises at 4 specific localities in southeastern Australia. It was found that stocking rate had the largest bearing on the enterprise gross margin (GM) $/ha. It was also determined that lambing from mid winter to mid spring was most profitable depending on enterprise and locality. Dual-purpose enterprises based on fine Merino Ewes were consistently the most profitable (prices averaged over 1999-2003 & adjusted for CPI) and seemed to be quite resilient in the face of changes in commodity prices. Most importantly there appears considerable scope for many sheep producers to improve their gross margin through attention to fine tuning stocking rate and lambing time regardless of their chosen enterprise.

Introduction

Many farmers regularly question whether changing enterprises would make them more profitable. Often the question relates to more dramatic shifts between cropping and grazing or between sheep and cattle enterprises, but in recent times the question is increasingly pertinent in deciding between the various sheep enterprise options. *"Would the farm make more money if I ran meat sheep rather than merinos"?*

More subtle is the question "what proportion of my merino ewes should I join to maternal or terminal sires"? To answer these questions the starting point is to determine the relative profitability of different sheep enterprises over the long term, under average market conditions and running in the same environment.

Project 1.2.6 of the Sheep CRC (1) was an "analysis of the profitability of sheep wool and meat enterprises in southern Australia". The project modelled grazing systems to determine the long term economic output of a large range of sheep enterprises run at a range of localities across south eastern Australia.

Project Outline

The GrassGro decision support system was used to model the productivity and economic output from a range of sheep enterprises under optimal management. Optimal management was judged on the basis of gross margin (GM) in dollars per hectare since land represents both the primary resource limitation and also the greatest capital investment.

Simulations were run at four localities (Mortlake, Rutherglen, Naracoorte and Cowra) across the 37 years from 1965 to 2002. GrassGro (Moore et al 1998) uses daily historical weather data to drive a pasture growth model that involves both soil and plant characteristics. Animals then graze the pasture and their intake physical performance and harvestable product calculated based on herbage intake and quality (Freer et al 1998).

The enterprises analysed include

1) merino wethers
2) self relacing merinos
3) 1ST cross lambs (dual purpose flocks)
4) 2nd cross lambs (prime lamb).

Pure merinos (1,2 & 3) were simulated for three different reference weights and corresponding fibre diameters (superfine, fine and medium). While first and second cross enterprises were simulated for three target markets including store lambs, trade lambs (44kg) and export lambs (53kg).

The critical management decisions of lambing time (LT) and stocking rate (SR) were varied in order to determine optimal economic management of each enterprise. Lambing times ranged from April to October and stocking rates from 4 to 20 sheep per ha depending on enterprise. Each enterprise was then compared under optimal management at each locality.

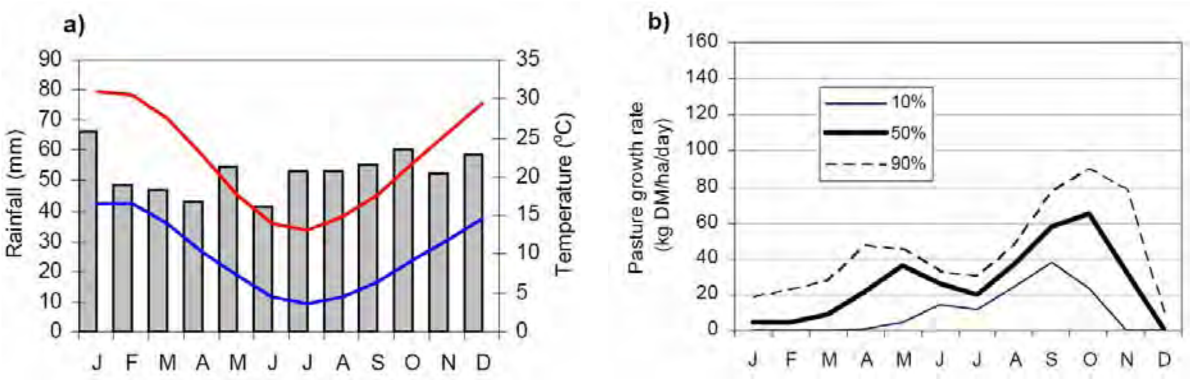
Project Results

For complete detail on every site and enterprise simulated I refer to the full project report available from the Sheep CRC (Warn et al 2006). In this paper I will draw mainly on the Cowra simulations but reference will be made to other localities in order to draw out specific points.

Simulation of Pasture Growth

Cowra simulations were of an annual pasture, grass dominant with 30% legume. Cowra is a non seasonal rainfall environment tending toward greater seasonal reliability in spring (figure 1. a). Winters are cool with regular frost incidence in June, July and August. Pasture growth is bimodal with both spring and autumn spikes in growth. The dark line in figure 1 b) represents the median growth rate averaged for each month of the year (for any given month the average growth rate has been above this line in 18 of the 37 years of the simulation). For example the median growth rate for July is 20 kg DM/ha/day while for October the median growth rate is 65 kg DM/ha/day. The pasture growth curve sets boundaries for the potential performance of the enterprises evaluated in the project.

Figure 1. Monthly climate and pasture growth rate percentiles for Cowra.

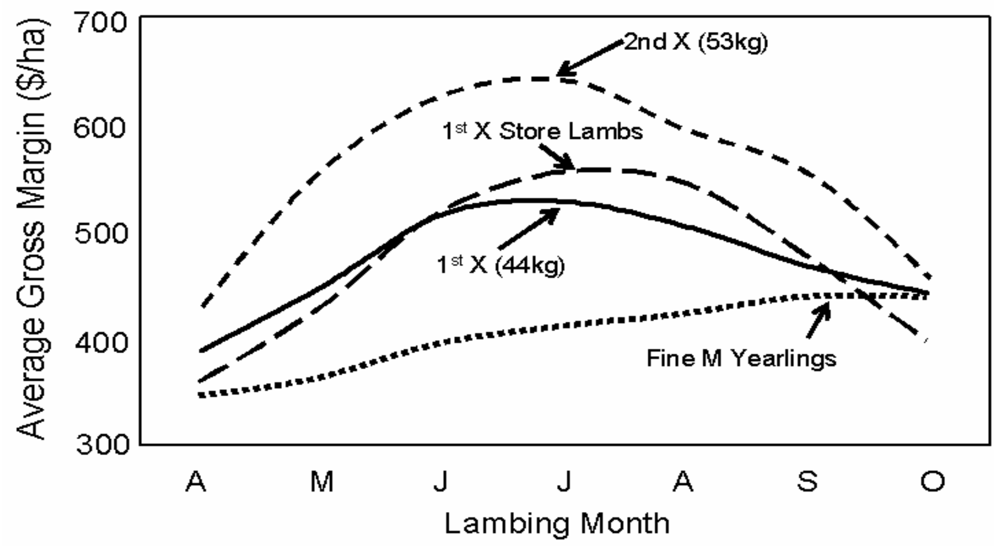


The Lambing Time x Stocking Rate Interaction

Analysis of the interaction between stocking rate and time of lambing determines the combination of these two factors that gives the greatest economic output per hectare.

Figure 2 illustrates the variation in GM by lambing date for four enterprises at Cowra. Given the shape of the pasture supply curve, enterprises that produce animals for sale as lambs give optimal returns by lambing in July.

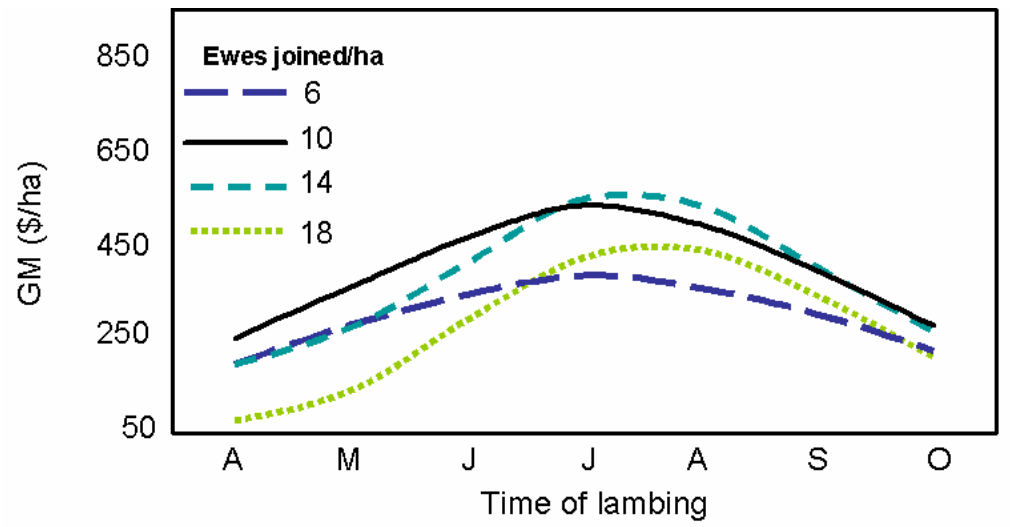
Figure 2. Change in average annual gross margin with lambing date for 4 breeding enterprises run at 10 ewes/ha on annual pastures at Cowra.



Contrasting this, a pure merino enterprise with sale of surplus young animals as yearlings (hoggets) which shows best returns with a September lambing. This timing allows sale animals the benefit of growth through a second spring season before sale. The optimal timing is a result of combining high live-weight at sale (kg/ha) with low cost of supplementation.

To derive the optimal combination of lambing time and stocking rate, simulations for every combination of these factors were run for each enterprise at each locality. Figure 3 summarises this exercise for a 2^{nd} cross store lamb enterprise. Maximum GM is generated by lambing in July at 10 to 14 ewes per ha.

Figure 3. The interaction between lambing time (LT) and stocking rate (SR) for a 2^{nd} cross store lamb enterprise at Cowra



Optimal scenarios were then screened using two other rules.

1) Ground cover > 70% from 1^{st} of Jan to the 30^{th} of Apr, at least 8 years in 10. (minimise risk of erosion and pasture degradation)

2) Ewes not fed > 30 kg of grain/head (wethers > 20 kg/head) more than 4years in 10. (only feed heavily in drought years)

Table 1. GM ($/ha) for stocking rate (SR) x lambing time (LT), highlighting constraints of ground cover and supplementary feeding.

Stocking Rate (ewes/ha)	Time of Lambing						
	April	May	June	July	Aug	Sept	Oct
4	146	195	236	259	249	214	166
6	198	274	338	373	355	299	224
8	234	334	417	464	437	358	256
10	243	356	460	527	492	393	271
14	196	281	420	550	525	406	257

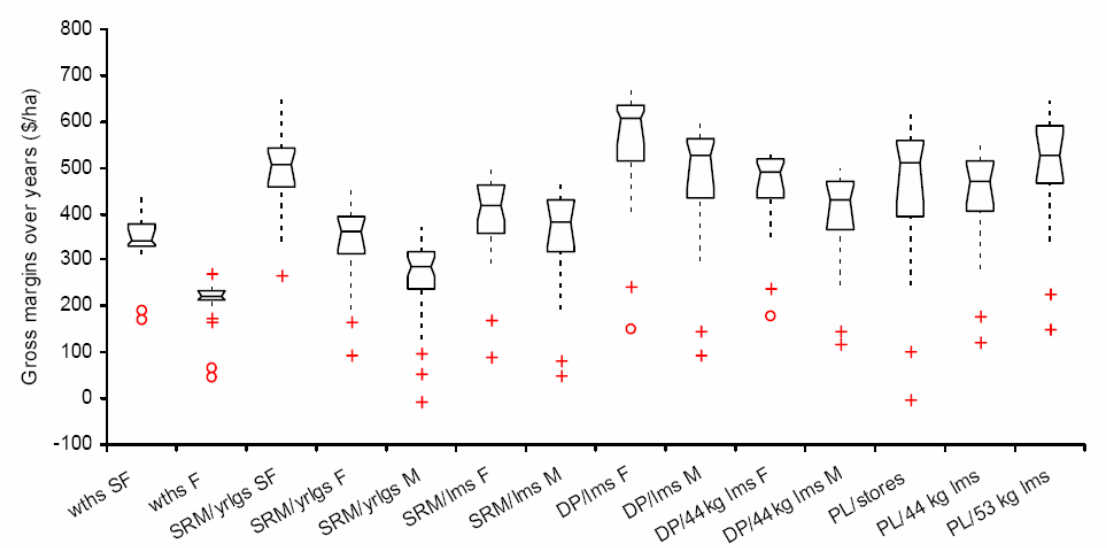
Feeding rule broken · Ground cover rule broken · Both rules broken

In Table 1, when these rules are met the optimum LT remains at July but the optimal SR is only 8 ewes per ha. Unshaded cells in the table show combinations of LT and SR that meet all necessary criteria. With all criteria met the expected average annual GM for this enterprise is $464/ha. This process has been repeated for all enterprises to enable a comparison of enterprise economic performance under optimal management.

The Comparisons

With a single set of assumptions regarding costs and prices there will always be one enterprise that, on average, generates more profit than all others. Figure 4 shows the distribution of gross margins for the years 1965 to 2002. The hourglass represents the middle 50% of the distribution while the dotted lines represent the probable statistical extremes. The symbols (+ and o) represent outliers (extreme droughts). For the defined Cowra locality the most profitable enterprise over the long run is a dual purpose flock (fine Merinos producing 1st cross store lambs). However a similar median GM can be achieved from dual purpose (medium merinos), self replacing super fine merinos and prime lambs (store and export).

Figure 4. Range in annual GM ($/ha) for simulated sheep enterprises at Cowra from 1965 -2002.



All enterprises can generate significant profits if managed optimally. Assuming farm overheads of $130/ha the average profit ranges from $84/ha up to $430/ha.

Comparison with industry benchmarks and Ag Census data suggests that in fact very few real farms are operating close to optimal levels. Adoption of simple technologies to increase

production per hectare (improved pastures, increased stocking rates and appropriate lambing time) can lead to large increases in net farm income (Webb Ware 2002, Lean etal 1997)

Reproductive Efficiency

The GrassGro simulations were also used to assess the economic impact of weaning more lambs. The results indicate it is important to first ensure that stocking rate and lambing time are optimised before focusing on weaning percentage as a profit driver. This is not to say that weaning rate is unimportant, indeed on farms already running at their carrying capacity (optimum stocking rate) it may even be profitable to run fewer ewes/ha in order to wean more lambs. Under-stocked farms should focus on lifting stock numbers closer to carrying capacity rather than simply on increased weaning rate.

Discussion

Valuable methodology not definitive results.

This work by the CRC represents a robust framework for comparison of enterprises in the context of the physical production system. It is especially useful in relation to quantifying production risks arising from climate variability. But it is only a snapshot of the production that might be expected under a very specific set of assumptions. It does not show there is a single optimal enterprise on any particular farm and certainly not that any one enterprise is the most profitable across any of the districts simulated. Nonetheless it does provide a robust methodology for exploring the productive potential of pasture systems for a range of pastures, soil types and climates.

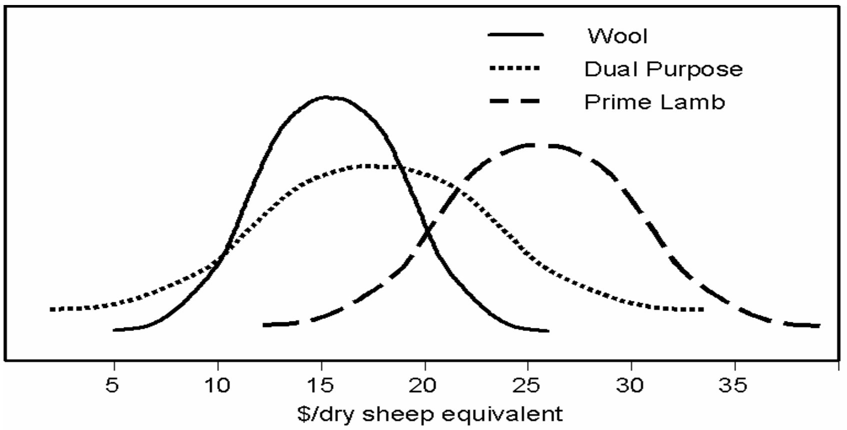
Salmon (2006) illustrates the power of modelling to reveal the spatial differences between farms in a search for the optimal stocking rate. GrassGro simulation for two properties in the Yass district showed that even at similar rainfall (710mm vs 760mm) shallower top soil and higher elevation reduced sustainable carrying capacity by one third (12 vs 18 wethers/ha). Similar differences between individual farms might be expected in most districts.

Variation within farms can be equally important. On any particular farm soil types and even climate characteristics may vary across the farm. On the Monaro average annual rainfall can vary by as much as 200mm within large properties due to the effects of elevation and topography. Despite this simulation modelling can provide the principles needed to make better decisions about stocking rate and lambing times and also give some clues as to optimal enterprise mix based on the mix of land capability and climate within the property.

Good management is a valuable as good enterprise choice.

One message is very clear, **"do what you do do, well"**. Benchmarking data illustrates the range in how well enterprises groupings are conducted in the real world (HSA 2005)

Figure 5. A graphical representation of the distribution of GM ($/dry sheep equivalent) for wool, dual purpose and prime lamb enterprises in AgInsights 2005 (HSA 2005)



Although the average gross margin per DSE differs between enterprises there are significant overlaps and the best performers for the worst enterprise are still better than the worst performers for the best enterprise (Figure 5). This reinforces it is more important to be good at whichever enterprises you choose to run. It is also important to acknowledge the costs involved when changing enterprises. Table 2. shows that in changing from Merinos to 1st cross ewes the time to break even depends of the price of replacement ewes. In recent years with 1st cross ewes making over $150/head it could take at least 5 years before the cumulative cash-flow would exceed that accrued by staying with the original Merino enterprise.

Table 2. Time to break even in the transition from a Merino enterprise to a 2nd cross store lamb enterprise as affected by 1st cross ewe purchase price (Rutherglen simulations).

Option	Ewe Cost ($/head)	Mean GM ($/hectare)	Break Even Time (Years)
Keep Merinos		$429	
Sell Merinos for $80 & Purchase first cross ewes.	$100	$631	1
	$130	$578	2
	$150	$542	5
	$180	$490	13
	$200	$454	40

Good genetics is equally important.
While the GrassGro modelling uses average animal genetics, there is clearly much to be gained through sourcing better than average genetics. In Table 3. a Merino genotype with 22% higher fleece weight at the same micron yields a GM almost 20% higher and the gap between the self replacing Merino enterprise and the dual purpose enterprise narrows considerably.

Table 3.Effect of improved genetics on economic output for a fine wool self replacing merino enterprise at Rutherglen.

Genotype	SR (ewes/ha)	Reference Wt. (Kg in CS 3)	Ewe FD (micron)	Wool Cut (greasy Kg/hd)	GM ($/ha)
Fine wool	8.5	50	19	4.1	$398
1st X lambs (fine wool)	9.5	50	19	4.1	$583
Fine Wool (22% more wool)	8.5	50	19	5.0	$474

This is reinforced by data from Merino bloodline comparisons (Atkins et al 2005). The most profitable bloodline yields a GM ($/dse) almost 40% higher than the average of all bloodlines while the lowest GM was almost 13% lower than the average.

The effect of genetics is equally important for meat enterprises. Fogarty et al (2005) reported the sire effect on GM ($/DSE) recorded by the Maternal sire Central Progeny Test (MCPT). The most common maternal sire breed (Border Leicester) ranged in GM from $28.32/dse to $39.77/dse for sires that were significantly better than the industry average (based on LAMPLAN figures), so it could be assumed that the potential range in GM due to genetics is even greater in the commercial industry.

Conclusion

The GrassGro analyses clearly showed that the most important economic drivers for sheep enterprises are optimising stocking rate and lambing times. In areas similar to those simulated there is considerable opportunity for sheep producers to increase their profits by refining their stocking rates and lambing times. Regardless of enterprise the focus should be on optimising the amount of meat and wool produced per hectare.

The strong performance of dual purpose enterprises and the relatively small difference in profit between self replacing Merinos and prime lamb flocks supports the option that many producers have taken in joining a proportion of their merino ewes to maternal or terminal sires. This option enables the producer to maintain important control over the flock genetics and greatly reduces the risk of introducing disease.

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The CRC for Sheep Industry Innovation and outputs from UNE research

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Summary

UNE is to be involved with a world first development with its role in the Information Nucleus of the new Sheep CRC. This innovation will provide genetic information for the sheep industry at the molecular and traditional level for traits never before available and provide an exciting opportunity for genetic gains through integration with SGA information systems. An AWI funded project on Integrated Parasite Management is a national project based at UNE has been successful in integrating a wide variety of control measures for parasites into packages suitable to different regions. It is clear that the strategies developed reduce the need for drenching and costs of production.

Two recent projects have focused on aspects of grazing management; the first a project funded by MLA has focused on grazing management options for Merinos in the New England area and has show clear advantages of intensive rotational systems over more conventional grazing strategies in terms of $/ha but also in maintenance of the pasture resource. In the Cicerone project funded by AWI, where farmlets have been used to compare systems differing in grazing management and pasture and fertilizer inputs over a number of years, the advantage in productivity and sustainability appear to favour high input systems compared to lower set stocking and cell grazing systems.

Introduction

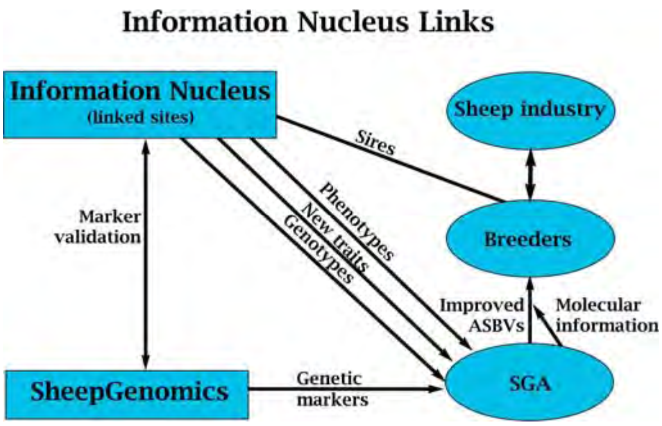
UNE has a role in a number of sheep projects that are funded by industry and are likely to be of interest to Merino breeders, in fact many attending this today may have already been exposed to some of the results of a number of years of research. UNE has had a long tradition of research associated with the sheep industry and the examination of the multifaceted nature of production systems. In my case these associations go back to the early 1980's when we initiated an evaluation of the consequences of selection for growth rate in Merinos on reproductive performance.

Of recent projects' results, three come to mind as having direct application to Merino producers in New England while one project, at its very beginning, also provides exciting prospects for genetic improvements within the sheep industry of the not too distant future.

The Information Nucleus

Most of you will have heard that the new *CRC for Sheep Industry Innovation* has been funded for 7 years commencing in July 2007. The CRC will be based on the UNE campus and many of my staff are involved in and excited about the research prospects created. The CRC has a major focus on advanced genetics as a way to improve sheep production in Australia and will focus on wool,

meat and reproductive traits in different programs. To assist in this research the plan is to establish an Information Nucleus flock, which will consist of 5000 base ewes located in 8 different locations across Australia that will be directly linked to breeders and industry through Sheep Genetics Australia.
The *Information Nucleus* is a world first innovation for sheep that will provide information to industry that will allow breeders and commercial producers to quickly exploit new technology and molecular information to achieve more rapid genetic improvement in their flocks and across the whole sheep industry. The Nucleus will also aim to identify new and novel traits difficult or expensive to measure on-farm that may be related to wool and meat quality, disease resistance and reproductive fitness.



The *Information Nucleus* will progeny test key young industry sires for an extensive range of traits in widely differing environments. These key young sires from industry flocks will be selected annually for progeny testing in the *Information Nucleus*. Their progeny phenotype information will be included immediately in the SGA database and contribute to ASBVs. The information will also pass to the Sheep Genomics program to provide information on genetic markers and validate their utility for industry sheep. Potential genetic markers will be validated and the results of collaborative research applied. The genetic information will flow directly and rapidly to breeders and industry through more accurate ASBVs, which will eventually be enhanced by molecular EBVs

The Information Nucleus will operate at 8research sites in NSW, Vic, SA and WA covering the spectrum of sheep environments in Australia. Each year 100 young sires with SGA information will be selected and mated by AI using frozen semen to 1000 ewes at each site. The matings will represent the major sheep types in the industry and generate Merino (MxM), Border Leicester X Merino (BLxM) and Terminal first (TxM) and second cross progeny (TxBLM).

The progeny will be evaluated for phenotypes for a large number of growth, carcass, meat, wool, reproduction and disease traits. The crossbred lambs will be grown out and slaughtered in processing plants with industry partners. Detailed information on carcass and meat traits, meat yield and samples for laboratory testing will be collected. The MxM progeny will be evaluated for a wide range of wool traits and the wethers will be subsequently slaughtered for carcass and meat evaluation. The MxM and BLxM ewes will be retained and mated naturally to evaluate reproduction traits. UNE is looking forward to being a significant part of this program with one of the sites being our Kirby Research station.

Integrated Parasite Management

The IPM national experimental program, funded by AWI has been operating for a number of years led by Lewis Kahn, Steve Walkden-Brown and Col Scrivener from and based around collaborating flocks in various production regions of Australia. The key objective of this research has been to integrate different management measures that influence parasite loads in such a way that drench usage is reduced and likewise costs of production.

Parasite control has been largely focused on chemical treatments but there are some on-farm examples of the benefits of integrating chemical and non-chemical control options and this project was designed to devise regional IPM programs and demonstrate their effect on 21 sheep farms.

The “tool box” of control options to be integrated includes monitoring, time of lambing, drench choice, cropping, grazing management, species mix, nutrition and genetics. To illustrate possibilities the results from a Deepwater property are shown below (Figure 1) with productivity being maintained almost at same level as worm free animals using IPM techniques and low drench costs. Cost savings overall have been estimated to be around $2.40 based on 2006/7 prices.

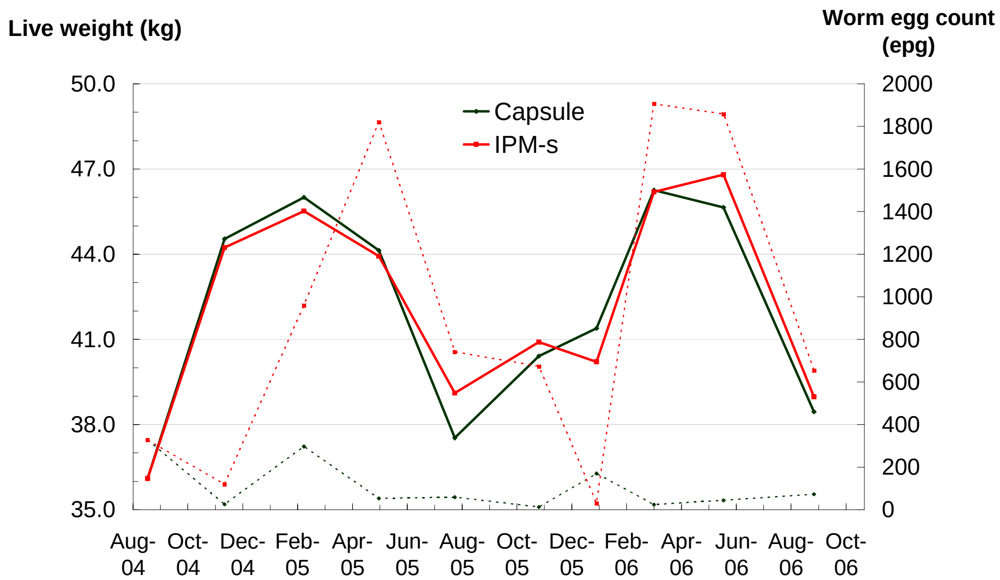


Figure 1 Liveweight and egg count data for IPM managed and “worm-free” flocks

Merino production, improved profits and resource management

This study, funded by MLA, has been conducted by Lewis Kahn and Rob Kelly on Rob’s property east of Guyra over the last few years. The aim of the project was explore the productive and financial potential of the best practice management approach In particular questions about optimising productivity and profitability per hectare while achieving animal targets and enhancing sustainability indicators such as ground cover, perenniality and water flow where the focus.

The trials focused on management systems which compared traditional systems (continuous stocking at 4.4 or 11.8 DSE/ha) with a high intensity rotational grazing system (12.4 DSE/ha). Grazing density at any point in time were respectively 4, 10.8 and 150+ ewes per ha.

There are a considerable number of outcomes from these trial but a key take home message seems to be that if managed correctly intensive rotational systems can maintain good pasture conditions while at the same time giving better returns per ha than traditional continuously grazed systems (Figure 2).

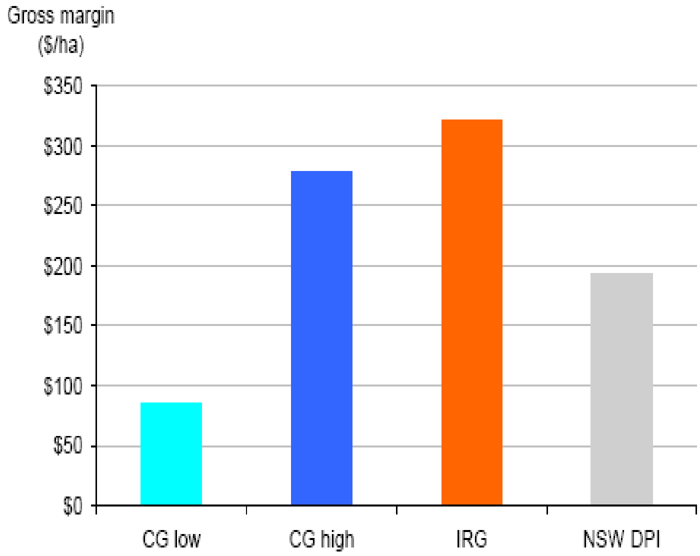


Figure 2 Gross margins generated from three grazing management systems

The Cicerone Project

This examination of farm systems has also just recently been completed and also focused on sustainability under commonly used grazing systems and high and low inputs. The experiment was run by a producer group and funded by AWI. Jim Scott has been the key UNE player involved in this project.

The high input system (farmlet A – with fertilizer and sown perennial pastures) maintained a significantly higher content of fertiliser-responsive perennial grasses than moderate input systems (farmlets B- continuous grazing typical of many grazed areas of New England and C- cell grazed) but even in the high input system , the desirable species declined over the five years of the study. The lack of persistence of fertiliser-responsive perennials in the two systems probably indicates the impact of both soil fertility status and grazing management. Diet selection data showed that the flexible grazing management practised on farmlets A and B allowed animals to express dietary selectivity, which led to higher animal performance.

Farmlets B and C had the same levels of input, but differed in grazing management; yet the performance of grazing animals (per head) was significantly higher under the typical district grazing (farmlet B) system than under intensive rotational grazing (farmlet C) and it was clearly shown that high levels of selection by grazing animals for certain pasture species over others can eliminate the preferred species from the pasture. These data seem to contrast somewhat with the previous study and is a subject for discussion over coffee. My suggestion is that the starting fertility baseline is a significant factor in the shorter term. Implications for animal production are interesting and clearly parasite management can be improved with the cell grazing model.

Conclusions

The descriptions that I have provided hopefully have given you food for thought, firstly about the opportunities that exist to save on parasite control by using an array of tools from the toolbox available to all producers. The management required to achieve this requires attention to detail but clearly, there is considerable potential for those willing to put in the time.

Grazing management has been a hot topic for a number of years and the results presented here for two experiments seem to have somewhat conflicting results. It seems that long-term sustainability is probably related to the maintenance of perennial species and that this is most easily achieved in a high input set stocked system. The study by Kahn and Kelly suggest that in such systems there may be advantages to productivity in the short to mid term of intensive grazing management systems.

Finally, there are great opportunities for people like yourselves to be involved in accessing the results of ground breaking genetic technologies that will come from the new CRC and I would encourage you to retain an interest in the melting pot of the Information Nucleus, which should provide opportunities for significant gains in many sheep production traits.

NEW CENTURY TOOLS FOR MERINOS

JUNE 19, 2007

RUTHERGLEN

PARTICPANTS: Allflex Pty Ltd • Australian Meat Processor Corporation Ltd • Australian Wool Innovation Limited • Australian Wool Testing Authority Limited • Commonwealth Scientific and Industrial Research Organisation • Hall Family Trust and Ritchie Family Trust trading as JRL Hall & Co • Holmes, Sackett and Associates Pty Limited • Mike Stephens & Associates • Meat & Livestock Australia Limited • Murdoch University • NSW Department of Primary Industries for and on behalf of the State of New South Wales • Ridley Agriproducts Pty Ltd • Sheepmeat Council of Australia • State of Queensland acting through the Department of Primary Industries and Fisheries • State of South Australia acting through the Department for Primary Industries and Resources (SA) trading as SARDI • State of Victoria acting through the Department of Primary Industries • State of Western Australia represented by the Director General of Agriculture • University of New England • University of Tasmania • University of Western Australia • WoolProducers Australia Limited

THE SHEEP CRC LTD IS A JOINT VENTURE ESTABLISHED AND SUPPORTED UNDER THE AUSTRALIAN GOVERNMENT'S COOPERATIVE RESEARCH CENTRES PROGRAM

CONTENTS

Sheep Genetics Australia information materials are provided in the forum bags.

Merino wool-meat interface

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Summary

Information on wool and meat traits was collected from some 16,000 Merino ewe and ram hoggets over two years in 27 co-operating breeders' flocks across Australia. Environmental information including rainfall and pasture growth rates was also recorded. There were no major genetic antagonisms between wool and meat traits, which mean they can be improved concurrently. Regional variation in estimated breeding values means breeders and producers can consider sourcing improved genetics from other regions according to their breeding objectives. OFDA2000 measurements allow use of coefficient of variation in fibre diameter to improve staple strength and curvature to predict crimp frequency and resistance to compression for new wool traits. Pasture growth data and fibre diameter profiles provide a retrospective means of improved feeding for better staple strength.

Introduction

The sheep industry in Australia has responded over the last three years to increased income from meat relative to wool. Up to 40% of Merino ewes have been mated to specialist meat breeds and a large proportion of wethers previously run for wool production have been replaced by breeding stock. Therefore, sheep producers are seeking ways to improve their income from both wool and meat simultaneously.

Improving both meat and wool production in Merinos has potential advantages from improved meat characteristics in Merino cross lambs. About 90% of lambs turned off for meat in Australia contain varying proportions of Merino genes.

An added advantage of having income from both wool and meat is the insulation against income vulnerability as commodity price swings for these products are cyclical and unrelated.

Aims

Our project had the primary aim of measuring relationships between wool and meat traits including some wool traits not currently part of the Sheep Genetics Australia (SGA) program. In addition, we obtained detailed information on the large range of environments to help develop improved breeding and management guidelines.

Project outline

Wool and meat traits were recorded over two years on some 16,000 2003 and 2004 born ewe and ram yearlings/hoggets with 27 co-operating Merino ram breeders across Australia (see Fig. 1 below). All flocks were recorded on SGA including standard wool and meat traits and ultrasound muscle and fat depths. In addition we collected mid side wool samples for (a) length, strength, yield, crimp frequency, laserscan and resistance to compression tests by the Australian Wool Testing Authority; (b) OFDA2000 testing by the Interactive Wool Group; and (c) visual and measured wool style by CSIRO at Chiswick. In addition, satellite data for each of the 27 sites obtained through CSIRO's Pastures from Space project gave pasture growth rates.

The location of breeder properties and grouping according to climatic regions is shown in Figure 1.

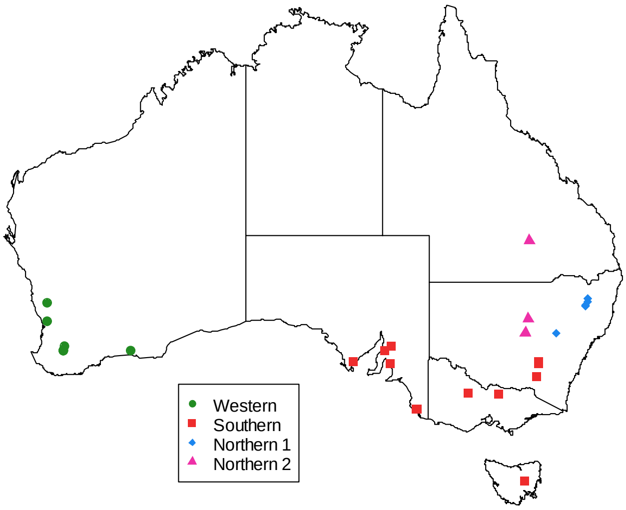


Figure 1: Location of co-operating Merino breeder flocks and regional groupings

Results and discussion

The results are presented as regional averages as outlined in Figure 1 under the following headings –

- Phenotypic means for wool and meat traits
- Genetic variability and associations between wool and meat traits
- Genetic means for wool and meat traits
- Fibre diameter profiles and pasture information

<u>Phenotypic means.</u>
Average phenotypic means for wool and meat traits are given by region in Table 1.

Table 1: Phenotypic means for wool and meat traits by regions and years

Region	**Year**	**Yearling or Hogget wt (kg)**	**Greasy fleece wt (kg)**	**Wool micron**	**Staple strength (N/ktex)**	**Eye muscle depth (mm)**	**Fat depth (mm)**
Western	1	45.4	4.0	17.4	31.1	21.2	2.5
	2	47.8	4.0	17.7	37.2	21.0	1.0
Southern	1	47.6	3.8	17.3	33.6	23.0	2.7
	2	47.8	3.6	17.8	32.2	21.9	2.7
Northern1	1	52.4	4.9	16.8	45.4	22.0	2.5
	2	48.1	4.0	15.7	46.4	23.3	2.8
Northern2	1	46.3	4.0	18.2	39.8	23.4	2.4
	2	36.0	2.8	17.7	31.3		

The above means represent environmental differences, independent of genetic differences, including climate, pasture and management. There are few obvious trends in the data though Northern1 (Northern Table Lands) appear to have comparatively heavier body weights and

fleece weights, despite lower wool micron, probably due to later weighing and shearing when animals are comparatively older.

Genetic variability and associations.

Heritabilities and genetic correlations describe the amount of genetic variability and associations between traits. A heritability of 0.30 or 30% means that 30% of the variability between animals is under genetic control through their breeding values. Genetic correlations describe how closely two traits are genetically related with values between -1 and 1. The nearer the values are to zero the weaker the relationship between traits.

Genetic correlations between core wool traits as in SGA, and the new wool traits including curvature, crimp frequency and resistance to compression, are given in the following table with heritabilities shown in bold.

Table 2: Genetic correlations and heritabilities for wool and meat traits.

	GFW	CFW	FD	FDCV	SS	CUR	CR	RTC	WT	EMD	FAT
GFW	**0.41**										
CFW	0.90	**0.30**									
FD	0.28	0.25	**0.73**								
FDCV	0.07	-0.06	-0.06	**0.52**							
SS	0.13	0.30	0.31	-0.50	**0.44**						
CUR	-0.28	-0.33	0.11	0.06	0.11	**0.27**					
CR	-0.38	-0.49	-0.15	-0.12	0.13	0.83	**0.41**				
RTC	-0.12	-0.14	0.35	0.23	0.03	0.77	0.49	**0.41**			
WT	0.46	0.43	0.17	-0.30	0.21	0.15	0.15	0.13	**0.47**		
EMD	-0.20	-0.12	0.13	-0.09	0.20	0.20	0.14	0.22	0.54	**0.23**	
FAT	-0.36	-0.15	0.20	0.02	0.16	0.09	0.13	0.16	0.45	0.54	**0.10**

GFW-greasy fleece weight; CFW-clean fleece weight; FD-fibre diameter; FDCV-CV of fibre diameter; SL-staple length; SS-staple strength; CUR-curvature; CR-crimp frequency; RTC-resistance to compression; WT-live weight; EMD-eye muscle depth; FAT- fat depth.

Wool traits were highly heritable, particularly fibre diameter at 0.71. There was a strong negative genetic correlation between CV of fibre diameter and staple strength meaning lower CVs indicated greater staple strength. Unfavourable genetic correlations existed between fleece weight and fibre diameter, and between fibre diameter and staple strength. The 0.31 correlation for the latter means selection for reduced fibre diameter will also cause staple strength to decline. These unfavourable correlations can be overcome by considering the traits in a weighted selection index. For the new wool traits, curvature was highly correlated with crimp and resistance to compression while both crimp and resistance to compression had moderately high heritabilities. Therefore, curvature measurements from OFDA2000 can be used to predict and select for crimp frequency and resistance to compression.

Body weight was highly heritable and eye muscle depth moderately. The meat traits were moderately positively correlated. There were moderate to high correlations between body weight and both wool and meat traits. However, there were some unfavourable correlations between eye muscle depth and both fleece weight and fibre diameter. Use of an appropriate selection index can allow eye muscle depth and fleece weight to be increased while fibre diameter is decreased.

The genetic correlations and heritabilities discussed above are similar to SGA estimates for their standard traits.

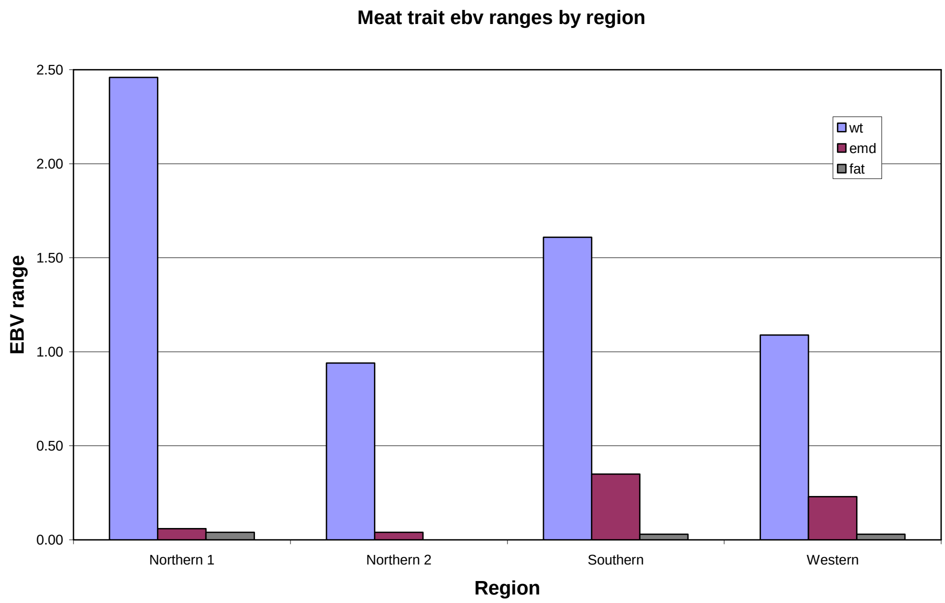
Genetic means for wool and meat traits.
Average breeding values (EBVs) have been calculated for key wool and meat traits in each flock. These EBVs are derived from the actual heritabilities and phenotypic values from this dataset as well as background pedigree information from the wider SGA database. Average EBVs for each region are given in Table 3 and ranges are in Fig. 1.

Table 3: Average estimated breeding values for the flocks in each region

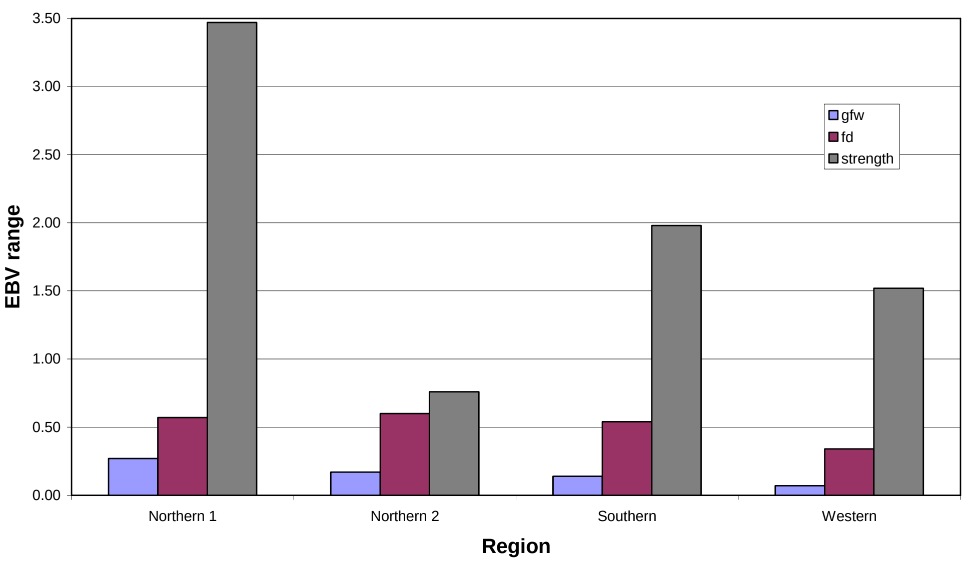
	Meat			wool			new wool		
Region WT	**EMD**	**FAT**	**GFW**	**FD**	**SS**	**RTC**	**CUR**	**CR**	
Northern1	-1.14	-0.16	-0.02	-0.08	-0.18	-0.27	-0.07	0.37	0.00
Northern2	0.32	-0.01	-0.04	0.05	-0.22	0.43	-0.05	-0.43	-0.02
Southern	0.29	-0.02	-0.01	0.08	-0.15	0.13	-0.11	-0.65	-0.05
Western	0.08	-0.05	-0.01	0.02	-0.06	0.31	0.00	0.34	0.05

Comparisons of average EBVs between regions indicate more variation in meat than wool traits. The Northern1 flocks (Northern Tablelands) appear on average to have less genetic potential for improved meat traits than their western and southern counterparts, however all four regions still have significant opportunity for selection. While the four regions have similar fleece weight genetics, the northern region has a tendency to lower micron and higher crimp frequency.

Ranges in meat and wool trait EBVs, relating to averages in Table 3 for each region are given in Figure 1 below. Note that these values can be positive and/or negative.



Wool trait ebv ranges by region



New wool trait ebv ranges by region

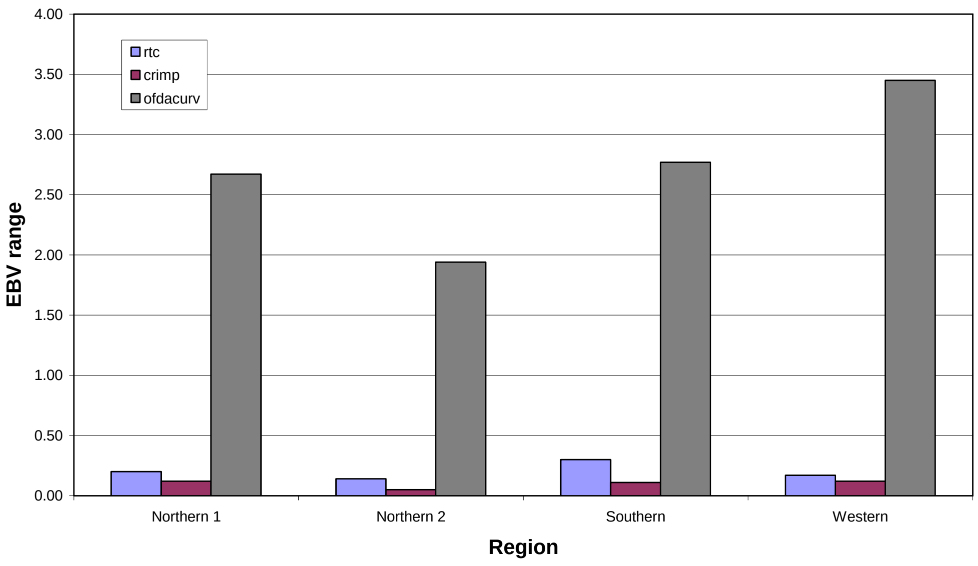


Figure 1: Ranges in average flock EBVs meat and wool traits in each region.

Note that the above graphs contain standardised EBV ranges.. The ranges for average flock breeding values showed that breeding flocks in the Northern1 region had comparatively greater variation in live weight and wool staple strength while western region flocks had the most variation in wool curvature. These results indicate comparatively greater potential for genetic improvement in live weight and staple strength in the Northern1 region than indicated by the average values in Table 4. The new wool traits, curvature in particular, had greatest variation in the western region. This provides opportunities for both breeders and commercial producers to explore these regional differences by sourcing genetic material to better match their breeding objectives.

Pasture information

Pasture growth information averaged over properties in the two contrasting Western and Northern1 regions for the two years of the project is given in Figure 2 below.

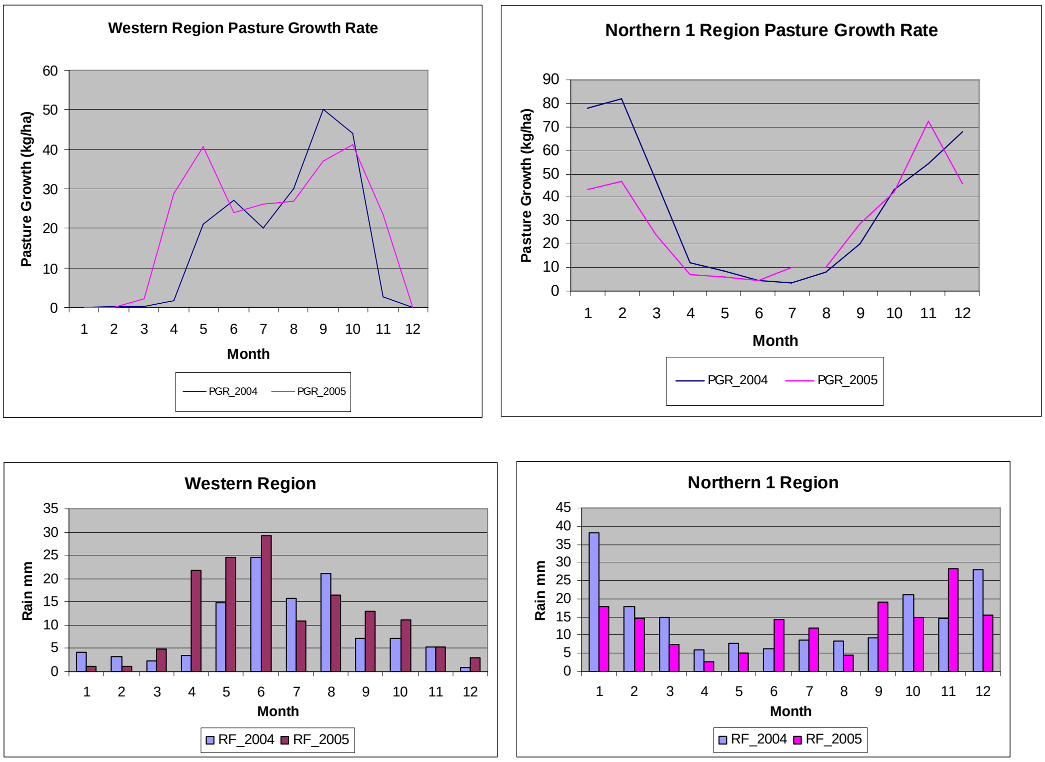
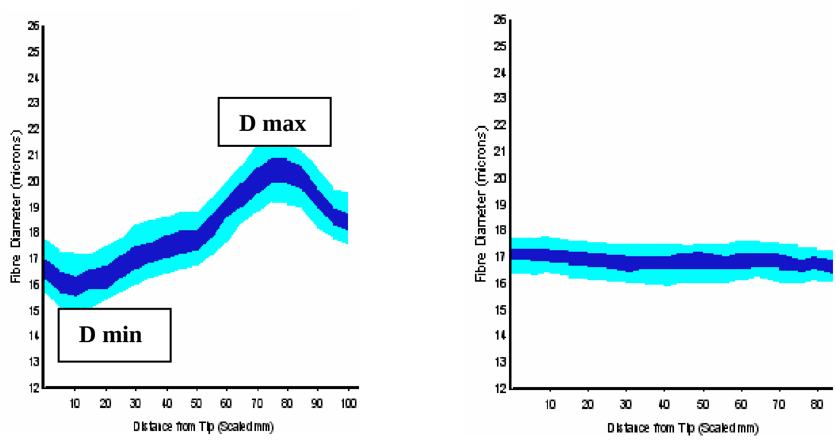


Figure 2: Average pasture growth rates and rainfall for the Western and Northern1 regions.

The pasture growth information in Fig. 2 above has been obtained from satellite data kindly supplied by CSIRO's Pastures from Space project. The two contrasting regions show winter (Western) and summer (Northern1) dominant pasture growth aligned with the rainfall data in the lower graphs. Within each of these regions, there was considerable variation among the various breeder properties in rainfall and pasture growth variation.

Fibre diameter profiles

The OFDA2000 measures fibre diameter profiles, which give changes in fibre diameter along the wool staple. Results from our project show there is much greater variation in fibre diameter in the southern and western regions with Mediterranean type climates with hot dry summers than in the more temperate northern climates with more equitable rainfall. Typical fibre diameter profiles from these contrasting regions are shown in Figure 3.



Mediterranean **Temperate**

Figure 3: Typical fibre diameter profiles from Mediterranean and temperate climates

Average flock differences between maximum (Dmax) and minimum (Dmin) fibre diameter are plotted against average staple strength for 18 of the co-operating flocks during year one of the project in Fig. 4.

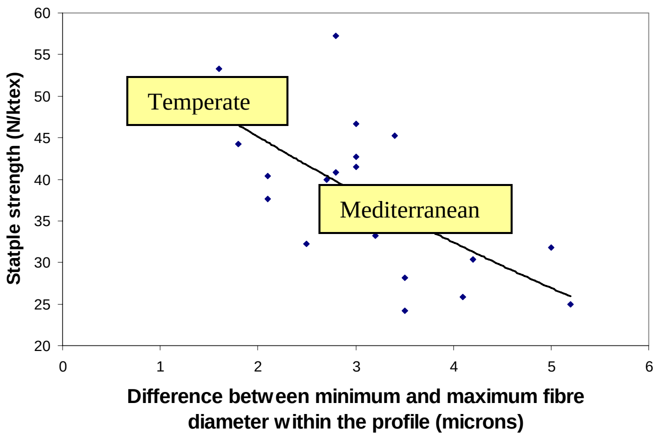


Fig. 4: Relationship between flocks with low fibre diameter profile variation in temperate regions in contrast with higher variation in Mediterranean climates.

The average flock differences between Dmax and Dmin gave a good indication of average staple strength as shown in Fig. 4 above.

For improved staple strength management, breeders should aim to flatten the profiles with most emphasis on preferential feeding during the time period of minimum fibre diameter. The example in Fig. 3 above indicates that under Mediterranean conditions with shearing in late spring preferential feeding over the summer would have improved staple strength. However, the cost effectiveness of this strategy would need to be assessed. This same principle applies in temperate conditions where there are low staple strength wools due to nutritional stress. Use of OFDA2000 and pasture growth rate data can define periods for preferential feeding.

Conclusions

The results from this project on wool and meat traits give breeders and commercial producers guidelines for genetic improvement in wool and meat production. There is also information

about use of pasture growth rates and fibre diameter profiles to improve wool staple strength. The main take home messages for breeders and producers are –

- The genetic parameters for standard SGA traits in this study did not vary greatly (with a few exceptions) from SGA values
- There are no major antagonisms between wool and meat traits in Merinos so breeders and their ram buyer clients can genetically improve both wool and meat production at the same time
- The unfavourable genetic correlations between fleece weight and fibre diameter, fibre diameter and staple strength, and eye muscle depth and greasy fleece weight/fibre diameter, can be overcome with use of appropriate selection indexes
- Regional variation in wool and meat trait EBVs provides opportunities for breeders and producers to source improved genetics
- Selection for lower coefficient of variation in fibre diameter from OFDA2000 profiles is the best tool to use for improvement in staple strength
- Values for the new wool trait curvature from OFDA2000 can be used to predict the other new wool traits of crimp frequency and resistance to compression.
- Pasture growth data and fibre diameter profiles can be used retrospectively for improved feeding during periods of pasture shortage to improve staple strength

Acknowledgements

Grateful acknowledgement is made to the following: the 27 co-operating Merino breeders; MLA and AWI for financial and technical support; AWTA and IWG for in-kind laboratory support; provision of Pastures from Space data by Graham Donald, CSIRO Chiswick; skilled technical input from Grant Uphill, Christine Dennis, Judi Kenny and Heather Brewer, CSIRO Chiswick.

Novel Merino Wool Quality Traits

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Summary

The project was conducted in conjunction with Sheep CRC Project 1.2.6, in which wool samples representing some 29 Sheep Genetics Australia (SGA) flocks were tested for a range of novel traits including resistance to compression, crimp frequency and measured and assessed style traits.

Genetic variation in novel traits:

- The novel traits of crimp frequency, resistance to compression, crimp definition, wool colour and staple size were moderately to highly heritable and therefore could be easily improved through selection.
- The genetic correlation between mean fibre curvature and crimp frequency was 0.84 to 0.93 suggesting that there is little need to measure crimp frequency to change it genetically.

Trueness to Type:

- The results also indicate that there is significant variation between Merino strains / flocks in their diameter and crimp relationships. That is some flocks have a measured fibre diameter consistently different to that predicted from their crimp frequency.
- A “Trueness to Type” score was calculated for each sheep which indicated its FD relative to that expected based on its crimp frequency.
- Given the strong genetic relationships between crimp frequency and fibre curvature it is also possible to predict a crimp frequency measurement from the standard fibre curvature measurement. This predicted crimp frequency measurement can also be used to calculate a Trueness to Type score. Trueness to Type classification could be made available in the near future following industry consultation and validation.

Prediction of resistance to compression:

- Measurements of resistance to compression can be predicted with moderate accuracy from the other wool measurements made in this study.
- At the genetic level, resistance to compression was significantly related to fibre diameter (0.36), fibre diameter coefficient of variation (0.21), fibre curvature (0.79), crimp frequency (0.52), variation in crimp frequency (0.96) and staple size (0.41). Therefore resistance to compression could easily be included in the breeding objective without the need for direct measurements.

Introduction

The focus of this project is to extend the scope of traits measured for SGA across-flock genetic evaluation, by developing the basis for trait definitions for several traits presently considered important to sheep classer and wool buyers – namely those relating to the visual ‘style’ and the tactile appeal of wool.

“Trueness to type” is a term used is the wool industry to define whether a fleece’s crimp frequency matches its fibre diameter. Across flocks there is a strong relationship between these traits, with finer wools displaying a much higher crimp frequency and curvature than broader wools. Nevertheless, at any given fibre diameter, flocks are often under or over crimped, and therefore not “true to type”.

Novel wool traits

Historically, trueness to type has been used by the wool trade as an integral component of a system allowing the prediction of processing performance to the yarn stage of greasy wool, using a system of “quality numbers”. In assigning a quality number, trueness to type was combined with assessment of handle, colour, length and strength to estimate the number of 560 yard hanks of yarn able to be spun from per imperial pound of scoured wool. While the prediction of processing performance based on objective raw wool measures has advanced substantially over the years, trueness to type is still an important price determinant in some wool markets.
The compression characteristics of wool represent an important aspect of wool quality with requirements depending upon end use and processing conditions. Resistance to compression has also been shown to be significantly related to fibre curvature and crimp frequency.

This study will develop the preliminary basis for the estimation of breeding values for:

- Crimp frequency: new measurement technology has been used which enables a routine and objective measurement of crimp frequency.
- Trueness to type: the relativity of fibre curvature and crimp frequency with fibre diameter.
- Compressibility: as estimated using the measurement of resistance to compression and other raw wool traits.

The Data Used

This project was conducted in conjunction with Sheep CRC Project 1.2.6, whereby wool samples representing some 29 client flocks of Sheep Genetic Australia were tested for a range of wool parameters by IWG using OFDA2000 and AWTA using Laserscan and other measurement technology. Samples were also measures for style traits using the Style Machine and the same samples were visual assessed/scored for a similar range of style related traits.

The data set contained 12,085 animals (7,130 females and 4,951 males) with data and 22,397 animals in the pedigree. There were 374 sires and 6,000 dams with recorded progeny. The data originated from 29 SGA flocks and all animals measured were born in 2003, 2004 and 2005. All animals were measured at either at yearling or hogget ages. Some flocks also shore / tipped their sheep as lambs where others did not.

Genetic variation in novel traits

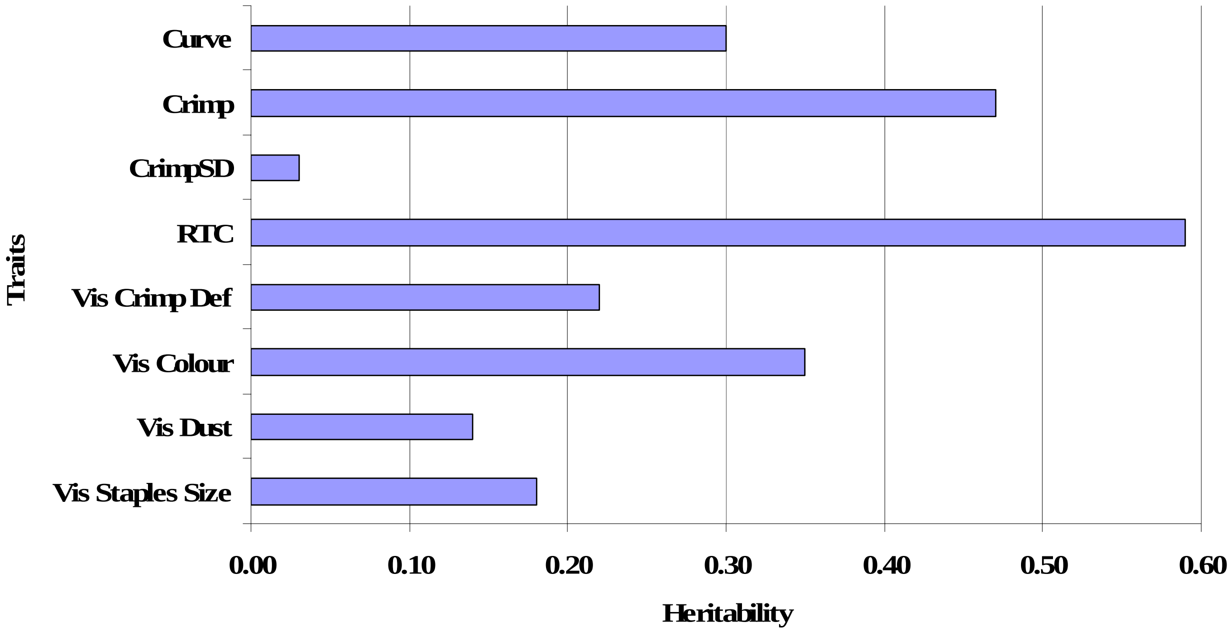
- The heritabilities of the standard wool traits agree with previous estimates from SGA data.
- As shown in Figure 1 below, the heritabilities for the novel traits were generally moderate to high except variation in crimp (CrimpSD) and dust penetration (Vis Dust).
- Visually assessed colour, crimp definition and dust were more highly heritable than the equivalent Style Machine traits.
- Fibre diameter measurements from Laserscan and OFDA were genetically and phenotypically the same traits, with genetic and phenotypic correlations of 0.98 and 0.89 respectively.
- Laserscan and OFDA fibre curvature had a high genetic correlation of 0.92, although the phenotypic correlation was only 0.53.
- Crimp frequency from AWTA was also genetically correlated with;
  - ✓ Greasy fleece weight -0.37
  - ✓ Staple length -0.43
  - ✓ Fibre diameter -0.15
  - ✓ Laserscan curvature 0.84
  - ✓ OFDA curvature 0.93

  The high genetic correlation between crimp frequency and curvature indicates that there is little need to measure crimp frequency directly in breeding programs. To put this in context, the genetic correlation between the traits of around 0.9 is much higher than the genetic correlation between CV of fibre diameter and staple strength (-0.5). CV of fibre diameter is regularly used as a proxy trait for staple strength.
- Some other interesting genetic correlations were;
  - ✓ Smaller staple size is associated with better crimp definition (0.83)

Novel wool traits

- ✓ Smaller staple size is associated with greater staple length (0.43)
- ✓ Higher crimp frequency was associated with short staple length (-0.44)

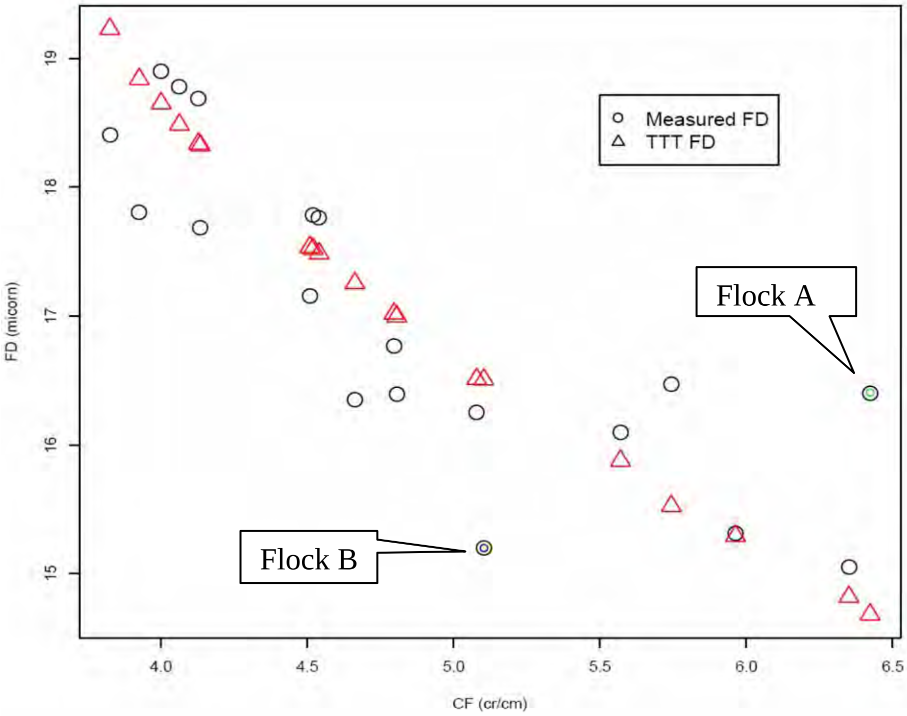
Figure 1: Heritabilities for selected novel wool traits



Trueness to Type

Trueness to type fibre diameter (TTT FD) was derived for each animal using crimp frequency and a modified version of published formulae. The deviation of each of these from the measured Laserscan FD was taken as the TTT score. Furthermore given the strong genetic relationship between crimp frequency and fibre curvature it is also possible to predict a crimp frequency measurement from the standard fibre curvature measurement and then derive TTT FD. Because breeding values for fibre diameter and curvature are currently available from SGA, the TTT classification could be implemented using current information, without the need to directly measure crimp frequency. Delivery could occur quite rapidly following industry consultation and validation.

Figure 2 Average Laserscan fibre diameter (AWTA FD), predicted "trueness to type" fibre diameter (TTT FD) and Crimp Frequency (CF) for each flock



The relationship between crimp frequency and fibre diameter in Figure 2 shows the effects we were trying to model. For example Flock A in figure 2 has an observed mean fibre diameter much higher than expected from its crimp frequency. Alternatively Flock B has a much low measured fibre diameter than expected from its crimp frequency.

Across all the animals there is a moderate negative relationship between fibre diameter and crimp frequency (correlation of -0.51). However, within flocks there are variable correlations ranging from low negative to low positive, hence the small genetic correlation between fibre diameter and crimp shown above. Other results suggest that the prediction function fits the data well at low to moderate crimp frequencies, but not so well at high crimp frequencies (>6 cr/cm).

The data set used in this study only contained animals with mean fibre diameters from approximately 14 microns to 19 microns. As this is not representative of wider industry the results need to be tested more with a data set which included more broader wools.

The results also demonstrated that the practice of tip/even-up shearing of lambs/weaners also affected the relationship between fibre diameter with crimp and curvature measurements.

Prediction of resistance to compression

Phenotypic Prediction

The ability to phenotypically predict RTC from the other measured traits was examined using both the Laserscan and OFDA data separately. The table below shows how much variation in RTC each trait explained.

	Laserscan	**OFDA**
Mean fibre curvature	33%	21%
Mean fibre diameter	8%	19%
Crimp frequency	7%	1%
Fibre diameter coefficient of variation	1%	1%
Variation in crimp frequency	1%	1%

Novel wool traits		
Total	**50%**	**43%**

Previous research has also demonstrated that the function of $D^2 * R^{-1.5}$ explained 91.2% of the variation in RTC where D is fibre diameter and R is the radius of fibre curvature. In the current study this prediction equation explained 41% and 38% of the variation in RTC based on Laserscan and OFDA measurements respectively. The accuracy of this prediction was also variable across each flock.

Genetic Prediction

Genetically resistance to compression was significantly related to fibre diameter (0.36 ± 0.05), fibre diameter coefficient of variation (0.21 ± 0.06), fibre curvature (0.79 ± 0.03), crimp frequency (0.52 ± 0.07), variation in crimp frequency (0.96 ± 0.25) and staple size (0.41 ± 0.09). Thus resistance to compression could easily be included in the breeding objective without the need for direct measurements.

Conclusions

- The novel traits of crimp frequency, crimp definition, wool colour and resistance to compression were moderately to highly heritable and therefore could be improved through selection.
- Curvature is significantly genetically and phenotypically related to crimp frequency such that there is little need for direct measurement of crimp frequency.
- The results also indicate that there is significant variation between Merino flocks in their diameter and crimp relationships. That is, some flocks have a measured fibre diameter consistently different to that predicted from their crimp frequency.
- A trueness to type score was able to be derived for each sheep which indicates its fibre diameter relative to that expected based on crimp frequency.
- As curvature and crimp frequency were significantly correlated a TTT score was also generated using fibre curvature rather than measured crimp frequency.
- This scoring system requires further consultation and validation by industry but could be implemented using existing information from SGA.
- Phenotypically, resistance to compression could be predicted with moderate accuracy from the other wool measurements made in this study.
- Genetically, resistance to compression was significantly related to many traits, therefore resistance to compression could be included in the breeding objective without the need for direct measurements.

Acknowledgements

This project involved the successful collaboration of several organisation including, AWI, AWTA, AGBU, CSIRO, Sheep CRC and IWG. The author would like to thank all parties for the valuable contributions but in particular Dr Paul Swan, Dr Trevor Mahar and David Crowe.

More Information

To obtain additional information about this project please contact Daniel Brown on email at dbrown2@une.edu.au or phone 02 6773 2160.

Information Nucleus

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Introduction

The Cooperative Research Centre for Sheep Industry Innovation (Sheep CRC), the successor to the Australian Sheep Industry CRC, will transform wool and meat products and the sheep that produce them with new research to 2014. A key program of the Sheep CRC is the *Information Nucleus*.

The *Information Nucleus*, a world first innovation for sheep, provides next-generation genetic and new trait information to industry and supports the three core research programs of the Sheep CRC:

- Transforming sheep and their management
- Next generation wool quality
- Next generation meat quality

Each year 5000 ewes in diverse *Information Nucleus* flocks across Australia will produce progeny by 100 Merino, maternal and terminal sires chosen from across industry. The progeny will be extensively measured and assessed for current and new traits in meat and wool quality, parasite resistance and reproduction.

Through the Sheep CRC's unique partnership with SGA Sheep Genetics Australia and SheepGenomics the information will be used to:

- Improve accuracy of Australian Sheep Breeding Values (ASBV) for current traits
- Contribute to development of ASBVs for new traits
- Validate molecular markers for current and new traits
- Develop breeding values that combine quantitative and molecular information.

Breeders and commercial producers will be able to quickly use the developments in new genetic technology and molecular information to advance their chosen breeding objectives. Both individual flocks and sheep across industry will achieve more rapid genetic gain.

What is the *Information Nucleus*?

The *Information Nucleus* is a series of flocks located at research sites around Australia that are directly linked to breeders and industry through SGA. The *Information Nucleus* uses key young and proven industry sires to progeny test for an extensive range of traits in widely differing environments.

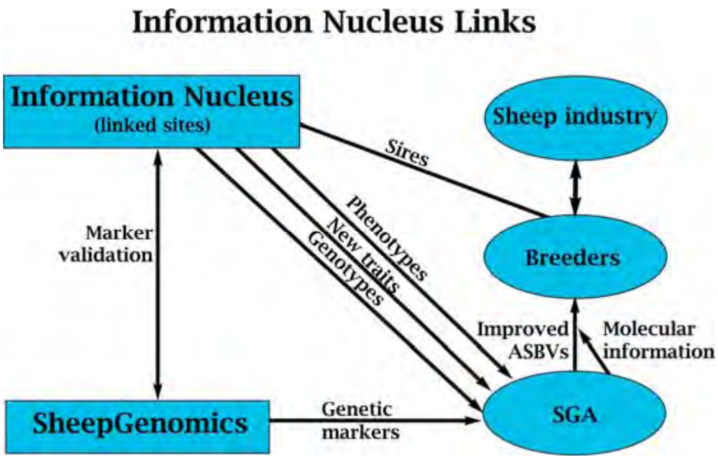
Working closely with SheepGenomics, the *Information Nucleus* will provide information on genetic markers and validate their usefulness for industry sheep.

With the information on phenotypes and genotypes generated from the *Information Nucleus*, potential genetic markers will be validated and the results from the other CRC research programs will be applied.

The genetic information will flow directly and rapidly to breeders and industry via SGA through more accurate Australian Sheep Breeding values (ASBVs) that will eventually be enhanced by the incorporation of molecular information.

What will the *Information Nucleus* do?

The *Information Nucleus* will generate genetic information about new and novel traits as well as traits that are difficult or expensive to measure commercially on-farm. These may be related to wool and meat quality, internal parasite resistance and reproductive performance. This will provide genetic parameters for traits such as staple strength, wool quality, meat eating quality, nutritional content, carcase yield and feed efficiency.



The *Information Nucleus* will also assess genetic variation and opportunities for improvement of new and novel traits such as wool UV-colour stability, traits of meat relating to human nutrition and characteristics that result in easier care and management of sheep.

Gene marker and SNP (single nucleotide polymorphism) discoveries will be tested and validated in sheep with different genetic backgrounds, sex and age in a range of environments.

The SheepGenomics program is developing new molecular technology that will allow animals to be quickly and cheaply tested for thousands of genetic markers and SNPs that will be validated in the *Information Nucleus*. The *Information Nucleus* will also be the focus of sheep management, wool and meat research being undertaken in the other CRC research programs.

How will the *Information Nucleus* help breeders?

Key sires from industry flocks are selected annually for mating in the *Information Nucleus*. Their progeny phenotype information will be included immediately in the SGA database and will contribute to ASBVs for the sires and to overall linkage of the SGA analyses. For most sires, the additional progeny will increase the accuracy of the sire ASBVs as well as the accuracy of the ASBVs for other related animals because of the greater across-flock linkage.

New traits that prove valuable to industry will be added directly to SGA if they are commercially applicable. A major advance will be the validation of gene markers and SNPs that will contribute to the development of molecular breeding values. These may eventually be incorporated into enhanced ASBVs that can be used to more accurately select sheep at a very young age and further increase the rate of genetic improvement.

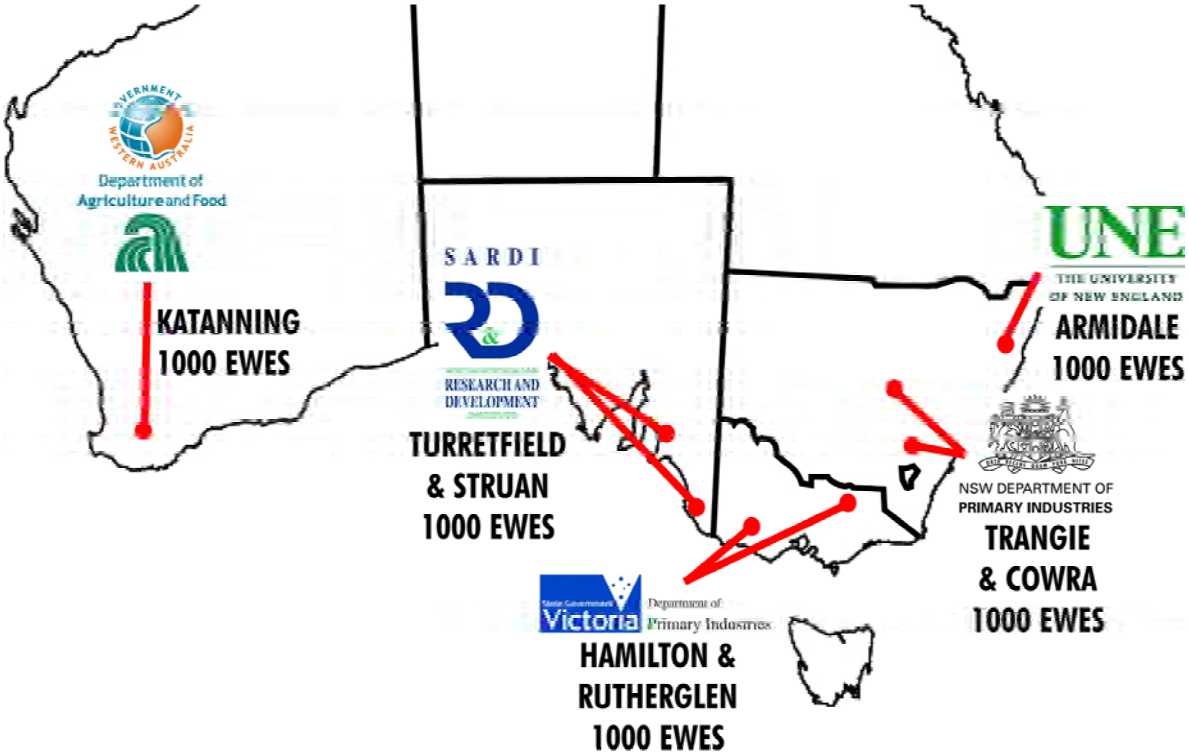
Selection of Sires

The *Information Nucleus* has been structured to provide genetic information for the most widely used production systems across Australia. The sires are selected on a combination of several attributes:

- High genetic merit for key production traits, including divergence for some other traits
- Genetic diversity of the selected team, so that a broad range of bloodlines, strains and breeds are sampled
- Linkage to the SGA database including potential for influence on future generations *(including some prominent bloodlines that have not yet been evaluated within SGA)*

How will the *Information Nucleus* work?

The *Information Nucleus* will operate at eight research sites covering a wide range of sheep environments in Australia:



Each year approximately 100 young sires will be selected and mated to 50 ewes each using artificial insemination and frozen semen. The first matings of the *Information Nucleus* occurred in early 2007 so that progeny will be available for evaluation in the first year of operation of the CRC for Sheep Industry Innovation (from July 2007).

The 5000 matings represent the major sheep types in the industry and generate Merino (MxM), Border Leicester X Merino (BLxM) and Terminal first (TxM) and second cross progeny (TxBLM) (see Table).

Approximate annual numbers of sires, ewes mated and progeny in the *Information Nucleus*

Sires	Ewes	Progeny	Retained (ewes)	Slaughter
40 Merino (M)	2000 M	1500 MxM	750	750
20 Border Leicester (BL)	1000 M	750 BLxM	375	375
40 Terminal (T)	1000 M	750 TxM	-	750
	1000 BLM	750 TxBLM	-	750
Total	5000	3750	1125	2625

The progeny will be evaluated for phenotypes for a large number of growth, carcase, meat, wool, reproduction and internal parasite resistance traits, which are not practical or economical to do on commercial farms. The crossbred lambs will be grown out and slaughtered in processing plants with industry partners. Detailed information on carcase and meat traits, meat yield and samples for laboratory testing will also be collected.

The MxM progeny will be evaluated for a wide range of wool traits and half the wethers will subsequently be slaughtered for carcase and meat evaluation. The MxM and BLxM ewes will be retained and mated naturally for two joinings to evaluate reproduction and maternal traits. Blood and tissue samples will also be collected for genotyping and molecular genetic studies.

It is planned that all *Information Nucleus* sites will have regular field days to enable industry to view progeny of sires and to keep up-to-date with the outcomes of the Sheep CRC programs.

Sheep Enterprise Comparisons – Using the GrassGro DSS to compare sheep enterprises run under optimal management.

Lisa Warn
The Mackinnon Project, University of Melbourne.

Summary

GrassGro was used to compare the economic output of a range of sheep enterprises at 4 specific localities in southeastern Australia. It was found that stocking rate had the largest bearing on the enterprise gross margin (GM) $/ha. It was also determined that lambing from mid winter to mid spring was most profitable depending on enterprise and locality. Dual-purpose enterprises based on fine Merino Ewes were consistently the most profitable (prices averaged over 1999-2003 & adjusted for CPI) and seemed to be quite resilient in the face of changes in commodity prices. Most importantly there appears considerable scope for many sheep producers to improve their gross margin through attention to fine tuning stocking rate and lambing time regardless of their chosen enterprise.

Introduction

Many farmers regularly question whether changing enterprises would make them more profitable. Often the question relates to more dramatic shifts between cropping and grazing or between sheep and cattle enterprises, but in recent times the question is increasingly pertinent in deciding between the various sheep enterprise options. *“Would the farm make more money if I ran meat sheep rather than merinos”?*

More subtle is the question “what proportion of my merino ewes should I join to maternal or terminal sires”? To answer these questions the starting point is to determine the relative profitability of different sheep enterprises over the long term, under average market conditions and running in the same environment.

Project 1.2.6 of the Sheep CRC (1) was an “analysis of the profitability of sheep wool and meat enterprises in southern Australia”. The project modelled grazing systems to determine the long term economic output of a large range of sheep enterprises run at a range of localities across south eastern Australia.

Project Outline

The GrassGro decision support system was used to model the productivity and economic output from a range of sheep enterprises under optimal management. Optimal management was judged on the basis of gross margin (GM) in dollars per hectare since land represents both the primary resource limitation and also the greatest capital investment.

Simulations were run at four localities (Mortlake, Rutherglen, Naracoorte and Cowra) across the 37 years from 1965 to 2002. GrassGro (Moore et al 1998) uses daily historical weather data to drive a pasture growth model that involves both soil and plant characteristics. Animals then graze the pasture and their intake physical performance and harvestable product calculated based on herbage intake and quality (Freer et al 1998).

The enterprises analysed include

1) merino wethers
2) self relacing merinos
3) 1ST cross lambs (dual purpose flocks)
4) 2nd cross lambs (prime lamb).

Pure merinos (1,2 & 3) were simulated for three different reference weights and corresponding fibre diameters (superfine, fine and medium). While first and second cross enterprises were simulated for three target markets including store lambs, trade lambs (44kg) and export lambs (53kg).

The critical management decisions of lambing time (LT) and stocking rate (SR) were varied in order to determine optimal economic management of each enterprise. Lambing times ranged from April to October and stocking rates from 4 to 20 sheep per ha depending on enterprise. Each enterprise was then compared under optimal management at each locality.

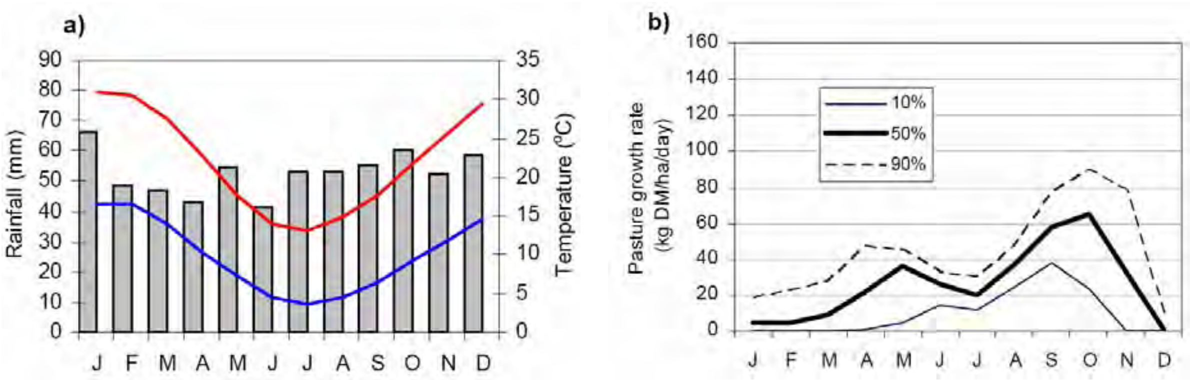
Project Results

For complete detail on every site and enterprise simulated I refer to the full project report available from the Sheep CRC (Warn et al 2006). In this paper I will draw mainly on the Cowra simulations but reference will be made to other localities in order to draw out specific points.

Simulation of Pasture Growth

Cowra simulations were of an annual pasture, grass dominant with 30% legume. Cowra is a non seasonal rainfall environment tending toward greater seasonal reliability in spring (figure 1. a). Winters are cool with regular frost incidence in June, July and August. Pasture growth is bimodal with both spring and autumn spikes in growth. The dark line in figure 1 b) represents the median growth rate averaged for each month of the year (for any given month the average growth rate has been above this line in 18 of the 37 years of the simulation). For example the median growth rate for July is 20 kg DM/ha/day while for October the median growth rate is 65 kg DM/ha/day. The pasture growth curve sets boundaries for the potential performance of the enterprises evaluated in the project.

Figure 1. Monthly climate and pasture growth rate percentiles for Cowra.

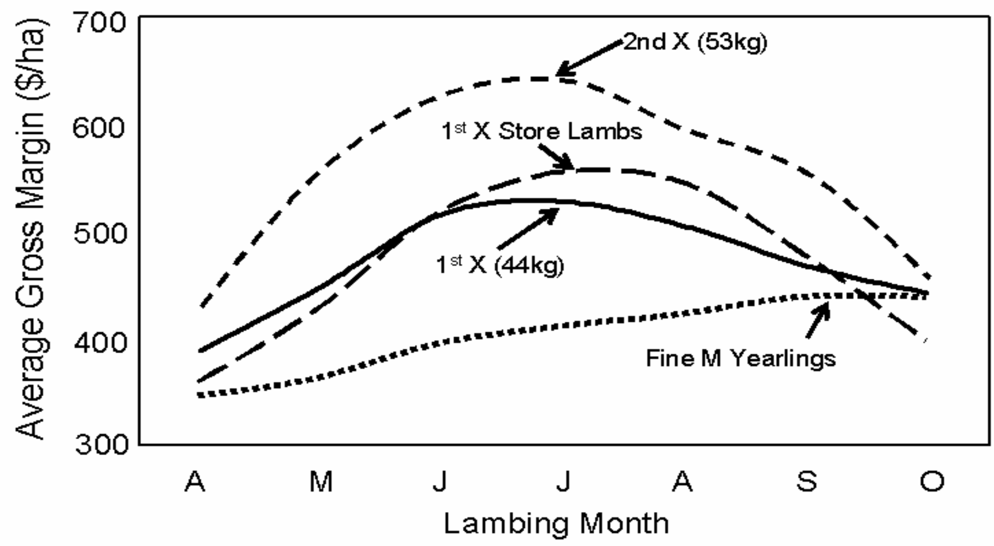


The Lambing Time x Stocking Rate Interaction

Analysis of the interaction between stocking rate and time of lambing determines the combination of these two factors that gives the greatest economic output per hectare.

Figure 2 illustrates the variation in GM by lambing date for four enterprises at Cowra. Given the shape of the pasture supply curve, enterprises that produce animals for sale as lambs give optimal returns by lambing in July.

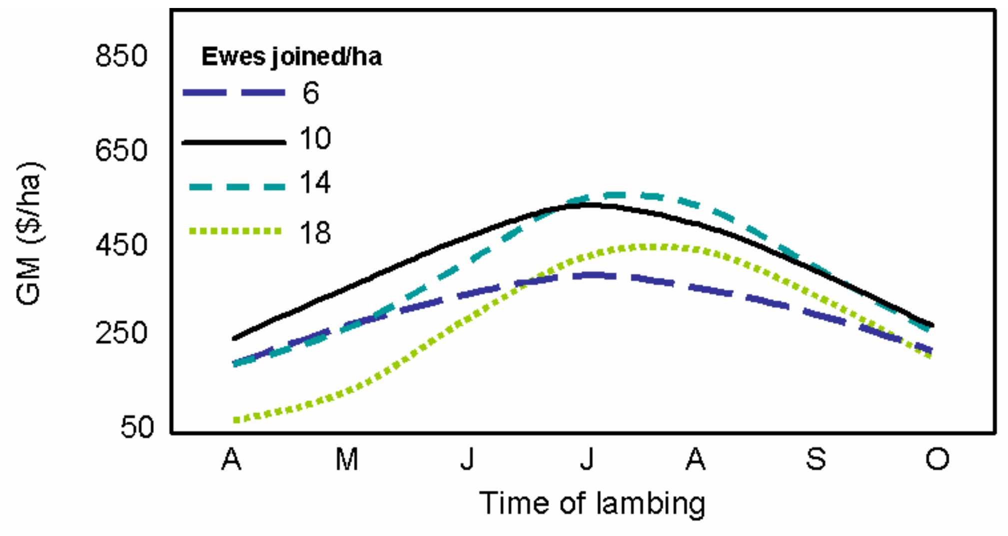
Figure 2. Change in average annual gross margin with lambing date for 4 breeding enterprises run at 10 ewes/ha on annual pastures at Cowra.



Contrasting this, a pure merino enterprise with sale of surplus young animals as yearlings (hoggets) which shows best returns with a September lambing. This timing allows sale animals the benefit of growth through a second spring season before sale. The optimal timing is a result of combining high live-weight at sale (kg/ha) with low cost of supplementation.

To derive the optimal combination of lambing time and stocking rate, simulations for every combination of these factors were run for each enterprise at each locality. Figure 3 summarises this exercise for a 2nd cross store lamb enterprise. Maximum GM is generated by lambing in July at 10 to 14 ewes per ha.

Figure 3. The interaction between lambing time (LT) and stocking rate (SR) for a 2nd cross store lamb enterprise at Cowra



Optimal scenarios were then screened using two other rules.

1) Ground cover > 70% from 1st of Jan to the 30th of Apr, at least 8 years in 10. (minimise risk of erosion and pasture degradation)

2) Ewes not fed > 30 kg of grain/head (wethers > 20 kg/head) more than 4years in 10. (only feed heavily in drought years)

Table 1. GM ($/ha) for stocking rate (SR) x lambing time (LT), highlighting constraints of ground cover and supplementary feeding.

Stocking Rate (ewes/ha)	Time of Lambing						
	April	May	June	July	Aug	Sept	Oct
4	146	195	236	259	249	214	166
6	198	274	338	373	355	299	224
8	234	334	417	464	437	358	256
10	243	356	460	527	492	393	271
14	196	281	420	550	525	406	257

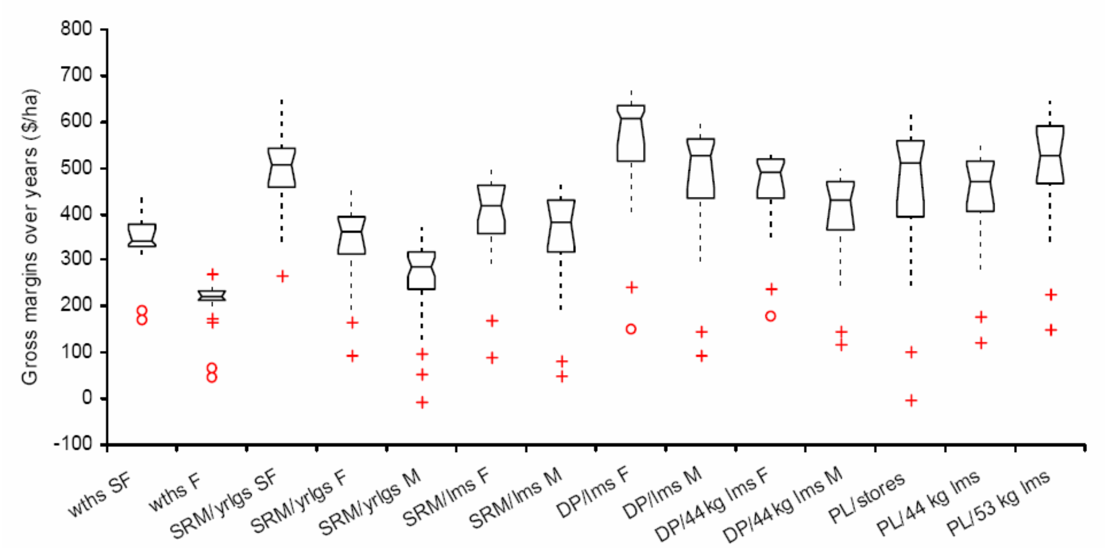
Feeding rule broken | Ground cover rule broken | Both rules broken

In Table 1, when these rules are met the optimum LT remains at July but the optimal SR is only 8 ewes per ha. Unshaded cells in the table show combinations of LT and SR that meet all necessary criteria. With all criteria met the expected average annual GM for this enterprise is $464/ha. This process has been repeated for all enterprises to enable a comparison of enterprise economic performance under optimal management.

The Comparisons

With a single set of assumptions regarding costs and prices there will always be one enterprise that, on average, generates more profit than all others. Figure 4 shows the distribution of gross margins for the years 1965 to 2002. The hourglass represents the middle 50% of the distribution while the dotted lines represent the probable statistical extremes. The symbols (+ and o) represent outliers (extreme droughts). For the defined Cowra locality the most profitable enterprise over the long run is a dual purpose flock (fine Merinos producing 1st cross store lambs). However a similar median GM can be achieved from dual purpose (medium merinos), self replacing super fine merinos and prime lambs (store and export).

Figure 4. Range in annual GM ($/ha) for simulated sheep enterprises at Cowra from 1965 -2002.



All enterprises can generate significant profits if managed optimally. Assuming farm overheads of $130/ha the average profit ranges from $84/ha up to $430/ha.

Comparison with industry benchmarks and Ag Census data suggests that in fact very few real farms are operating close to optimal levels. Adoption of simple technologies to increase

production per hectare (improved pastures, increased stocking rates and appropriate lambing time) can lead to large increases in net farm income (Webb Ware 2002, Lean etal 1997)

Reproductive Efficiency

The GrassGro simulations were also used to assess the economic impact of weaning more lambs. The results indicate it is important to first ensure that stocking rate and lambing time are optimised before focusing on weaning percentage as a profit driver. This is not to say that weaning rate is unimportant, indeed on farms already running at their carrying capacity (optimum stocking rate) it may even be profitable to run fewer ewes/ha in order to wean more lambs. Under-stocked farms should focus on lifting stock numbers closer to carrying capacity rather than simply on increased weaning rate.

Discussion

Valuable methodology not definitive results.

This work by the CRC represents a robust framework for comparison of enterprises in the context of the physical production system. It is especially useful in relation to quantifying production risks arising from climate variability. But it is only a snapshot of the production that might be expected under a very specific set of assumptions. It does not show there is a single optimal enterprise on any particular farm and certainly not that any one enterprise is the most profitable across any of the districts simulated. Nonetheless it does provide a robust methodology for exploring the productive potential of pasture systems for a range of pastures, soil types and climates.

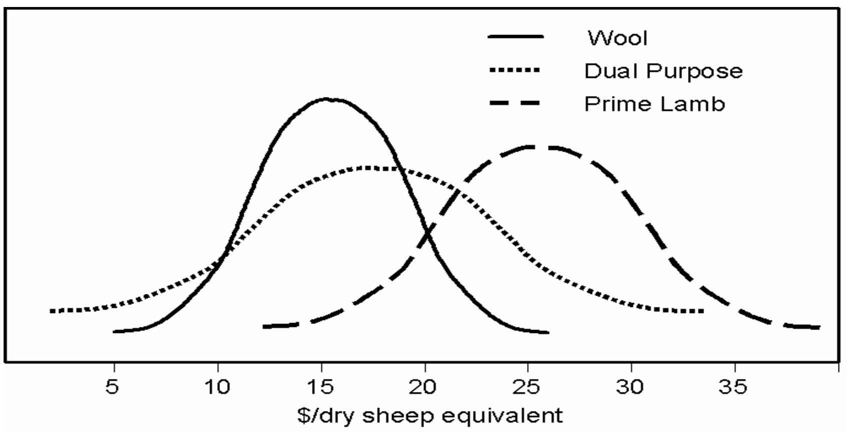
Salmon (2006) illustrates the power of modelling to reveal the spatial differences between farms in a search for the optimal stocking rate. GrassGro simulation for two properties in the Yass district showed that even at similar rainfall (710mm vs 760mm) shallower top soil and higher elevation reduced sustainable carrying capacity by one third (12 vs 18 wethers/ha). Similar differences between individual farms might be expected in most districts.

Variation within farms can be equally important. On any particular farm soil types and even climate characteristics may vary across the farm. On the Monaro average annual rainfall can vary by as much as 200mm within large properties due to the effects of elevation and topography. Despite this simulation modelling can provide the principles needed to make better decisions about stocking rate and lambing times and also give some clues as to optimal enterprise mix based on the mix of land capability and climate within the property.

Good management is a valuable as good enterprise choice.

One message is very clear, **"do what you do do, well"**. Benchmarking data illustrates the range in how well enterprises groupings are conducted in the real world (HSA 2005)

Figure 5. A graphical representation of the distribution of GM ($/dry sheep equivalent) for wool, dual purpose and prime lamb enterprises in AgInsights 2005 (HSA 2005)



Although the average gross margin per DSE differs between enterprises there are significant overlaps and the best performers for the worst enterprise are still better than the worst performers for the best enterprise (Figure 5). This reinforces it is more important to be good at whichever enterprises you choose to run. It is also important to acknowledge the costs involved when changing enterprises. Table 2. shows that in changing from Merinos to 1st cross ewes the time to break even depends of the price of replacement ewes. In recent years with 1st cross ewes making over $150/head it could take at least 5 years before the cumulative cash-flow would exceed that accrued by staying with the original Merino enterprise.

Table 2. Time to break even in the transition from a Merino enterprise to a 2nd cross store lamb enterprise as affected by 1st cross ewe purchase price (Rutherglen simulations).

Option	Ewe Cost ($/head)	Mean GM ($/hectare)	Break Even Time (Years)
Keep Merinos		$429	
Sell Merinos for $80 & Purchase first cross ewes.	$100	$631	1
	$130	$578	2
	$150	$542	5
	$180	$490	13
	$200	$454	40

Good genetics is equally important.
While the GrassGro modelling uses average animal genetics, there is clearly much to be gained through sourcing better than average genetics. In Table 3. a Merino genotype with 22% higher fleece weight at the same micron yields a GM almost 20% higher and the gap between the self replacing Merino enterprise and the dual purpose enterprise narrows considerably.

Table 3.Effect of improved genetics on economic output for a fine wool self replacing merino enterprise at Rutherglen.

Genotype	SR (ewes/ha)	Reference Wt. (Kg in CS 3)	Ewe FD (micron)	Wool Cut (greasy Kg/hd)	GM ($/ha)
Fine wool	8.5	50	19	4.1	$398
1st X lambs (fine wool)	9.5	50	19	4.1	$583
Fine Wool (22% more wool)	8.5	50	19	5.0	$474

This is reinforced by data from Merino bloodline comparisons (Atkins et al 2005). The most profitable bloodline yields a GM ($/dse) almost 40% higher than the average of all bloodlines while the lowest GM was almost 13% lower than the average.

The effect of genetics is equally important for meat enterprises. Fogarty et al (2005) reported the sire effect on GM ($/DSE) recorded by the Maternal sire Central Progeny Test (MCPT). The most common maternal sire breed (Border Leicester) ranged in GM from $28.32/dse to $39.77/dse for sires that were significantly better than the industry average (based on LAMPLAN figures), so it could be assumed that the potential range in GM due to genetics is even greater in the commercial industry.

Conclusion

The GrassGro analyses clearly showed that the most important economic drivers for sheep enterprises are optimising stocking rate and lambing times. In areas similar to those simulated there is considerable opportunity for sheep producers to increase their profits by refining their stocking rates and lambing times. Regardless of enterprise the focus should be on optimising the amount of meat and wool produced per hectare.

The strong performance of dual purpose enterprises and the relatively small difference in profit between self replacing Merinos and prime lamb flocks supports the option that many producers have taken in joining a proportion of their merino ewes to maternal or terminal sires. This option enables the producer to maintain important control over the flock genetics and greatly reduces the risk of introducing disease.

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On-farm adoption of *lifetimewool* principles for improved flock performance and risk management

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Summary

New knowledge about the impacts of ewe condition on flock productivity during different stages of the reproductive cycle is assisting producers to make improved management decisions regarding the allocation of feed resources to stock. These producers actively set ewe condition score targets for key periods during the year and manage ewes to achieve these targets. Producers report gains in flock performance as well as added benefits in reducing production risk.

Introduction

Lifetimewool is a national project funded by Australian Wool Innovation Limited and state government departments of Victoria, Western Australia, New South Wales, South Australia and Tasmania. The project commenced with plot scale experiments at Austral Park, Coleraine, Victoria and Billandri, Kendenup, Western Australia with a range of production measurements being collected from over 10,000 individual merinos exposed to various nutritional treatments. Lifetimewool guidelines were then tested across five states at 18 paddock-scale sites using commercial sized flocks and more than 200 producer demonstration sites from 2003 to 2007.

In Victoria, the Lifetimewool principles were initially tested with the establishment of 15 producer demonstration groups in 2004. Each group consisted of 4 producers in a localised area and were assigned a group coordinator to undertake a 2-year 'Lifetimewool on-farm management' pilot program. Evaluation of the program in 2005 highlighted an opportunity for further program development. In October 2006 a new nationally recognised competency based training course modelled on the pilot program was released. In its first year, the course titled 'Lifetime Ewe Management' has 23 producer groups (92 participants) operating throughout Victoria.

Why monitor condition score?

Ewe condition score effects the production and profitability of ewe enterprises. Ewe condition plays a vital role in:

- improving ewe health and survival
- increasing wool production and tensile strength
- improving ewe reproduction
- increasing lamb survival
- increasing progeny fleece weight and lowering fibre diameter

Knowledge of ewe condition impacts can be used to predict levels of production for both the ewe and her progeny based on the condition score profile the ewe undergoes during the year.

More importantly, this information allows producers to weigh-up different ewe management options by comparing the estimated production values that will be achieved with each option.

Economic analysis has determined that farm profit is affected by these changes in ewe condition over the year and that management strategies focussing on manipulating the ewe condition profile can have significant financial benefits. Using this analysis in combination with the biological impacts, lifetimewool has developed an optimum condition score profile with targets for joining, mid pregnancy and lambing (see Figure 1 for recommended condition score profile for high rainfall zone south eastern Australia).

Missing condition score targets can be very expensive. Current farm modelling suggests that failing to meet the recommended condition score lambing target by 1 condition score will cost around $16 per ewe for a typical merino wool enterprise given average seasonal conditions.

So measuring ewe condition and managing ewes to condition score targets can:

1. Increase farm profitability by running ewes in their most economical condition.
2. Assist producers manage risk by avoiding large production losses that can result from missing key condition score targets.

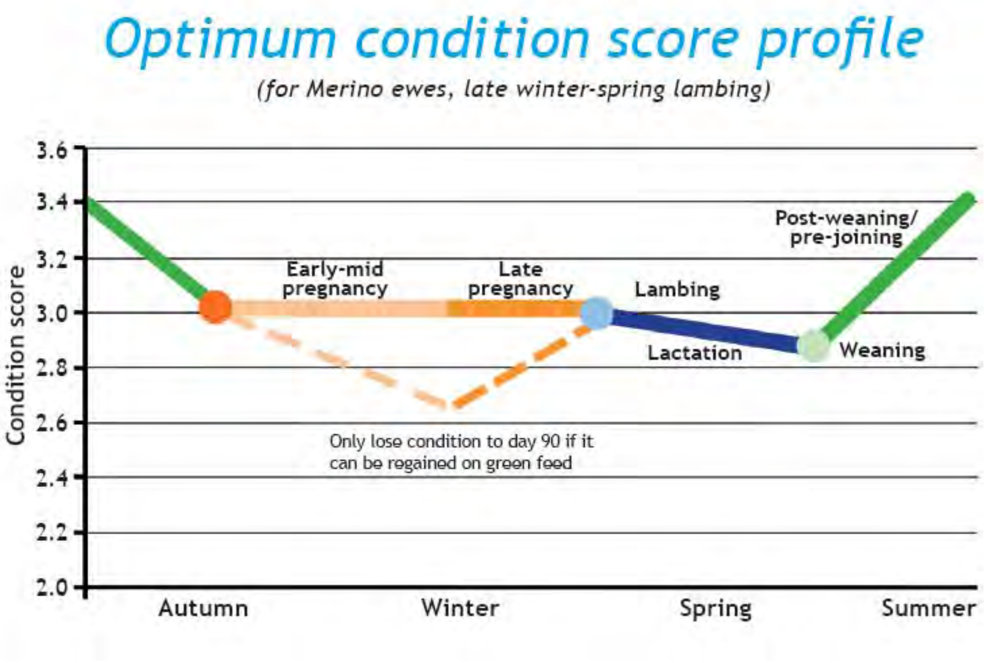

Figure 1. Recommended condition score profile for south eastern Australia High Rainfall Zone.

The condition scoring method

Ewe condition score is a 'hands-on' assessment of the amount of muscle and fat in the loin region of the animal. The assessor feels the ends of the short ribs, the spinal column and the muscle and fat cover between the spine and short rib ends in making the assessment.

Ewe condition scores range from (1-5), with 1 being a very thin animal and 5 being a grossly fat animal. For a standard 50 kg merino ewe each condition score equates to around 10 kg live weight, so that when this same animal is in condition score 2 she would be around 40 kg. In south eastern Australia, the average condition score of merino ewe mobs typically fluctuate from 2.0-2.5 to 3.5-4.0 throughout any given year, although there is large variation between properties and seasons.

Scoring a random sample of 50 ewes within a mob is sufficient to workout an average ewe condition score for the mob to a high level of accuracy. With some training, assessors are confident scoring individual animals down to an accuracy of 0.25 of a condition score. The technique enables small changes in mob condition to be detected over time, whereby a shift in the mob average of 0.1 of a condition score is equivalent to around 1.0 kg live weight for a typical merino ewe.

Benefits in adopting a ‘measure to manage’ approach

The approach is really about ‘measuring to manage’, where producers monitor ewe condition for the purpose of assisting ewe management decisions.

Producers who have incorporated Lifetimewool principles on-farm identify two main benefits in adopting this approach:

1. They meet key ewe condition targets more often than other producers. To have any confidence that condition targets are being met, or to identify a period where a condition target will not be met unless ewe management is altered in some way, producers must condition score.
2. They derive ‘peace of mind’ in knowing the condition of their ewes and have confidence in how their stock will perform. Without monitoring, it’s very difficult to be confident about condition of a mob at any given time. Whereas producers who condition score are confident in both the way their stock are being managed and in the production outcomes that will result.

Adoption of ‘new’ management practices

With knowledge of production impacts, potential economic benefits and a desire to improve ewe management decisions, there are three main areas of enterprise management likely to be influenced :

1. Changes to the way feed resources are allocated.
2. Adjustments to the calendar of operations e.g. length of joining, earlier weaning.
3. Permanent or temporary adjustments to stocking rates (increases & decreases).

In order to more effectively allocate feed, pregnancy scanning has been used to identify twin bearing ewes who have a higher nutritional requirement. This practice allows different management of these twinning ewes leading up to lambing through access to better pastures and higher rates of supplement. Particularly in seasons of low pasture availability, this management technique has led to improvements in overall lamb survival and rates of ewe mortality.

Drafting ewes based on ewe condition at weaning time has also been common. This allows the allocation of the best pasture to the individuals that need it most i.e the thin ewes. This allows maximum weight gain of poorer ewes prior to next years’ joining on late spring/early summer pastures.

As producers monitor their ewes they can easily identify periods where supplementary feeding rations and the rates of feeding need to be adjusted. The producer also makes adjustments to the ration based on the condition score targets set and the cost:benefit ratio of feeding to maintain condition at specific times during the breeding cycle.

Adjustments to the calendar of operations can include major changes such as the time of lambing or more simple techniques such as autumn deferment of pastures. This technique allows greater pasture mass to be available to ewes in the important stages of late pregnancy. Other practices have included a shortening of the joining period and weaning lambs earlier which both have the ability of allowing more time to improve ewe condition following weaning.

Monitoring ewe condition has also enabled producers to make decisions about matching stocking rate to their production system. Some producers have decided to permanently increase or decrease stocking rates after realising they were consistently missing condition targets, either above or below optimum. Likewise, identifying periods where seasonal conditions have been favourable or unfavourable in meeting condition targets, producers have made temporary adjustments to stocking rate.

Conclusions

Based on feedback from producers who have successfully incorporated Lifetimewool principles into on-farm management, significant advances in the management of sheep businesses can be made.

The adoption of a 'measure to manage' approach has enabled producers to more consistently meet the most profitable ewe condition targets, with the added advantage of giving these manager's 'peace of mind' through precise knowledge of ewe condition and it's impacts on productivity at any given time.

For more information on Lifetimewool guidelines please visit www.lifetimewool.com.au

NEW CENTURY TOOLS FOR MERINOS

JUNE 22, 2007

ROSEDALE

PARTICPANTS: Allflex Pty Ltd • Australian Meat Processor Corporation Ltd • Australian Wool Innovation Limited • Australian Wool Testing Authority Limited • Commonwealth Scientific and Industrial Research Organisation • Hall Family Trust and Ritchie Family Trust trading as JRL Hall & Co • Holmes, Sackett and Associates Pty Limited • Mike Stephens & Associates • Meat & Livestock Australia Limited • Murdoch University • NSW Department of Primary Industries for and on behalf of the State of New South Wales • Ridley Agriproducts Pty Ltd • Sheepmeat Council of Australia • State of Queensland acting through the Department of Primary Industries and Fisheries • State of South Australia acting through the Department for Primary Industries and Resources (SA) trading as SARDI • State of Victoria acting through the Department of Primary Industries • State of Western Australia represented by the Director General of Agriculture • University of New England • University of Tasmania • University of Western Australia • WoolProducers Australia Limited

THE SHEEP CRC LTD IS A JOINT VENTURE ESTABLISHED AND SUPPORTED UNDER THE AUSTRALIAN GOVERNMENT'S COOPERATIVE RESEARCH CENTRES PROGRAM

CONTENTS

Sheep Genetics Australia information materials are provided in the forum bags.

Merino wool-meat interface

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Summary

Information on wool and meat traits was collected from some 16,000 Merino ewe and ram hoggets over two years in 27 co-operating breeders' flocks across Australia. Environmental information including rainfall and pasture growth rates was also recorded. There were no major genetic antagonisms between wool and meat traits, which mean they can be improved concurrently. Regional variation in estimated breeding values means breeders and producers can consider sourcing improved genetics from other regions according to their breeding objectives. OFDA2000 measurements allow use of coefficient of variation in fibre diameter to improve staple strength and curvature to predict crimp frequency and resistance to compression for new wool traits. Pasture growth data and fibre diameter profiles provide a retrospective means of improved feeding for better staple strength.

Introduction

The sheep industry in Australia has responded over the last three years to increased income from meat relative to wool. Up to 40% of Merino ewes have been mated to specialist meat breeds and a large proportion of wethers previously run for wool production have been replaced by breeding stock. Therefore, sheep producers are seeking ways to improve their income from both wool and meat simultaneously.

Improving both meat and wool production in Merinos has potential advantages from improved meat characteristics in Merino cross lambs. About 90% of lambs turned off for meat in Australia contain varying proportions of Merino genes.

An added advantage of having income from both wool and meat is the insulation against income vulnerability as commodity price swings for these products are cyclical and unrelated.

Aims

Our project had the primary aim of measuring relationships between wool and meat traits including some wool traits not currently part of the Sheep Genetics Australia (SGA) program. In addition, we obtained detailed information on the large range of environments to help develop improved breeding and management guidelines.

Project outline

Wool and meat traits were recorded over two years on some 16,000 2003 and 2004 born ewe and ram yearlings/hoggets with 27 co-operating Merino ram breeders across Australia (see Fig. 1 below). All flocks were recorded on SGA including standard wool and meat traits and ultrasound muscle and fat depths. In addition we collected mid side wool samples for (a) length, strength, yield, crimp frequency, laserscan and resistance to compression tests by the Australian Wool Testing Authority; (b) OFDA2000 testing by the Interactive Wool Group; and (c) visual and measured wool style by CSIRO at Chiswick. In addition, satellite data for each of the 27 sites obtained through CSIRO's Pastures from Space project gave pasture growth rates.

The location of breeder properties and grouping according to climatic regions is shown in Figure 1.

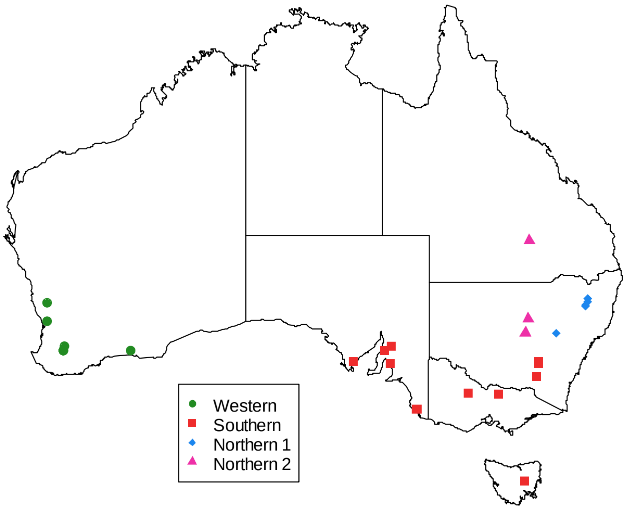


Figure 1: Location of co-operating Merino breeder flocks and regional groupings

Results and discussion

The results are presented as regional averages as outlined in Figure 1 under the following headings –

- Phenotypic means for wool and meat traits
- Genetic variability and associations between wool and meat traits
- Genetic means for wool and meat traits
- Fibre diameter profiles and pasture information

<u>Phenotypic means.</u>
Average phenotypic means for wool and meat traits are given by region in Table 1.

Table 1: Phenotypic means for wool and meat traits by regions and years

Region	Year	Yearling or Hogget wt (kg)	Greasy fleece wt (kg)	Wool micron	Staple strength (N/ktex)	Eye muscle depth (mm)	Fat depth (mm)
Western	1	45.4	4.0	17.4	31.1	21.2	2.5
	2	47.8	4.0	17.7	37.2	21.0	1.0
Southern	1	47.6	3.8	17.3	33.6	23.0	2.7
	2	47.8	3.6	17.8	32.2	21.9	2.7
Northern1	1	52.4	4.9	16.8	45.4	22.0	2.5
	2	48.1	4.0	15.7	46.4	23.3	2.8
Northern2	1	46.3	4.0	18.2	39.8	23.4	2.4
	2	36.0	2.8	17.7	31.3		

The above means represent environmental differences, independent of genetic differences, including climate, pasture and management. There are few obvious trends in the data though Northern1 (Northern Table Lands) appear to have comparatively heavier body weights and

fleece weights, despite lower wool micron, probably due to later weighing and shearing when animals are comparatively older.

Genetic variability and associations.

Heritabilities and genetic correlations describe the amount of genetic variability and associations between traits. A heritability of 0.30 or 30% means that 30% of the variability between animals is under genetic control through their breeding values. Genetic correlations describe how closely two traits are genetically related with values between -1 and 1. The nearer the values are to zero the weaker the relationship between traits.

Genetic correlations between core wool traits as in SGA, and the new wool traits including curvature, crimp frequency and resistance to compression, are given in the following table with heritabilities shown in bold.

Table 2: Genetic correlations and heritabilities for wool and meat traits.

	GFW	CFW	FD	FDCV	SS	CUR	CR	RTC	WT	EMD	FAT
GFW	**0.41**										
CFW	0.90	**0.30**									
FD	0.28	0.25	**0.73**								
FDCV	0.07	-0.06	-0.06	**0.52**							
SS	0.13	0.30	0.31	-0.50	**0.44**						
CUR	-0.28	-0.33	0.11	0.06	0.11	**0.27**					
CR	-0.38	-0.49	-0.15	-0.12	0.13	0.83	**0.41**				
RTC	-0.12	-0.14	0.35	0.23	0.03	0.77	0.49	**0.41**			
WT	0.46	0.43	0.17	-0.30	0.21	0.15	0.15	0.13	**0.47**		
EMD	-0.20	-0.12	0.13	-0.09	0.20	0.20	0.14	0.22	0.54	**0.23**	
FAT	-0.36	-0.15	0.20	0.02	0.16	0.09	0.13	0.16	0.45	0.54	**0.10**

GFW-greasy fleece weight; CFW-clean fleece weight; FD-fibre diameter; FDCV-CV of fibre diameter; SL-staple length; SS-staple strength; CUR-curvature; CR-crimp frequency; RTC-resistance to compression; WT-live weight; EMD-eye muscle depth; FAT- fat depth.

Wool traits were highly heritable, particularly fibre diameter at 0.71. There was a strong negative genetic correlation between CV of fibre diameter and staple strength meaning lower CVs indicated greater staple strength. Unfavourable genetic correlations existed between fleece weight and fibre diameter, and between fibre diameter and staple strength. The 0.31 correlation for the latter means selection for reduced fibre diameter will also cause staple strength to decline. These unfavourable correlations can be overcome by considering the traits in a weighted selection index. For the new wool traits, curvature was highly correlated with crimp and resistance to compression while both crimp and resistance to compression had moderately high heritabilities. Therefore, curvature measurements from OFDA2000 can be used to predict and select for crimp frequency and resistance to compression.

Body weight was highly heritable and eye muscle depth moderately. The meat traits were moderately positively correlated. There were moderate to high correlations between body weight and both wool and meat traits. However, there were some unfavourable correlations between eye muscle depth and both fleece weight and fibre diameter. Use of an appropriate selection index can allow eye muscle depth and fleece weight to be increased while fibre diameter is decreased.

The genetic correlations and heritabilities discussed above are similar to SGA estimates for their standard traits.

Genetic means for wool and meat traits.

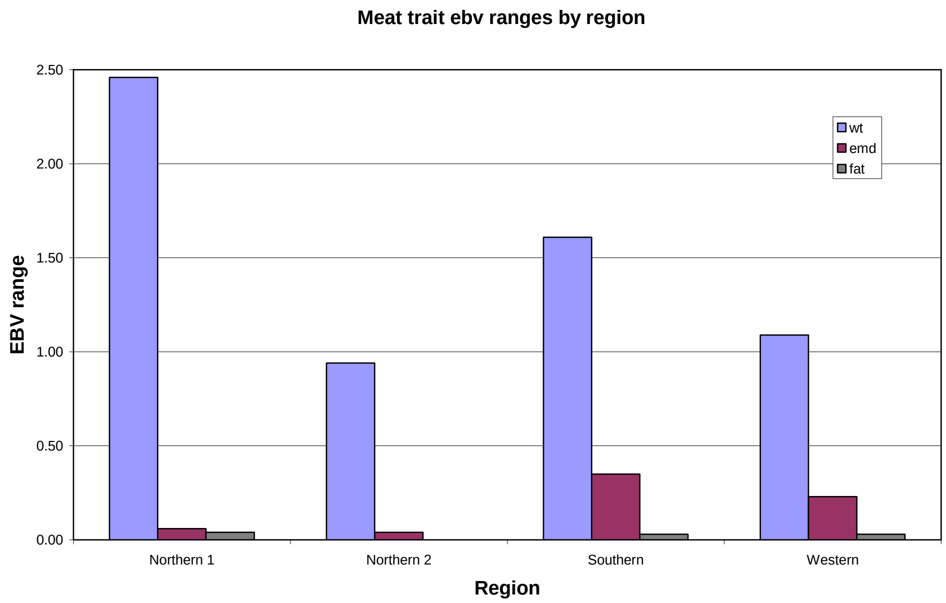
Average breeding values (EBVs) have been calculated for key wool and meat traits in each flock. These EBVs are derived from the actual heritabilities and phenotypic values from this dataset as well as background pedigree information from the wider SGA database. Average EBVs for each region are given in Table 3 and ranges are in Fig. 1.

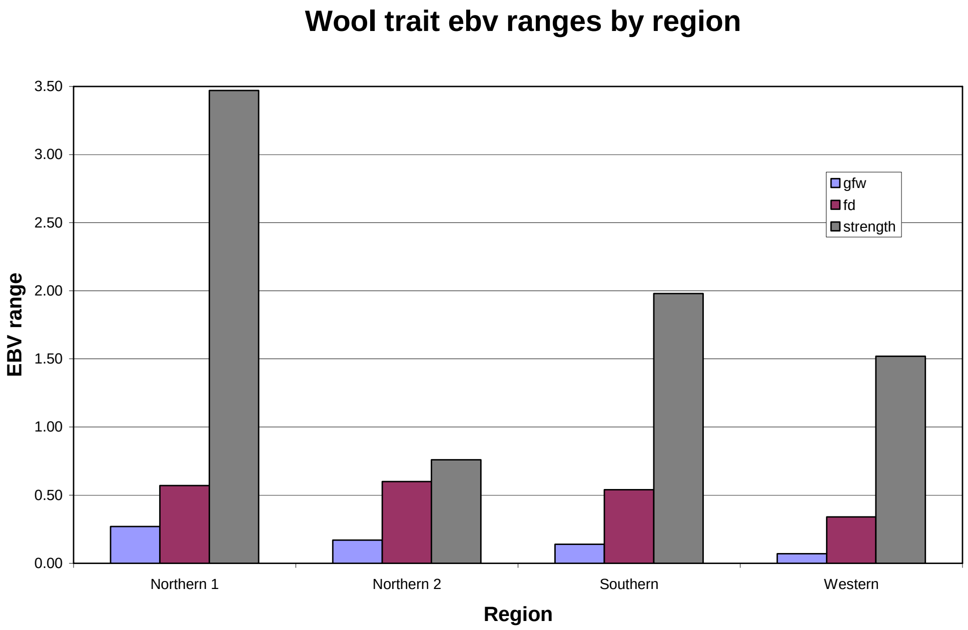
Table 3: Average estimated breeding values for the flocks in each region

		Meat			wool			new wool	
Region WT	**EMD**	**FAT**	**GFW**	**FD**	**SS**	**RTC**	**CUR**	**CR**	
Northern1	-1.14	-0.16	-0.02	-0.08	-0.18	-0.27	-0.07	0.37	0.00
Northern2	0.32	-0.01	-0.04	0.05	-0.22	0.43	-0.05	-0.43	-0.02
Southern	0.29	-0.02	-0.01	0.08	-0.15	0.13	-0.11	-0.65	-0.05
Western	0.08	-0.05	-0.01	0.02	-0.06	0.31	0.00	0.34	0.05

Comparisons of average EBVs between regions indicate more variation in meat than wool traits. The Northern1 flocks (Northern Tablelands) appear on average to have less genetic potential for improved meat traits than their western and southern counterparts, however all four regions still have significant opportunity for selection. While the four regions have similar fleece weight genetics, the northern region has a tendency to lower micron and higher crimp frequency.

Ranges in meat and wool trait EBVs, relating to averages in Table 3 for each region are given in Figure 1 below. Note that these values can be positive and/or negative.





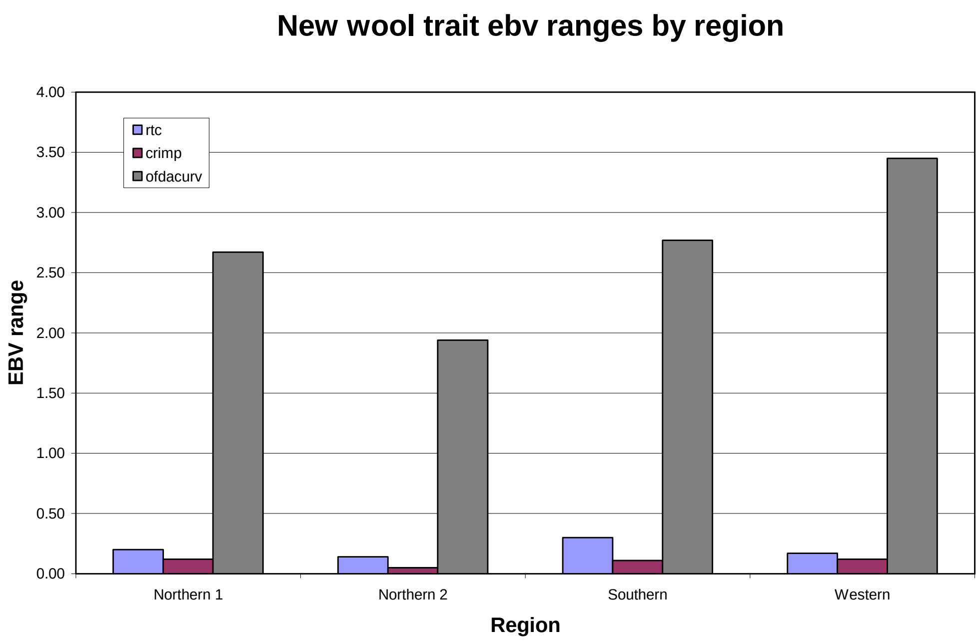


Figure 1: Ranges in average flock EBVs meat and wool traits in each region.

Note that the above graphs contain standardised EBV ranges.. The ranges for average flock breeding values showed that breeding flocks in the Northern1 region had comparatively greater variation in live weight and wool staple strength while western region flocks had the most variation in wool curvature. These results indicate comparatively greater potential for genetic improvement in live weight and staple strength in the Northern1 region than indicated by the average values in Table 4. The new wool traits, curvature in particular, had greatest variation in the western region. This provides opportunities for both breeders and commercial producers to explore these regional differences by sourcing genetic material to better match their breeding objectives.

Pasture information

Pasture growth information averaged over properties in the two contrasting Western and Northern1 regions for the two years of the project is given in Figure 2 below.

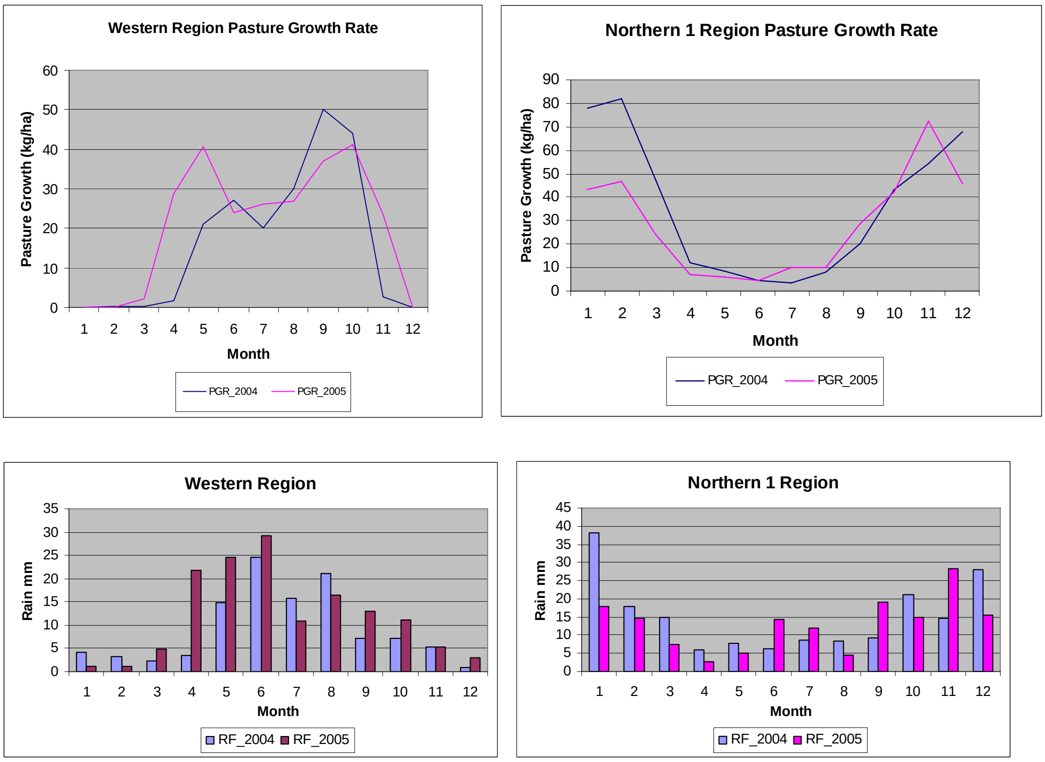
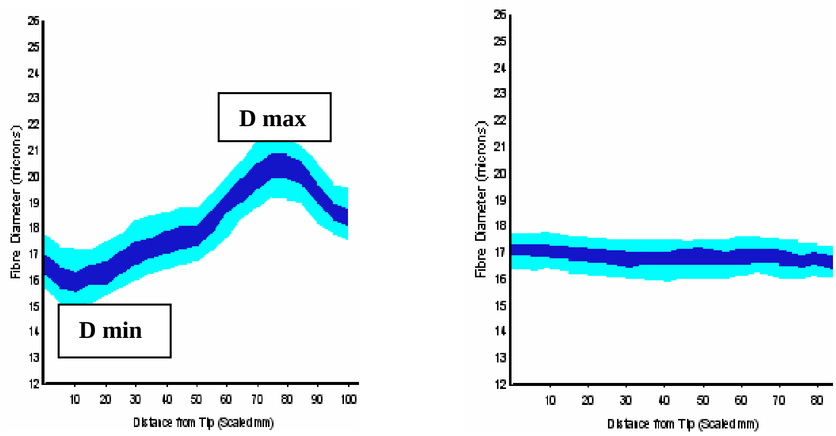


Figure 2: Average pasture growth rates and rainfall for the Western and Northern1 regions.

The pasture growth information in Fig. 2 above has been obtained from satellite data kindly supplied by CSIRO's Pastures from Space project. The two contrasting regions show winter (Western) and summer (Northern1) dominant pasture growth aligned with the rainfall data in the lower graphs. Within each of these regions, there was considerable variation among the various breeder properties in rainfall and pasture growth variation.

Fibre diameter profiles

The OFDA2000 measures fibre diameter profiles, which give changes in fibre diameter along the wool staple. Results from our project show there is much greater variation in fibre diameter in the southern and western regions with Mediterranean type climates with hot dry summers than in the more temperate northern climates with more equitable rainfall. Typical fibre diameter profiles from these contrasting regions are shown in Figure 3.



Mediterranean **Temperate**

Figure 3: Typical fibre diameter profiles from Mediterranean and temperate climates

Average flock differences between maximum (Dmax) and minimum (Dmin) fibre diameter are plotted against average staple strength for 18 of the co-operating flocks during year one of the project in Fig. 4.

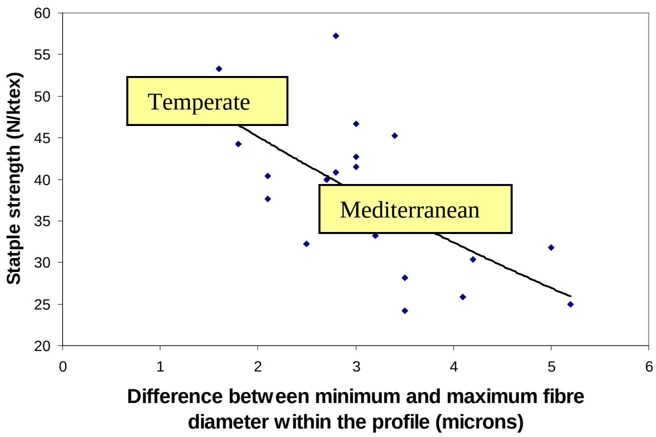


Fig. 4: Relationship between flocks with low fibre diameter profile variation in temperate regions in contrast with higher variation in Mediterranean climates.

The average flock differences between Dmax and Dmin gave a good indication of average staple strength as shown in Fig. 4 above.

For improved staple strength management, breeders should aim to flatten the profiles with most emphasis on preferential feeding during the time period of minimum fibre diameter. The example in Fig. 3 above indicates that under Mediterranean conditions with shearing in late spring preferential feeding over the summer would have improved staple strength. However, the cost effectiveness of this strategy would need to be assessed. This same principle applies in temperate conditions where there are low staple strength wools due to nutritional stress. Use of OFDA2000 and pasture growth rate data can define periods for preferential feeding.

Conclusions

The results from this project on wool and meat traits give breeders and commercial producers guidelines for genetic improvement in wool and meat production. There is also information

about use of pasture growth rates and fibre diameter profiles to improve wool staple strength. The main take home messages for breeders and producers are –

- The genetic parameters for standard SGA traits in this study did not vary greatly (with a few exceptions) from SGA values
- There are no major antagonisms between wool and meat traits in Merinos so breeders and their ram buyer clients can genetically improve both wool and meat production at the same time
- The unfavourable genetic correlations between fleece weight and fibre diameter, fibre diameter and staple strength, and eye muscle depth and greasy fleece weight/fibre diameter, can be overcome with use of appropriate selection indexes
- Regional variation in wool and meat trait EBVs provides opportunities for breeders and producers to source improved genetics
- Selection for lower coefficient of variation in fibre diameter from OFDA2000 profiles is the best tool to use for improvement in staple strength
- Values for the new wool trait curvature from OFDA2000 can be used to predict the other new wool traits of crimp frequency and resistance to compression.
- Pasture growth data and fibre diameter profiles can be used retrospectively for improved feeding during periods of pasture shortage to improve staple strength

Acknowledgements

Grateful acknowledgement is made to the following: the 27 co-operating Merino breeders; MLA and AWI for financial and technical support; AWTA and IWG for in-kind laboratory support; provision of Pastures from Space data by Graham Donald, CSIRO Chiswick; skilled technical input from Grant Uphill, Christine Dennis, Judi Kenny and Heather Brewer, CSIRO Chiswick.

Novel Merino Wool Quality Traits

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Summary

The project was conducted in conjunction with Sheep CRC Project 1.2.6, in which wool samples representing some 29 Sheep Genetics Australia (SGA) flocks were tested for a range of novel traits including resistance to compression, crimp frequency and measured and assessed style traits.

Genetic variation in novel traits:

- The novel traits of crimp frequency, resistance to compression, crimp definition, wool colour and staple size were moderately to highly heritable and therefore could be easily improved through selection.
- The genetic correlation between mean fibre curvature and crimp frequency was 0.84 to 0.93 suggesting that there is little need to measure crimp frequency to change it genetically.

Trueness to Type:

- The results also indicate that there is significant variation between Merino strains / flocks in their diameter and crimp relationships. That is some flocks have a measured fibre diameter consistently different to that predicted from their crimp frequency.
- A “Trueness to Type” score was calculated for each sheep which indicated its FD relative to that expected based on its crimp frequency.
- Given the strong genetic relationships between crimp frequency and fibre curvature it is also possible to predict a crimp frequency measurement from the standard fibre curvature measurement. This predicted crimp frequency measurement can also be used to calculate a Trueness to Type score. Trueness to Type classification could be made available in the near future following industry consultation and validation.

Prediction of resistance to compression:

- Measurements of resistance to compression can be predicted with moderate accuracy from the other wool measurements made in this study.
- At the genetic level, resistance to compression was significantly related to fibre diameter (0.36), fibre diameter coefficient of variation (0.21), fibre curvature (0.79), crimp frequency (0.52), variation in crimp frequency (0.96) and staple size (0.41). Therefore resistance to compression could easily be included in the breeding objective without the need for direct measurements.

Introduction

The focus of this project is to extend the scope of traits measured for SGA across-flock genetic evaluation, by developing the basis for trait definitions for several traits presently considered important to sheep classer and wool buyers – namely those relating to the visual ‘style’ and the tactile appeal of wool.

“Trueness to type” is a term used is the wool industry to define whether a fleece’s crimp frequency matches its fibre diameter. Across flocks there is a strong relationship between these traits, with finer wools displaying a much higher crimp frequency and curvature than broader wools. Nevertheless, at any given fibre diameter, flocks are often under or over crimped, and therefore not “true to type”.

Novel wool traits

Historically, trueness to type has been used by the wool trade as an integral component of a system allowing the prediction of processing performance to the yarn stage of greasy wool, using a system of “quality numbers”. In assigning a quality number, trueness to type was combined with assessment of handle, colour, length and strength to estimate the number of 560 yard hanks of yarn able to be spun from per imperial pound of scoured wool. While the prediction of processing performance based on objective raw wool measures has advanced substantially over the years, trueness to type is still an important price determinant in some wool markets.
The compression characteristics of wool represent an important aspect of wool quality with requirements depending upon end use and processing conditions. Resistance to compression has also been shown to be significantly related to fibre curvature and crimp frequency.

This study will develop the preliminary basis for the estimation of breeding values for:

- Crimp frequency: new measurement technology has been used which enables a routine and objective measurement of crimp frequency.
- Trueness to type: the relativity of fibre curvature and crimp frequency with fibre diameter.
- Compressibility: as estimated using the measurement of resistance to compression and other raw wool traits.

The Data Used

This project was conducted in conjunction with Sheep CRC Project 1.2.6, whereby wool samples representing some 29 client flocks of Sheep Genetic Australia were tested for a range of wool parameters by IWG using OFDA2000 and AWTA using Laserscan and other measurement technology. Samples were also measures for style traits using the Style Machine and the same samples were visual assessed/scored for a similar range of style related traits.

The data set contained 12,085 animals (7,130 females and 4,951 males) with data and 22,397 animals in the pedigree. There were 374 sires and 6,000 dams with recorded progeny. The data originated from 29 SGA flocks and all animals measured were born in 2003, 2004 and 2005. All animals were measured at either at yearling or hogget ages. Some flocks also shore / tipped their sheep as lambs where others did not.

Genetic variation in novel traits

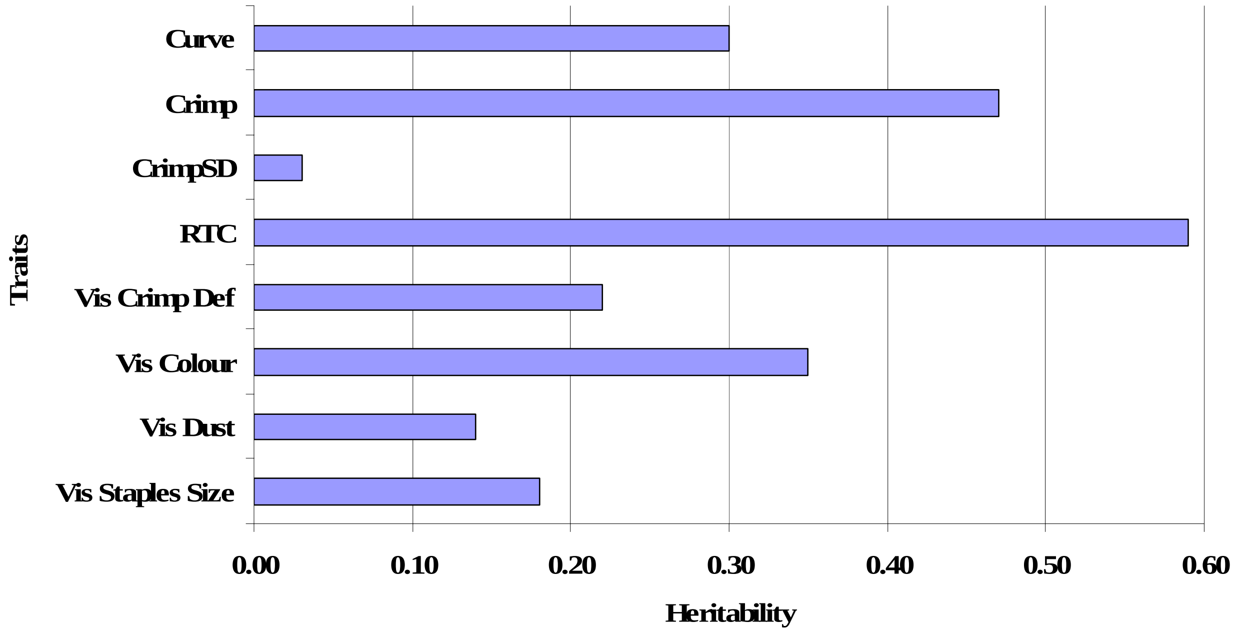
- The heritabilities of the standard wool traits agree with previous estimates from SGA data.
- As shown in Figure 1 below, the heritabilities for the novel traits were generally moderate to high except variation in crimp (CrimpSD) and dust penetration (Vis Dust).
- Visually assessed colour, crimp definition and dust were more highly heritable than the equivalent Style Machine traits.
- Fibre diameter measurements from Laserscan and OFDA were genetically and phenotypically the same traits, with genetic and phenotypic correlations of 0.98 and 0.89 respectively.
- Laserscan and OFDA fibre curvature had a high genetic correlation of 0.92, although the phenotypic correlation was only 0.53.
- Crimp frequency from AWTA was also genetically correlated with;
    - ✓ Greasy fleece weight -0.37
    - ✓ Staple length -0.43
    - ✓ Fibre diameter -0.15
    - ✓ Laserscan curvature 0.84
    - ✓ OFDA curvature 0.93

  The high genetic correlation between crimp frequency and curvature indicates that there is little need to measure crimp frequency directly in breeding programs. To put this in context, the genetic correlation between the traits of around 0.9 is much higher than the genetic correlation between CV of fibre diameter and staple strength (-0.5). CV of fibre diameter is regularly used as a proxy trait for staple strength.
- Some other interesting genetic correlations were;
    - ✓ Smaller staple size is associated with better crimp definition (0.83)

Novel wool traits

- ✓ Smaller staple size is associated with greater staple length (0.43)
- ✓ Higher crimp frequency was associated with short staple length (-0.44)

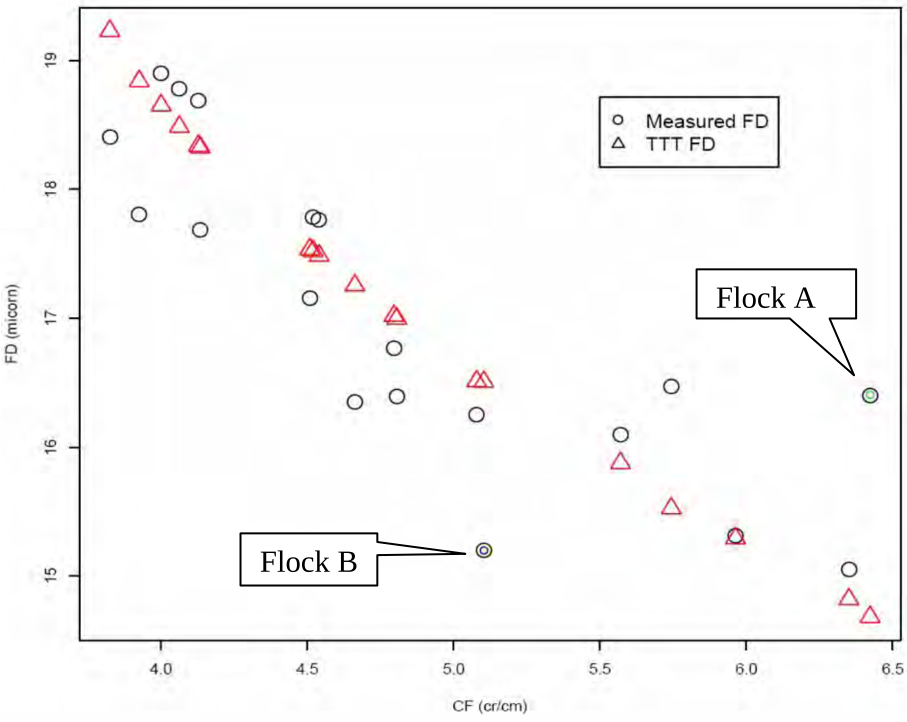
Figure 1: Heritabilities for selected novel wool traits



Trueness to Type

Trueness to type fibre diameter (TTT FD) was derived for each animal using crimp frequency and a modified version of published formulae. The deviation of each of these from the measured Laserscan FD was taken as the TTT score. Furthermore given the strong genetic relationship between crimp frequency and fibre curvature it is also possible to predict a crimp frequency measurement from the standard fibre curvature measurement and then derive TTT FD. Because breeding values for fibre diameter and curvature are currently available from SGA, the TTT classification could be implemented using current information, without the need to directly measure crimp frequency. Delivery could occur quite rapidly following industry consultation and validation.

Figure 2 Average Laserscan fibre diameter (AWTA FD), predicted "trueness to type" fibre diameter (TTT FD) and Crimp Frequency (CF) for each flock



The relationship between crimp frequency and fibre diameter in Figure 2 shows the effects we were trying to model. For example Flock A in figure 2 has an observed mean fibre diameter much higher than expected from its crimp frequency. Alternatively Flock B has a much low measured fibre diameter than expected from its crimp frequency.

Across all the animals there is a moderate negative relationship between fibre diameter and crimp frequency (correlation of -0.51). However, within flocks there are variable correlations ranging from low negative to low positive, hence the small genetic correlation between fibre diameter and crimp shown above. Other results suggest that the prediction function fits the data well at low to moderate crimp frequencies, but not so well at high crimp frequencies (>6 cr/cm).

The data set used in this study only contained animals with mean fibre diameters from approximately 14 microns to 19 microns. As this is not representative of wider industry the results need to be tested more with a data set which included more broader wools.

The results also demonstrated that the practice of tip/even-up shearing of lambs/weaners also affected the relationship between fibre diameter with crimp and curvature measurements.

Prediction of resistance to compression

Phenotypic Prediction

The ability to phenotypically predict RTC from the other measured traits was examined using both the Laserscan and OFDA data separately. The table below shows how much variation in RTC each trait explained.

	Laserscan	**OFDA**
Mean fibre curvature	33%	21%
Mean fibre diameter	8%	19%
Crimp frequency	7%	1%
Fibre diameter coefficient of variation	1%	1%
Variation in crimp frequency	1%	1%

Novel wool traits

Total	**50%**	**43%**

Previous research has also demonstrated that the function of $D^2 * R^{-1.5}$ explained 91.2% of the variation in RTC where D is fibre diameter and R is the radius of fibre curvature. In the current study this prediction equation explained 41% and 38% of the variation in RTC based on Laserscan and OFDA measurements respectively. The accuracy of this prediction was also variable across each flock.

Genetic Prediction

Genetically resistance to compression was significantly related to fibre diameter (0.36 ± 0.05), fibre diameter coefficient of variation (0.21 ± 0.06), fibre curvature (0.79 ± 0.03), crimp frequency (0.52 ± 0.07), variation in crimp frequency (0.96 ± 0.25) and staple size (0.41 ± 0.09). Thus resistance to compression could easily be included in the breeding objective without the need for direct measurements.

Conclusions

- The novel traits of crimp frequency, crimp definition, wool colour and resistance to compression were moderately to highly heritable and therefore could be improved through selection.
- Curvature is significantly genetically and phenotypically related to crimp frequency such that there is little need for direct measurement of crimp frequency.
- The results also indicate that there is significant variation between Merino flocks in their diameter and crimp relationships. That is, some flocks have a measured fibre diameter consistently different to that predicted from their crimp frequency.
- A trueness to type score was able to be derived for each sheep which indicates its fibre diameter relative to that expected based on crimp frequency.
- As curvature and crimp frequency were significantly correlated a TTT score was also generated using fibre curvature rather than measured crimp frequency.
- This scoring system requires further consultation and validation by industry but could be implemented using existing information from SGA.
- Phenotypically, resistance to compression could be predicted with moderate accuracy from the other wool measurements made in this study.
- Genetically, resistance to compression was significantly related to many traits, therefore resistance to compression could be included in the breeding objective without the need for direct measurements.

Acknowledgements

This project involved the successful collaboration of several organisation including, AWI, AWTA, AGBU, CSIRO, Sheep CRC and IWG. The author would like to thank all parties for the valuable contributions but in particular Dr Paul Swan, Dr Trevor Mahar and David Crowe.

More Information

To obtain additional information about this project please contact Daniel Brown on email at dbrown2@une.edu.au or phone 02 6773 2160.

Information Nucleus

Dr Forbes Brien
South Australian Research and Development Institute

Introduction

The Cooperative Research Centre for Sheep Industry Innovation (Sheep CRC), the successor to the Australian Sheep Industry CRC, will transform wool and meat products and the sheep that produce them with new research to 2014. A key program of the Sheep CRC is the *Information Nucleus*.

The *Information Nucleus*, a world first innovation for sheep, provides next-generation genetic and new trait information to industry and supports the three core research programs of the Sheep CRC:

- Transforming sheep and their management
- Next generation wool quality
- Next generation meat quality

Each year 5000 ewes in diverse *Information Nucleus* flocks across Australia will produce progeny by 100 Merino, maternal and terminal sires chosen from across industry. The progeny will be extensively measured and assessed for current and new traits in meat and wool quality, parasite resistance and reproduction.

Through the Sheep CRC's unique partnership with SGA Sheep Genetics Australia and SheepGenomics the information will be used to:

- Improve accuracy of Australian Sheep Breeding Values (ASBV) for current traits
- Contribute to development of ASBVs for new traits
- Validate molecular markers for current and new traits
- Develop breeding values that combine quantitative and molecular information.

Breeders and commercial producers will be able to quickly use the developments in new genetic technology and molecular information to advance their chosen breeding objectives. Both individual flocks and sheep across industry will achieve more rapid genetic gain.

What is the *Information Nucleus*?

The *Information Nucleus* is a series of flocks located at research sites around Australia that are directly linked to breeders and industry through SGA. The *Information Nucleus* uses key young and proven industry sires to progeny test for an extensive range of traits in widely differing environments.

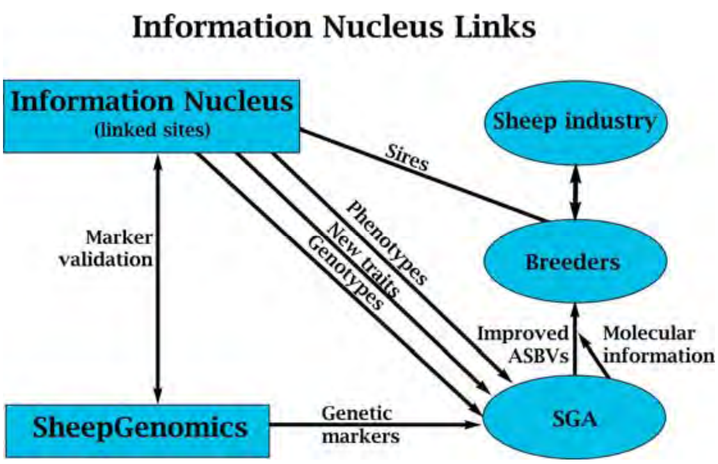
Working closely with SheepGenomics, the *Information Nucleus* will provide information on genetic markers and validate their usefulness for industry sheep.

With the information on phenotypes and genotypes generated from the *Information Nucleus*, potential genetic markers will be validated and the results from the other CRC research programs will be applied.

The genetic information will flow directly and rapidly to breeders and industry via SGA through more accurate Australian Sheep Breeding values (ASBVs) that will eventually be enhanced by the incorporation of molecular information.

What will the *Information Nucleus* do?

The *Information Nucleus* will generate genetic information about new and novel traits as well as traits that are difficult or expensive to measure commercially on-farm. These may be related to wool and meat quality, internal parasite resistance and reproductive performance. This will provide genetic parameters for traits such as staple strength, wool quality, meat eating quality, nutritional content, carcase yield and feed efficiency.



The *Information Nucleus* will also assess genetic variation and opportunities for improvement of new and novel traits such as wool UV-colour stability, traits of meat relating to human nutrition and characteristics that result in easier care and management of sheep.

Gene marker and SNP (single nucleotide polymorphism) discoveries will be tested and validated in sheep with different genetic backgrounds, sex and age in a range of environments.

The SheepGenomics program is developing new molecular technology that will allow animals to be quickly and cheaply tested for thousands of genetic markers and SNPs that will be validated in the *Information Nucleus*. The *Information Nucleus* will also be the focus of sheep management, wool and meat research being undertaken in the other CRC research programs.

How will the *Information Nucleus* help breeders?

Key sires from industry flocks are selected annually for mating in the *Information Nucleus*. Their progeny phenotype information will be included immediately in the SGA database and will contribute to ASBVs for the sires and to overall linkage of the SGA analyses. For most sires, the additional progeny will increase the accuracy of the sire ASBVs as well as the accuracy of the ASBVs for other related animals because of the greater across-flock linkage.

New traits that prove valuable to industry will be added directly to SGA if they are commercially applicable. A major advance will be the validation of gene markers and SNPs that will contribute to the development of molecular breeding values. These may eventually be incorporated into enhanced ASBVs that can be used to more accurately select sheep at a very young age and further increase the rate of genetic improvement.

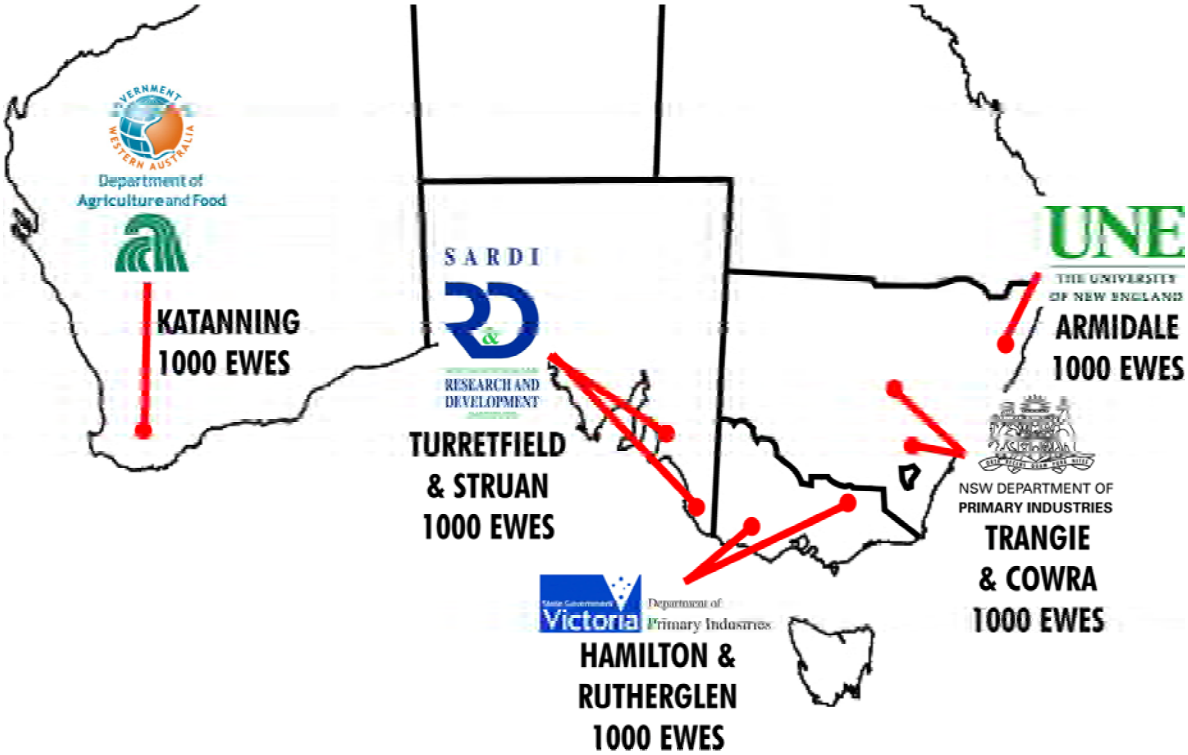
Selection of Sires

The *Information Nucleus* has been structured to provide genetic information for the most widely used production systems across Australia. The sires are selected on a combination of several attributes:

- High genetic merit for key production traits, including divergence for some other traits
- Genetic diversity of the selected team, so that a broad range of bloodlines, strains and breeds are sampled
- Linkage to the SGA database including potential for influence on future generations *(including some prominent bloodlines that have not yet been evaluated within SGA)*

How will the *Information Nucleus* work?

The *Information Nucleus* will operate at eight research sites covering a wide range of sheep environments in Australia:



Each year approximately 100 young sires will be selected and mated to 50 ewes each using artificial insemination and frozen semen. The first matings of the *Information Nucleus* occurred in early 2007 so that progeny will be available for evaluation in the first year of operation of the CRC for Sheep Industry Innovation (from July 2007).

The 5000 matings represent the major sheep types in the industry and generate Merino (MxM), Border Leicester X Merino (BLxM) and Terminal first (TxM) and second cross progeny (TxBLM) (see Table).

Approximate annual numbers of sires, ewes mated and progeny in the *Information Nucleus*

Sires	Ewes	Progeny	Retained (ewes)	Slaughter
40 Merino (M)	2000 M	1500 MxM	750	750
20 Border Leicester (BL)	1000 M	750 BLxM	375	375
40 Terminal (T)	1000 M	750 TxM	-	750
	1000 BLM	750 TxBLM	-	750
Total	5000	3750	1125	2625

The progeny will be evaluated for phenotypes for a large number of growth, carcase, meat, wool, reproduction and internal parasite resistance traits, which are not practical or economical to do on commercial farms. The crossbred lambs will be grown out and slaughtered in processing plants with industry partners. Detailed information on carcase and meat traits, meat yield and samples for laboratory testing will also be collected.

The MxM progeny will be evaluated for a wide range of wool traits and half the wethers will subsequently be slaughtered for carcase and meat evaluation. The MxM and BLxM ewes will be retained and mated naturally for two joinings to evaluate reproduction and maternal traits. Blood and tissue samples will also be collected for genotyping and molecular genetic studies.

It is planned that all *Information Nucleus* sites will have regular field days to enable industry to view progeny of sires and to keep up-to-date with the outcomes of the Sheep CRC programs.

Sheep Enterprise Comparisons – Using the GrassGro DSS to compare sheep enterprises run under optimal management.

Doug Alcock
Livestock Officer (Sheep and Wool) NSW DPI, Cooma.

Summary

GrassGro was used to compare the economic output of a range of sheep enterprises at 4 specific localities in southeastern Australia. It was found that stocking rate had the largest bearing on the enterprise gross margin (GM) $/ha. It was also determined that lambing from mid winter to mid spring was most profitable depending on enterprise and locality. Dual-purpose enterprises based on fine Merino Ewes were consistently the most profitable (prices averaged over 1999-2003 & adjusted for CPI) and seemed to be quite resilient in the face of changes in commodity prices. Most importantly there appears considerable scope for many sheep producers to improve their gross margin through attention to fine tuning stocking rate and lambing time regardless of their chosen enterprise.

Introduction

Many farmers regularly question whether changing enterprises would make them more profitable. Often the question relates to more dramatic shifts between cropping and grazing or between sheep and cattle enterprises, but in recent times the question is increasingly pertinent in deciding between the various sheep enterprise options. *"Would the farm make more money if I ran meat sheep rather than merinos"?*

More subtle is the question "what proportion of my merino ewes should I join to maternal or terminal sires"? To answer these questions the starting point is to determine the relative profitability of different sheep enterprises over the long term, under average market conditions and running in the same environment.

Project 1.2.6 of the Sheep CRC (1) was an "analysis of the profitability of sheep wool and meat enterprises in southern Australia". The project modelled grazing systems to determine the long term economic output of a large range of sheep enterprises run at a range of localities across south eastern Australia.

Project Outline

The GrassGro decision support system was used to model the productivity and economic output from a range of sheep enterprises under optimal management. Optimal management was judged on the basis of gross margin (GM) in dollars per hectare since land represents both the primary resource limitation and also the greatest capital investment.

Simulations were run at four localities (Mortlake, Rutherglen, Naracoorte and Cowra) across the 37 years from 1965 to 2002. GrassGro (Moore et al 1998) uses daily historical weather data to drive a pasture growth model that involves both soil and plant characteristics. Animals then graze the pasture and their intake physical performance and harvestable product calculated based on herbage intake and quality (Freer et al 1998).

The enterprises analysed include

1) merino wethers
2) self relacing merinos
3) 1ST cross lambs (dual purpose flocks)
4) 2nd cross lambs (prime lamb).

Pure merinos (1,2 & 3) were simulated for three different reference weights and corresponding fibre diameters (superfine, fine and medium). While first and second cross enterprises were simulated for three target markets including store lambs, trade lambs (44kg) and export lambs (53kg).

The critical management decisions of lambing time (LT) and stocking rate (SR) were varied in order to determine optimal economic management of each enterprise. Lambing times ranged from April to October and stocking rates from 4 to 20 sheep per ha depending on enterprise. Each enterprise was then compared under optimal management at each locality.

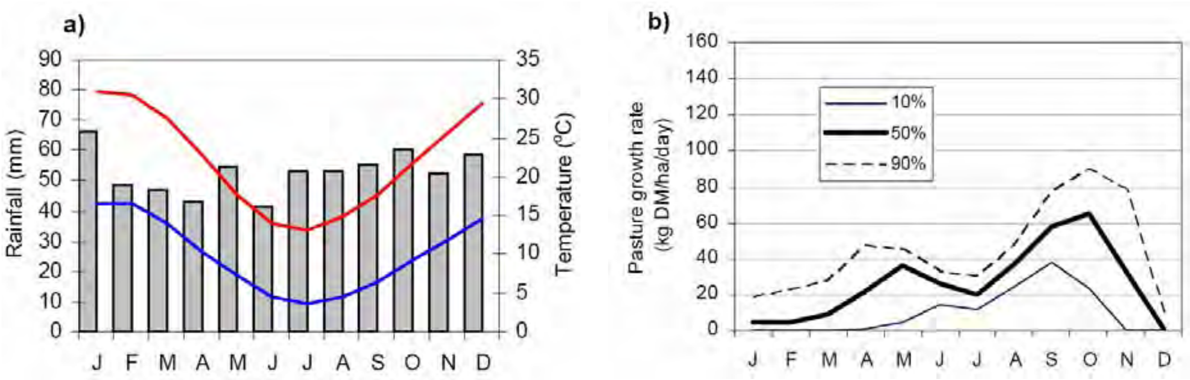
Project Results

For complete detail on every site and enterprise simulated I refer to the full project report available from the Sheep CRC (Warn et al 2006). In this paper I will draw mainly on the Cowra simulations but reference will be made to other localities in order to draw out specific points.

Simulation of Pasture Growth

Cowra simulations were of an annual pasture, grass dominant with 30% legume. Cowra is a non seasonal rainfall environment tending toward greater seasonal reliability in spring (figure 1. a). Winters are cool with regular frost incidence in June, July and August. Pasture growth is bimodal with both spring and autumn spikes in growth. The dark line in figure 1 b) represents the median growth rate averaged for each month of the year (for any given month the average growth rate has been above this line in 18 of the 37 years of the simulation). For example the median growth rate for July is 20 kg DM/ha/day while for October the median growth rate is 65 kg DM/ha/day. The pasture growth curve sets boundaries for the potential performance of the enterprises evaluated in the project.

Figure 1. Monthly climate and pasture growth rate percentiles for Cowra.

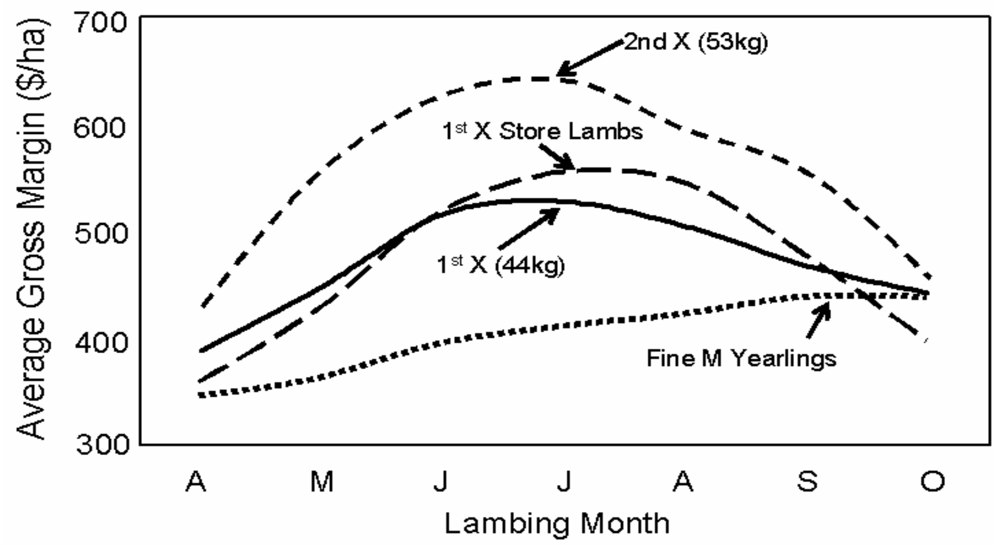


The Lambing Time x Stocking Rate Interaction

Analysis of the interaction between stocking rate and time of lambing determines the combination of these two factors that gives the greatest economic output per hectare.

Figure 2 illustrates the variation in GM by lambing date for four enterprises at Cowra. Given the shape of the pasture supply curve, enterprises that produce animals for sale as lambs give optimal returns by lambing in July.

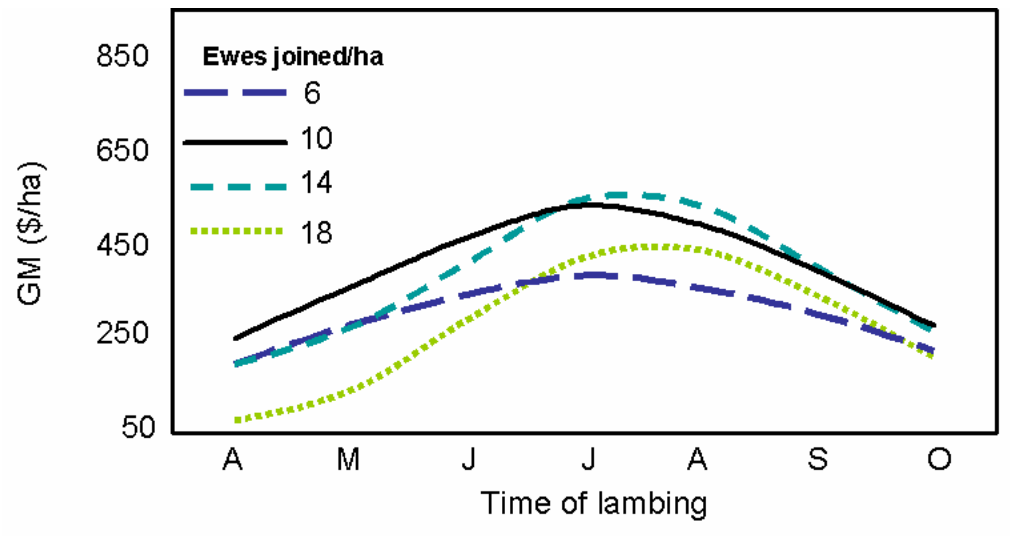
Figure 2. Change in average annual gross margin with lambing date for 4 breeding enterprises run at 10 ewes/ha on annual pastures at Cowra.



Contrasting this, a pure merino enterprise with sale of surplus young animals as yearlings (hoggets) which shows best returns with a September lambing. This timing allows sale animals the benefit of growth through a second spring season before sale. The optimal timing is a result of combining high live-weight at sale (kg/ha) with low cost of supplementation.

To derive the optimal combination of lambing time and stocking rate, simulations for every combination of these factors were run for each enterprise at each locality. Figure 3 summarises this exercise for a 2nd cross store lamb enterprise. Maximum GM is generated by lambing in July at 10 to 14 ewes per ha.

Figure 3. The interaction between lambing time (LT) and stocking rate (SR) for a 2nd cross store lamb enterprise at Cowra



Optimal scenarios were then screened using two other rules.

1) Ground cover > 70% from 1st of Jan to the 30th of Apr, at least 8 years in 10. (minimise risk of erosion and pasture degradation)

2) Ewes not fed > 30 kg of grain/head (wethers > 20 kg/head) more than 4years in 10. (only feed heavily in drought years)

Table 1. GM ($/ha) for stocking rate (SR) x lambing time (LT), highlighting constraints of ground cover and supplementary feeding.

Stocking Rate (ewes/ha)	Time of Lambing						
	April	May	June	July	Aug	Sept	Oct
4	146	195	236	259	249	214	166
6	198	274	338	373	355	299	224
8	234	334	417	464	437	358	256
10	243	356	460	527	492	393	271
14	196	281	420	550	525	406	257

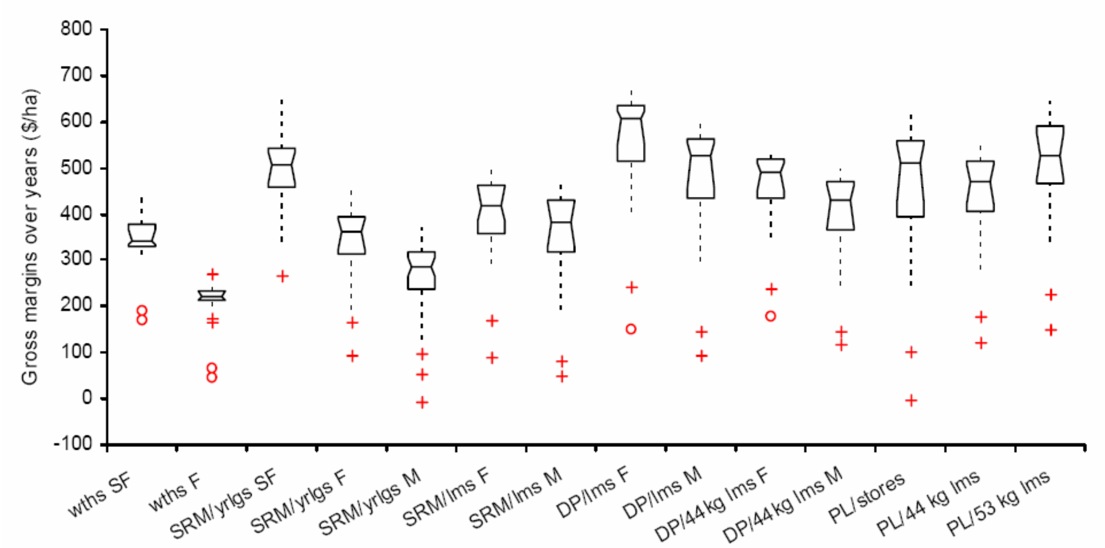
Feeding rule broken | Ground cover rule broken | Both rules broken

In Table 1, when these rules are met the optimum LT remains at July but the optimal SR is only 8 ewes per ha. Unshaded cells in the table show combinations of LT and SR that meet all necessary criteria. With all criteria met the expected average annual GM for this enterprise is $464/ha. This process has been repeated for all enterprises to enable a comparison of enterprise economic performance under optimal management.

The Comparisons

With a single set of assumptions regarding costs and prices there will always be one enterprise that, on average, generates more profit than all others. Figure 4 shows the distribution of gross margins for the years 1965 to 2002. The hourglass represents the middle 50% of the distribution while the dotted lines represent the probable statistical extremes. The symbols (+ and o) represent outliers (extreme droughts). For the defined Cowra locality the most profitable enterprise over the long run is a dual purpose flock (fine Merinos producing 1st cross store lambs). However a similar median GM can be achieved from dual purpose (medium merinos), self replacing super fine merinos and prime lambs (store and export).

Figure 4. Range in annual GM ($/ha) for simulated sheep enterprises at Cowra from 1965 -2002.



All enterprises can generate significant profits if managed optimally. Assuming farm overheads of $130/ha the average profit ranges from $84/ha up to $430/ha.

Comparison with industry benchmarks and Ag Census data suggests that in fact very few real farms are operating close to optimal levels. Adoption of simple technologies to increase

production per hectare (improved pastures, increased stocking rates and appropriate lambing time) can lead to large increases in net farm income (Webb Ware 2002, Lean etal 1997)

Reproductive Efficiency

The GrassGro simulations were also used to assess the economic impact of weaning more lambs. The results indicate it is important to first ensure that stocking rate and lambing time are optimised before focusing on weaning percentage as a profit driver. This is not to say that weaning rate is unimportant, indeed on farms already running at their carrying capacity (optimum stocking rate) it may even be profitable to run fewer ewes/ha in order to wean more lambs. Under-stocked farms should focus on lifting stock numbers closer to carrying capacity rather than simply on increased weaning rate.

Discussion

Valuable methodology not definitive results.

This work by the CRC represents a robust framework for comparison of enterprises in the context of the physical production system. It is especially useful in relation to quantifying production risks arising from climate variability. But it is only a snapshot of the production that might be expected under a very specific set of assumptions. It does not show there is a single optimal enterprise on any particular farm and certainly not that any one enterprise is the most profitable across any of the districts simulated. Nonetheless it does provide a robust methodology for exploring the productive potential of pasture systems for a range of pastures, soil types and climates.

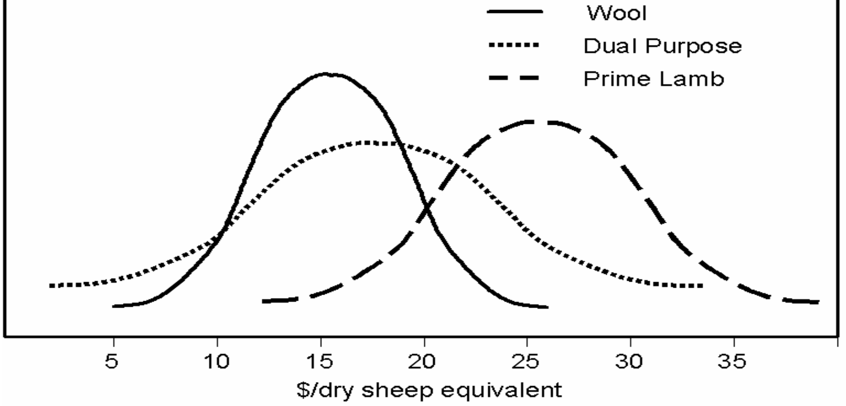
Salmon (2006) illustrates the power of modelling to reveal the spatial differences between farms in a search for the optimal stocking rate. GrassGro simulation for two properties in the Yass district showed that even at similar rainfall (710mm vs 760mm) shallower top soil and higher elevation reduced sustainable carrying capacity by one third (12 vs 18 wethers/ha). Similar differences between individual farms might be expected in most districts.

Variation within farms can be equally important. On any particular farm soil types and even climate characteristics may vary across the farm. On the Monaro average annual rainfall can vary by as much as 200mm within large properties due to the effects of elevation and topography. Despite this simulation modelling can provide the principles needed to make better decisions about stocking rate and lambing times and also give some clues as to optimal enterprise mix based on the mix of land capability and climate within the property.

Good management is a valuable as good enterprise choice.

One message is very clear, **“do what you do do, well”**. Benchmarking data illustrates the range in how well enterprises groupings are conducted in the real world (HSA 2005)

Figure 5. A graphical representation of the distribution of GM ($/dry sheep equivalent) for wool, dual purpose and prime lamb enterprises in AgInsights 2005 (HSA 2005)



Although the average gross margin per DSE differs between enterprises there are significant overlaps and the best performers for the worst enterprise are still better than the worst performers for the best enterprise (Figure 5). This reinforces it is more important to be good at whichever enterprises you choose to run. It is also important to acknowledge the costs involved when changing enterprises. Table 2. shows that in changing from Merinos to 1st cross ewes the time to break even depends of the price of replacement ewes. In recent years with 1st cross ewes making over $150/head it could take at least 5 years before the cumulative cash-flow would exceed that accrued by staying with the original Merino enterprise.

Table 2. Time to break even in the transition from a Merino enterprise to a 2nd cross store lamb enterprise as affected by 1st cross ewe purchase price (Rutherglen simulations).

Option	Ewe Cost ($/head)	Mean GM ($/hectare)	Break Even Time (Years)
Keep Merinos		$429	
Sell Merinos for $80 & Purchase first cross ewes.	$100	$631	1
	$130	$578	2
	$150	$542	5
	$180	$490	13
	$200	$454	40

Good genetics is equally important.

While the GrassGro modelling uses average animal genetics, there is clearly much to be gained through sourcing better than average genetics. In Table 3. a Merino genotype with 22% higher fleece weight at the same micron yields a GM almost 20% higher and the gap between the self replacing Merino enterprise and the dual purpose enterprise narrows considerably.

Table 3.Effect of improved genetics on economic output for a fine wool self replacing merino enterprise at Rutherglen.

Genotype	SR (ewes/ha)	Reference Wt. (Kg in CS 3)	Ewe FD (micron)	Wool Cut (greasy Kg/hd)	GM ($/ha)
Fine wool	8.5	50	19	4.1	$398
1st X lambs (fine wool)	9.5	50	19	4.1	$583
Fine Wool (22% more wool)	8.5	50	19	5.0	$474

This is reinforced by data from Merino bloodline comparisons (Atkins et al 2005). The most profitable bloodline yields a GM ($/dse) almost 40% higher than the average of all bloodlines while the lowest GM was almost 13% lower than the average.

The effect of genetics is equally important for meat enterprises. Fogarty et al (2005) reported the sire effect on GM ($/DSE) recorded by the Maternal sire Central Progeny Test (MCPT). The most common maternal sire breed (Border Leicester) ranged in GM from $28.32/dse to $39.77/dse for sires that were significantly better than the industry average (based on LAMPLAN figures), so it could be assumed that the potential range in GM due to genetics is even greater in the commercial industry.

Conclusion

The GrassGro analyses clearly showed that the most important economic drivers for sheep enterprises are optimising stocking rate and lambing times. In areas similar to those simulated there is considerable opportunity for sheep producers to increase their profits by refining their stocking rates and lambing times. Regardless of enterprise the focus should be on optimising the amount of meat and wool produced per hectare.

The strong performance of dual purpose enterprises and the relatively small difference in profit between self replacing Merinos and prime lamb flocks supports the option that many producers have taken in joining a proportion of their merino ewes to maternal or terminal sires. This option enables the producer to maintain important control over the flock genetics and greatly reduces the risk of introducing disease.

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MERINO SELECTION DEMONSTRATION FLOCKS: Genetic Trends from 1997 to 2005 for Key Traits

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INTRODUCTION

A brief background to the Selection Demonstration Flocks (SDF) project is given in an appendix to this report.

For estimating genetic changes in the Selection Demonstration Flocks, we have traditionally relied on comparisons to the unselected Control flock and this remains a valid method when available. Commencing with the description of hogget results of the 2003 drop at the 2005 field day, we have also estimated genetic change by calculating the average genetic merit of animals in each year utilising Estimated Breeding Values (EBVs). This method removes the influence of the environment in each year on the animals' performance, leaving only their genetic performance. By plotting average EBVs for each flock over a number of years, a genetic trend is estimated. This has become our preferred method and is, or can be, used for industry flocks that have sufficient pedigree records. Few, if any commercial breeding programs maintain an unselected line for tracking genetic progress.

This is the last year of results from the Selection Demonstration Flocks, as the 2005 progeny were the final ones born before the breeding ewes making up the flocks were reallocated to other projects in late 2005. The key messages from previously reported results from the SDF project are well summarised in a brochure developed by Cox Inall Communications, distributed to all on the project mailing list. Copies of the brochure are also available at this field day.

RECORDS AND METHOD USED

Hogget performance of each animal born into the SDF project from 1997 to 2005 was used to calculate the individual's genetic merit – EBV. Please note in this analysis that performance from animals born in 2005 has only been based on female progeny. Each animal's EBV was combined with others from their flock and averaged within each birth year. To maximise the accuracy of the EBVs, sire and dam pedigrees were traced back to the SDF project founder animals and then to their ancestors in the Merino Resource Flock (1989 to 1996). For AI sires and ewes introduced in the FM+ flock, no further pedigrees beyond foundation animals were used. The calculation of EBVs was performed by Restricted Maximum Likelihood procedures, using the ASREML package (Gilmour et al. 2000).

Figures 1 to 7 show genetic trends for Clean Fleece Weight, Fibre Diameter, Staple Length, Staple Strength, Body Weight, Standard Deviation and Coefficient of Variation of Fibre Diameter, respectively. Please note that a display of the genetic trends for conformation traits in the SDFs can be viewed at today's field day. These were calculated by Richard Curnow, who was an Honours student in 2006 with the University of Adelaide.

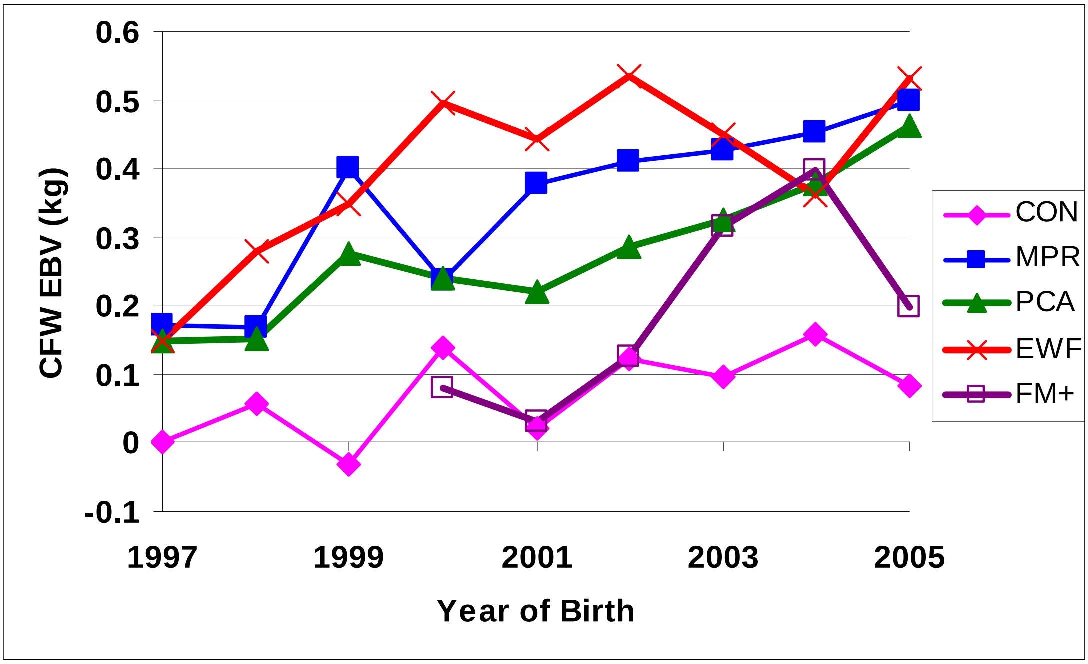

Figure 1. Genetic trend for Clean Fleece Weight

Clean Fleece Weight. The advantage of the selected flocks over the Control in the 1997 & 1998 drops came from use of outside AI sires and from screening the ewes to establish the project. Despite efforts to avoid deliberate selection, the Control increased genetically in CFW during the project. The MPR, PCA and EWF have gradually increased in CFW from the 1997 to 2005 drops. The FM+, starting from a lower base with its first progeny in 2000, increased rapidly to catch up to the other selected flocks in the 2004 progeny, but suffered a sharp reduction in CFW in the 2005 progeny. Notwithstanding, all selected flocks are meeting their original objective of maintaining or slightly increasing fleece weight.

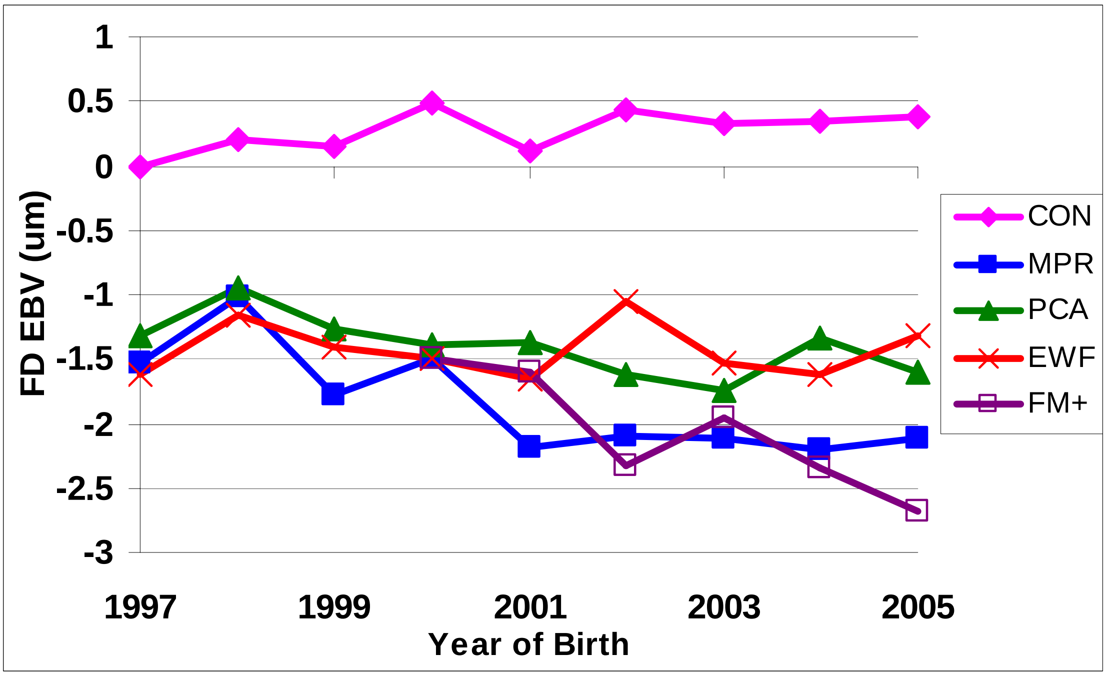

Figure 2. Genetic trend for Mean Fibre Diameter

Mean Fibre Diameter. The Control has remained genetically constant for mean fibre diameter since the 1997-drop. As a result of using outside AI sires and screening ewes to establish the project, all original selected flocks genetically reduced mean fibre diameter by about 1.5 micron in the 1997 drop, but since the 2000 drop, only the MPR and the FM+ flocks have managed to achieve further reductions. Indeed, only the FM+ has made consistent reductions since the 2001 drop. For the 2004 and 2005 drops, the PCA and EWF are at similar levels to the 1997-drop.

Staple Length. Most of the selection flocks have stayed close to the Control over the life of the project. However, the PCA flock has hovered between 2-5 mm shorter in hogget staple length than the other flocks since 1997.

Apart from the EWF, which commenced over 3 mm shorter in staple length than the Control in the 1997 drop and have since caught up, the MPR and FM+ have fluctuated over the years of the project within 1 to 2 mm of the Control.

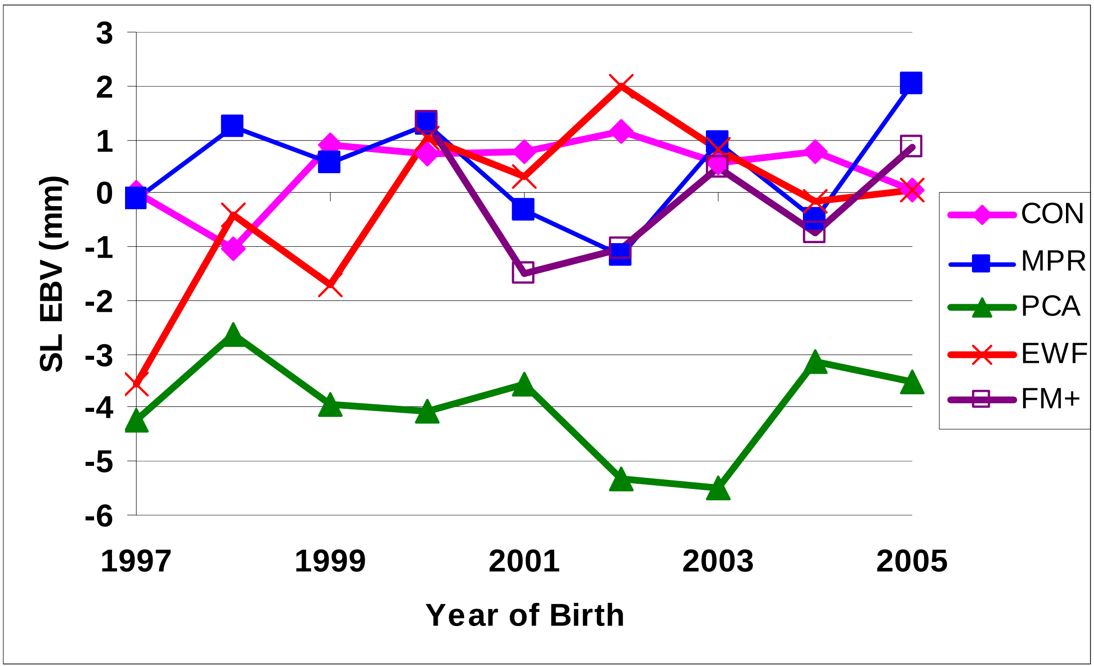

Figure 3. Genetic trend for Staple Length

Staple Strength. Staple strength has been quite variable, with the Control being the most stable. The MPR and the PCA have experienced genetic reductions in staple strength, but have subsequently recovered, especially the MPR.

The EWF has kept its staple strength equivalent to, or better than the Control in recent years.

None of the flocks had staple strength as an active focus of their original breeding objectives, but have wanted to avoid unintended reductions. Staple strength has become an increasingly important contributor to overall fleece value over the life of the project.

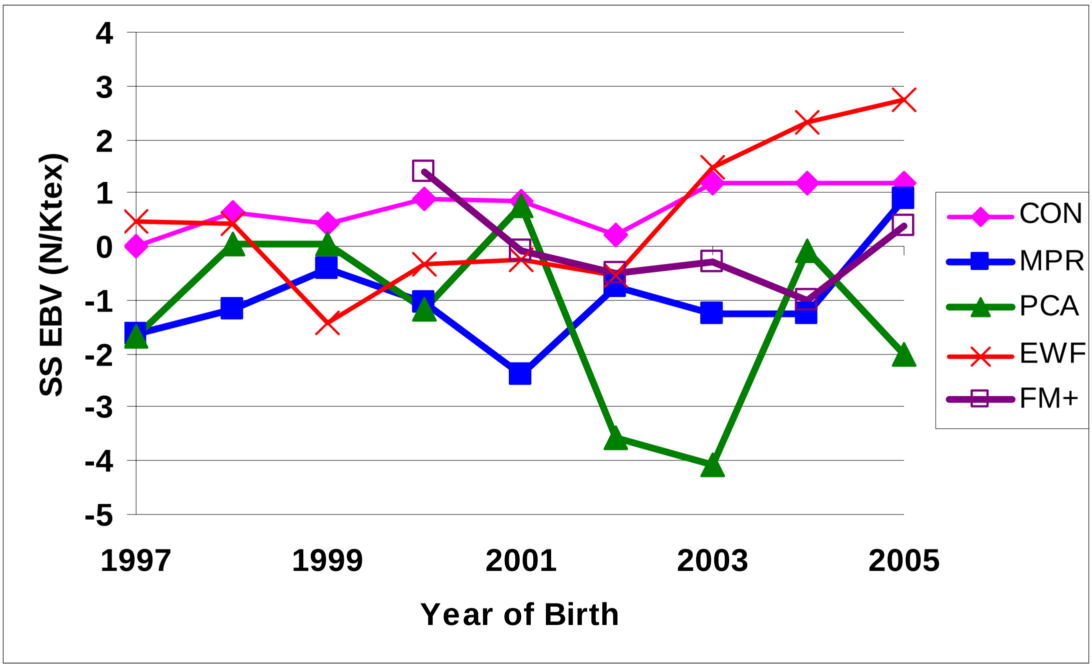

Figure 4. Genetic trend for Staple Strength

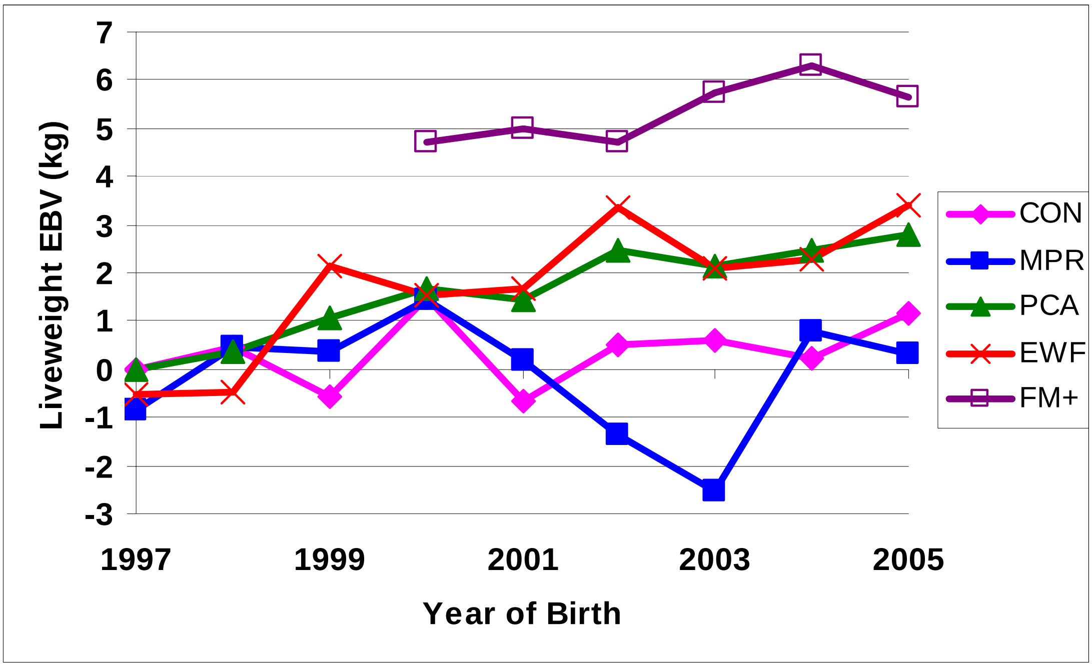

Figure 5. Genetic Trend for Liveweight

Liveweight. The original selected flocks have all maintained or slightly improved hogget liveweight. Although the 2002 and 2003 drops of the MPR were around 2 to 3 kg lighter than the Control, the 2004 and 2005 drops were similar. Over the life of the project the PCA, EWF and FM+ genetically gained weight.

Since commencement, the FM+ has been 4 to 6 kg heavier than the Control flock, as hoggets. This reflects the fact that larger ewes were screened from industry flocks to establish the FM+ and further selection pressure on liveweight has been applied since.

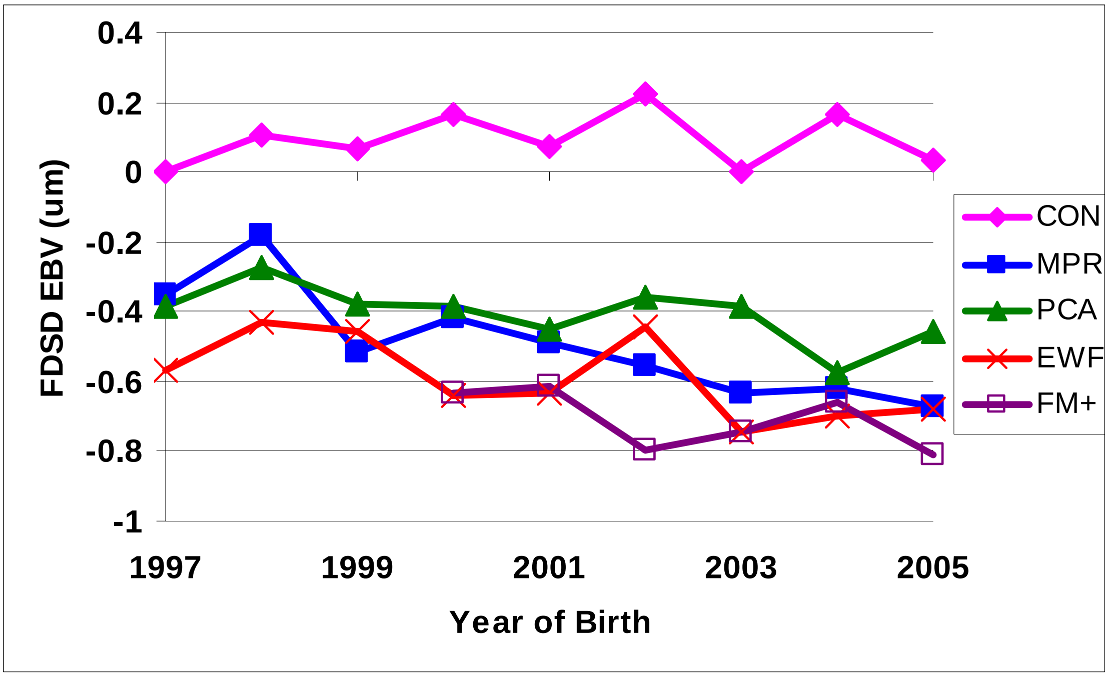

Figure 6. Genetic trend for Standard Deviation of Fibre Diameter

Standard Deviation of Fibre Diameter. All selected flocks have achieved a genetic reduction of between 0.5 to 0.8 micron in SDFD by the time of the 2005-drop, whilst the Control has stayed close to genetically constant over the life of the project.

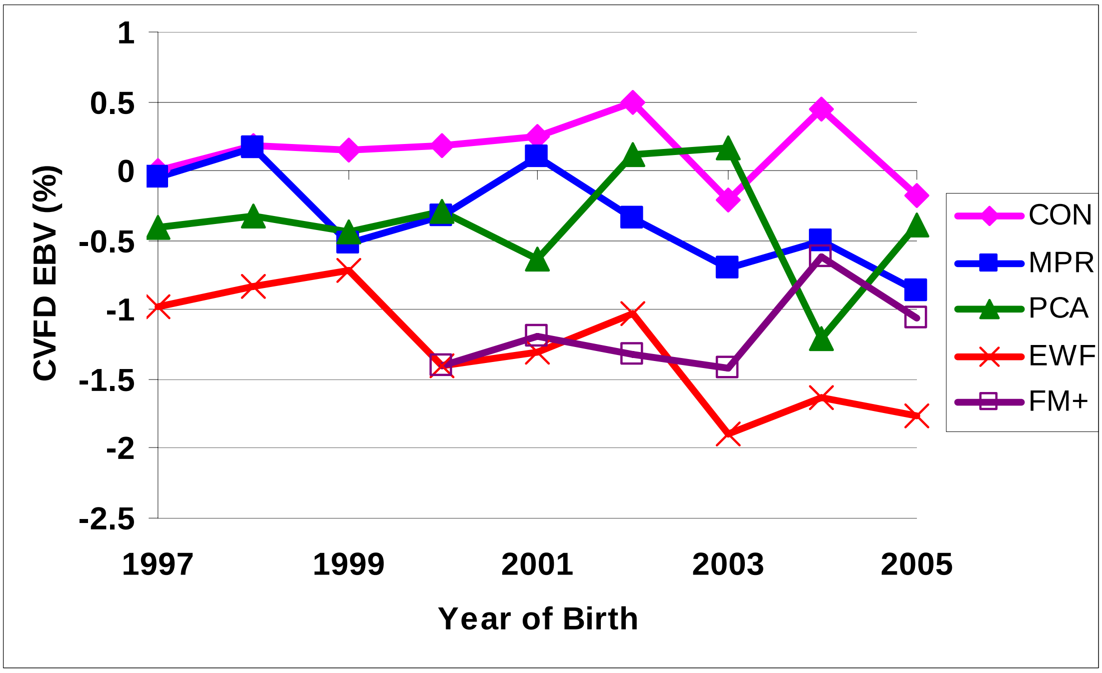

Figure 7. Genetic Trend for Coefficient of Variation of Fibre Diameter

Coefficient of Variation of Fibre Diameter. The Control flock has maintained much the same level between the 1997 and 2005 drops, with PCA and MPR maintaining a slight advantage over the Control in most years of around 0.5%. The EWF, although it has not reduced Mean Fibre Diameter since the 1997 drop, has achieved the greatest reduction in CVFD of between 1.5 to 2% over the life of the project.

The FM+, although commencing at a similar level to the EWF in the 2000 drop, has increased slightly in CVFD.

CONCLUDING REMARKS

Apart from a reduction in the genetic merit of the FM+ line for clean fleece weight in progeny born in 2005, genetic trends for all the key traits of Fibre Diameter, Staple Length and Strength, Body Weight and the two measures of Fibre Diameter Variability (Standard Deviation and Coefficient of Variation of Fibre Diameter) for progeny born from 1997 to 2005 reflect the pattern of results previously reported at earlier field days, in project newsletters and in the key messages outlined in the project brochure written by Cox Inall Communications.

ACKNOWLEDGEMENTS

The SDF project would not have been possible without substantial funding provided by Australian Wool Innovation Ltd and the continued support of SARDI. We recognize Dr. Raul Ponzoni as the creator of the SDF project and thank him for his insight into the needs of the wool industry.

A major feature of the SDF project and a critical part of its success was the large contribution of time and effort made by industry members involved in the selection committees and as independent classers. We thank you all.

Finally, the SDF project involved a large number of staff at Turretfield Research Centre and we thank Greg Mattiske, Ian Molloy, John Evans and Anthony Jaensch for their commitment to the project.

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APPENDIX

BACKGROUND INFORMATION ON THE SELECTION DEMONSTRATION FLOCKS PROJECT

Established in 1996, the Selection Demonstration Flocks (SDF) project examined the strengths and weaknesses of the three prevailing approaches to Merino sheep breeding. The original flocks represented measured performance and quantitative genetics (MPR), visual and tactile appraisal by professional sheep classers (PCA), the Elite wool or 'soft rolling skin' approach (EWF) and a randomly selected Control line.

The breeding objective of the original flocks was to improve the profitability of the South Australian Merino, to be achieved by:

- greatly improving wool quality by reducing fibre diameter, reducing the variation in fibre diameter and improving style, whilst
- maintaining or slightly improving fleece weight and body weight.

The project was expanded in latter years to include two new breeding directions, a Meat Merino line (FM+) and a Fine Wool flock (FWF). The FM+ selection line used a combination of measured performance and visual appraisal to improve live weight and carcase traits, reduce fibre diameter and maintain fleece weight. The FWF demonstrated the production of fine wool in a traditionally medium to strong wool environment (the FWF is discussed in detail in this report).

The original selection flocks each consist of 200 breeding ewes. The ewes were sourced from the same flock, which was made up of representatives from traditional South Australian bloodlines. For the first 2 years each flock used external sires from the Merino industry via AI, since that time seven drops of progeny have been born from sires generated within the flocks. The FM+ flock was assembled in 1999 based on contributed ewes from seven participating producers plus a small number of surplus SDF ewes. The FM+ flock remained open throughout the project to genetic contributions from outside. Further ewes were contributed in 2000 and 2001. Industry sires were used for 4 years from 2000 to 2003 via AI. The 2004 and 2005 matings were the first where all FM+ sires were selected from those bred within the flock.

Each of the selection lines was driven by industry participants and not by technical staff or scientists. The people making the selection decisions were practising ram breeders, woolgrowers, sheep classers or sheep consultants who were advocates of the selection system used in their particular flock.

NEW CENTURY TOOLS FOR MERINOS

JUNE 25, 2007

KATANNING

PARTICPANTS: Allflex Pty Ltd • Australian Meat Processor Corporation Ltd • Australian Wool Innovation Limited • Australian Wool Testing Authority Limited • Commonwealth Scientific and Industrial Research Organisation • Hall Family Trust and Ritchie Family Trust trading as JRL Hall & Co • Holmes, Sackett and Associates Pty Limited • Mike Stephens & Associates • Meat & Livestock Australia Limited • Murdoch University • NSW Department of Primary Industries for and on behalf of the State of New South Wales • Ridley Agriproducts Pty Ltd • Sheepmeat Council of Australia • State of Queensland acting through the Department of Primary Industries and Fisheries • State of South Australia acting through the Department for Primary Industries and Resources (SA) trading as SARDI • State of Victoria acting through the Department of Primary Industries • State of Western Australia represented by the Director General of Agriculture • University of New England • University of Tasmania • University of Western Australia • WoolProducers Australia Limited
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CONTENTS

Sheep Genetics Australia information materials are provided in the forum bags.

Merino wool-meat interface

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Summary

Information on wool and meat traits was collected from some 16,000 Merino ewe and ram hoggets over two years in 27 co-operating breeders' flocks across Australia. Environmental information including rainfall and pasture growth rates was also recorded. There were no major genetic antagonisms between wool and meat traits, which mean they can be improved concurrently. Regional variation in estimated breeding values means breeders and producers can consider sourcing improved genetics from other regions according to their breeding objectives. OFDA2000 measurements allow use of coefficient of variation in fibre diameter to improve staple strength and curvature to predict crimp frequency and resistance to compression for new wool traits. Pasture growth data and fibre diameter profiles provide a retrospective means of improved feeding for better staple strength.

Introduction

The sheep industry in Australia has responded over the last three years to increased income from meat relative to wool. Up to 40% of Merino ewes have been mated to specialist meat breeds and a large proportion of wethers previously run for wool production have been replaced by breeding stock. Therefore, sheep producers are seeking ways to improve their income from both wool and meat simultaneously.

Improving both meat and wool production in Merinos has potential advantages from improved meat characteristics in Merino cross lambs. About 90% of lambs turned off for meat in Australia contain varying proportions of Merino genes.

An added advantage of having income from both wool and meat is the insulation against income vulnerability as commodity price swings for these products are cyclical and unrelated.

Aims

Our project had the primary aim of measuring relationships between wool and meat traits including some wool traits not currently part of the Sheep Genetics Australia (SGA) program. In addition, we obtained detailed information on the large range of environments to help develop improved breeding and management guidelines.

Project outline

Wool and meat traits were recorded over two years on some 16,000 2003 and 2004 born ewe and ram yearlings/hoggets with 27 co-operating Merino ram breeders across Australia (see Fig. 1 below). All flocks were recorded on SGA including standard wool and meat traits and ultrasound muscle and fat depths. In addition we collected mid side wool samples for (a) length, strength, yield, crimp frequency, laserscan and resistance to compression tests by the Australian Wool Testing Authority; (b) OFDA2000 testing by the Interactive Wool Group; and (c) visual and measured wool style by CSIRO at Chiswick. In addition, satellite data for each of the 27 sites obtained through CSIRO's Pastures from Space project gave pasture growth rates.

The location of breeder properties and grouping according to climatic regions is shown in Figure 1.

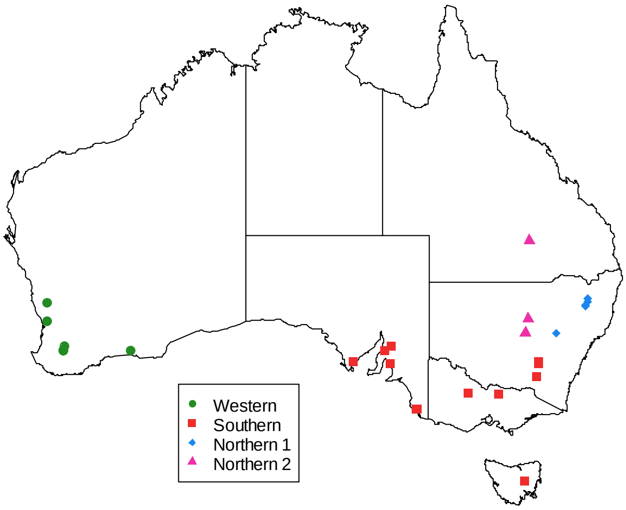


Figure 1: Location of co-operating Merino breeder flocks and regional groupings

Results and discussion

The results are presented as regional averages as outlined in Figure 1 under the following headings –

- Phenotypic means for wool and meat traits
- Genetic variability and associations between wool and meat traits
- Genetic means for wool and meat traits
- Fibre diameter profiles and pasture information

<u>Phenotypic means.</u>
Average phenotypic means for wool and meat traits are given by region in Table 1.

Table 1: Phenotypic means for wool and meat traits by regions and years

Region	Year	Yearling or Hogget wt (kg)	Greasy fleece wt (kg)	Wool micron	Staple strength (N/ktex)	Eye muscle depth (mm)	Fat depth (mm)
Western	1	45.4	4.0	17.4	31.1	21.2	2.5
	2	47.8	4.0	17.7	37.2	21.0	1.0
Southern	1	47.6	3.8	17.3	33.6	23.0	2.7
	2	47.8	3.6	17.8	32.2	21.9	2.7
Northern1	1	52.4	4.9	16.8	45.4	22.0	2.5
	2	48.1	4.0	15.7	46.4	23.3	2.8
Northern2	1	46.3	4.0	18.2	39.8	23.4	2.4
	2	36.0	2.8	17.7	31.3		

The above means represent environmental differences, independent of genetic differences, including climate, pasture and management. There are few obvious trends in the data though Northern1 (Northern Table Lands) appear to have comparatively heavier body weights and

fleece weights, despite lower wool micron, probably due to later weighing and shearing when animals are comparatively older.

Genetic variability and associations.
Heritabilities and genetic correlations describe the amount of genetic variability and associations between traits. A heritability of 0.30 or 30% means that 30% of the variability between animals is under genetic control through their breeding values. Genetic correlations describe how closely two traits are genetically related with values between -1 and 1. The nearer the values are to zero the weaker the relationship between traits.

Genetic correlations between core wool traits as in SGA, and the new wool traits including curvature, crimp frequency and resistance to compression, are given in the following table with heritabilities shown in bold.

Table 2: Genetic correlations and heritabilities for wool and meat traits.

	GFW	CFW	FD	FDCV	SS	CUR	CR	RTC	WT	EMD	FAT
GFW	**0.41**										
CFW	0.90	**0.30**									
FD	0.28	0.25	**0.73**								
FDCV	0.07	-0.06	-0.06	**0.52**							
SS	0.13	0.30	0.31	-0.50	**0.44**						
CUR	-0.28	-0.33	0.11	0.06	0.11	**0.27**					
CR	-0.38	-0.49	-0.15	-0.12	0.13	0.83	**0.41**				
RTC	-0.12	-0.14	0.35	0.23	0.03	0.77	0.49	**0.41**			
WT	0.46	0.43	0.17	-0.30	0.21	0.15	0.15	0.13	**0.47**		
EMD	-0.20	-0.12	0.13	-0.09	0.20	0.20	0.14	0.22	0.54	**0.23**	
FAT	-0.36	-0.15	0.20	0.02	0.16	0.09	0.13	0.16	0.45	0.54	**0.10**

GFW-greasy fleece weight; CFW-clean fleece weight; FD-fibre diameter; FDCV-CV of fibre diameter; SL-staple length; SS-staple strength; CUR-curvature; CR-crimp frequency; RTC-resistance to compression; WT-live weight; EMD-eye muscle depth; FAT- fat depth.

Wool traits were highly heritable, particularly fibre diameter at 0.71. There was a strong negative genetic correlation between CV of fibre diameter and staple strength meaning lower CVs indicated greater staple strength. Unfavourable genetic correlations existed between fleece weight and fibre diameter, and between fibre diameter and staple strength. The 0.31 correlation for the latter means selection for reduced fibre diameter will also cause staple strength to decline. These unfavourable correlations can be overcome by considering the traits in a weighted selection index. For the new wool traits, curvature was highly correlated with crimp and resistance to compression while both crimp and resistance to compression had moderately high heritabilities. Therefore, curvature measurements from OFDA2000 can be used to predict and select for crimp frequency and resistance to compression.

Body weight was highly heritable and eye muscle depth moderately. The meat traits were moderately positively correlated. There were moderate to high correlations between body weight and both wool and meat traits. However, there were some unfavourable correlations between eye muscle depth and both fleece weight and fibre diameter. Use of an appropriate selection index can allow eye muscle depth and fleece weight to be increased while fibre diameter is decreased.

The genetic correlations and heritabilities discussed above are similar to SGA estimates for their standard traits.

Genetic means for wool and meat traits.

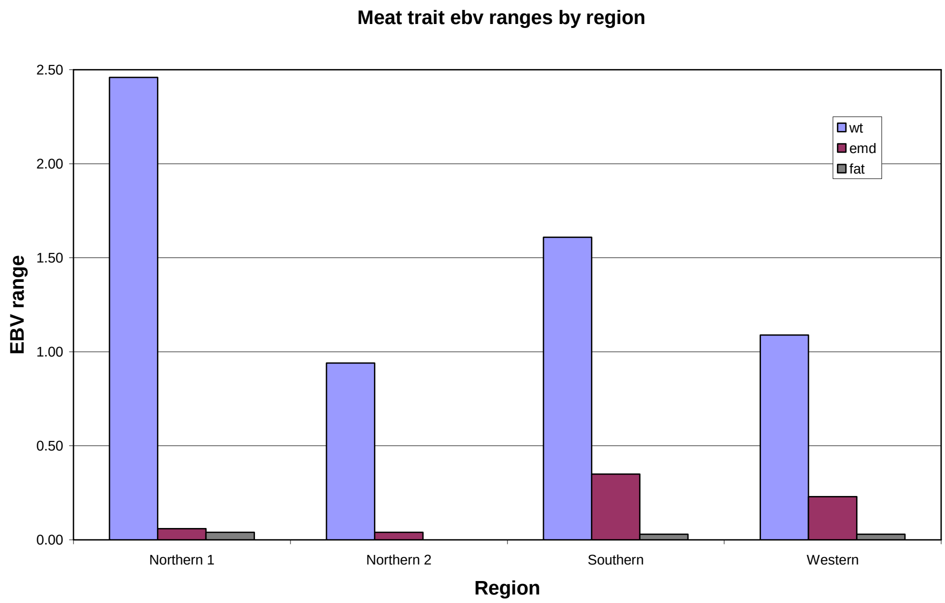
Average breeding values (EBVs) have been calculated for key wool and meat traits in each flock. These EBVs are derived from the actual heritabilities and phenotypic values from this dataset as well as background pedigree information from the wider SGA database. Average EBVs for each region are given in Table 3 and ranges are in Fig. 1.

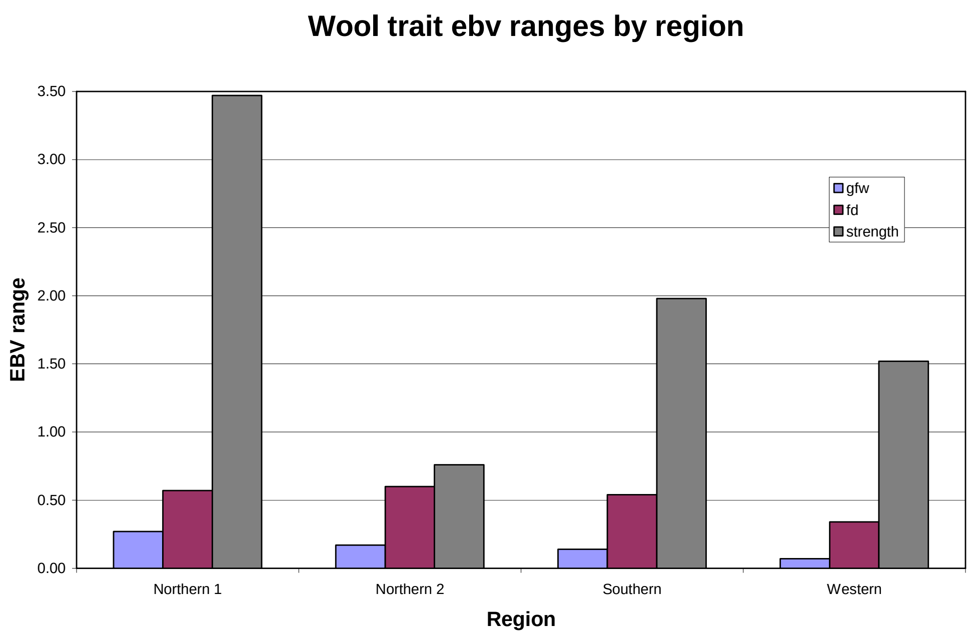
Table 3: Average estimated breeding values for the flocks in each region

		Meat			wool			new wool	
Region WT	**EMD**	**FAT**	**GFW**	**FD**	**SS**	**RTC**	**CUR**	**CR**	
Northern1	-1.14	-0.16	-0.02	-0.08	-0.18	-0.27	-0.07	0.37	0.00
Northern2	0.32	-0.01	-0.04	0.05	-0.22	0.43	-0.05	-0.43	-0.02
Southern	0.29	-0.02	-0.01	0.08	-0.15	0.13	-0.11	-0.65	-0.05
Western	0.08	-0.05	-0.01	0.02	-0.06	0.31	0.00	0.34	0.05

Comparisons of average EBVs between regions indicate more variation in meat than wool traits. The Northern1 flocks (Northern Tablelands) appear on average to have less genetic potential for improved meat traits than their western and southern counterparts, however all four regions still have significant opportunity for selection. While the four regions have similar fleece weight genetics, the northern region has a tendency to lower micron and higher crimp frequency.

Ranges in meat and wool trait EBVs, relating to averages in Table 3 for each region are given in Figure 1 below. Note that these values can be positive and/or negative.





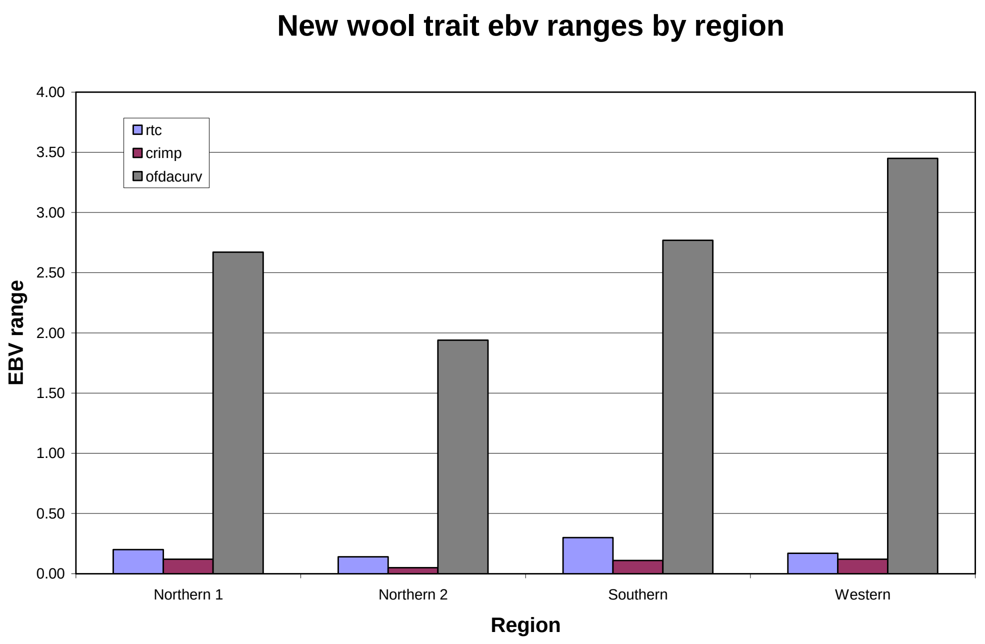


Figure 1: Ranges in average flock EBVs meat and wool traits in each region.

Note that the above graphs contain standardised EBV ranges.. The ranges for average flock breeding values showed that breeding flocks in the Northern1 region had comparatively greater variation in live weight and wool staple strength while western region flocks had the most variation in wool curvature. These results indicate comparatively greater potential for genetic improvement in live weight and staple strength in the Northern1 region than indicated by the average values in Table 4. The new wool traits, curvature in particular, had greatest variation in the western region. This provides opportunities for both breeders and commercial producers to explore these regional differences by sourcing genetic material to better match their breeding objectives.

Pasture information
Pasture growth information averaged over properties in the two contrasting Western and Northern1 regions for the two years of the project is given in Figure 2 below.

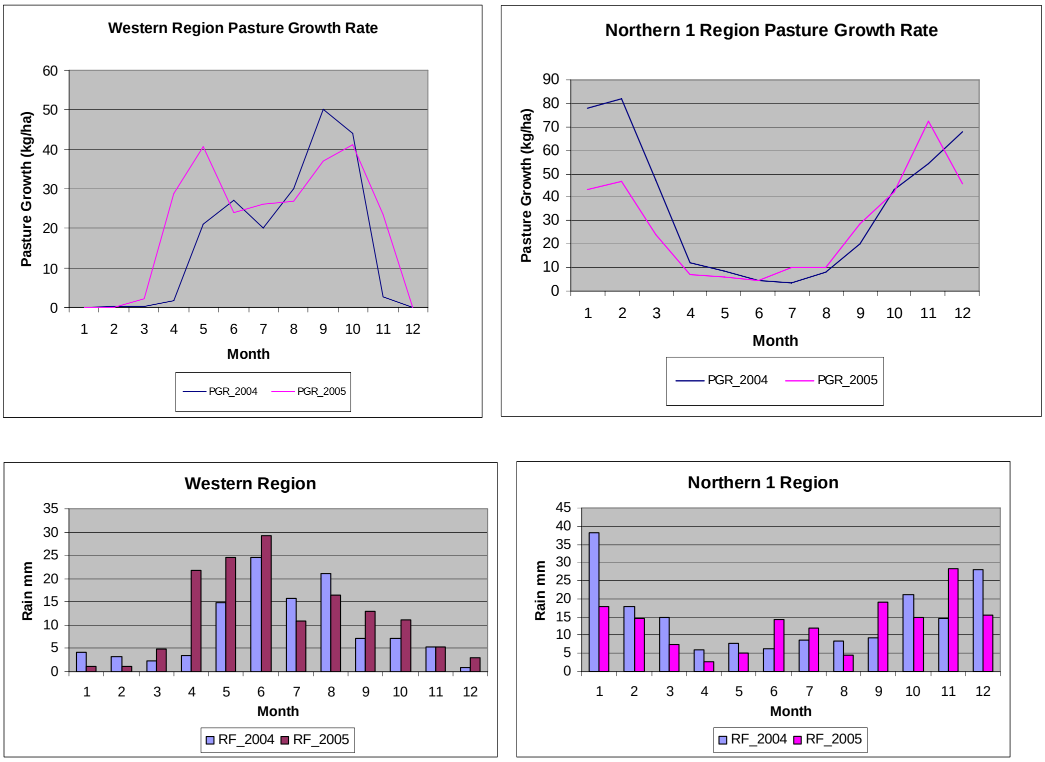
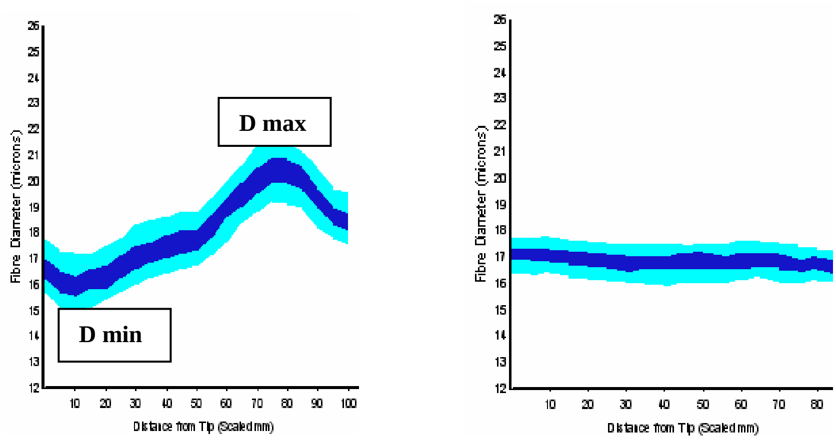


Figure 2: Average pasture growth rates and rainfall for the Western and Northern1 regions.

The pasture growth information in Fig. 2 above has been obtained from satellite data kindly supplied by CSIRO's Pastures from Space project. The two contrasting regions show winter (Western) and summer (Northern1) dominant pasture growth aligned with the rainfall data in the lower graphs. Within each of these regions, there was considerable variation among the various breeder properties in rainfall and pasture growth variation.

Fibre diameter profiles
The OFDA2000 measures fibre diameter profiles, which give changes in fibre diameter along the wool staple. Results from our project show there is much greater variation in fibre diameter in the southern and western regions with Mediterranean type climates with hot dry summers than in the more temperate northern climates with more equitable rainfall. Typical fibre diameter profiles from these contrasting regions are shown in Figure 3.



Mediterranean **Temperate**

Figure 3: Typical fibre diameter profiles from Mediterranean and temperate climates

Average flock differences between maximum (Dmax) and minimum (Dmin) fibre diameter are plotted against average staple strength for 18 of the co-operating flocks during year one of the project in Fig. 4.

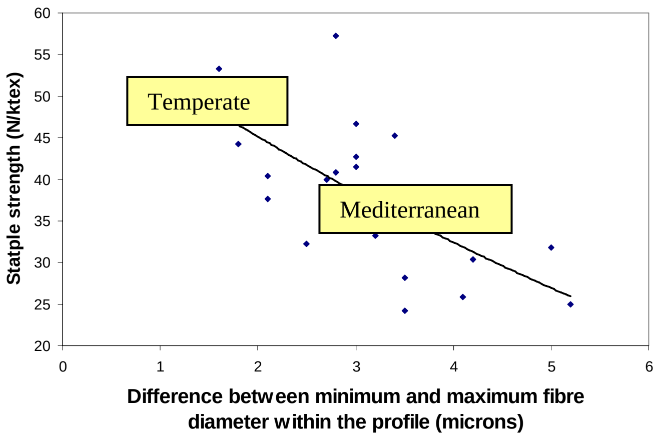


Fig. 4: Relationship between flocks with low fibre diameter profile variation in temperate regions in contrast with higher variation in Mediterranean climates.

The average flock differences between Dmax and Dmin gave a good indication of average staple strength as shown in Fig. 4 above.

For improved staple strength management, breeders should aim to flatten the profiles with most emphasis on preferential feeding during the time period of minimum fibre diameter. The example in Fig. 3 above indicates that under Mediterranean conditions with shearing in late spring preferential feeding over the summer would have improved staple strength. However, the cost effectiveness of this strategy would need to be assessed. This same principle applies in temperate conditions where there are low staple strength wools due to nutritional stress. Use of OFDA2000 and pasture growth rate data can define periods for preferential feeding.

Conclusions

The results from this project on wool and meat traits give breeders and commercial producers guidelines for genetic improvement in wool and meat production. There is also information

about use of pasture growth rates and fibre diameter profiles to improve wool staple strength. The main take home messages for breeders and producers are –

- The genetic parameters for standard SGA traits in this study did not vary greatly (with a few exceptions) from SGA values
- There are no major antagonisms between wool and meat traits in Merinos so breeders and their ram buyer clients can genetically improve both wool and meat production at the same time
- The unfavourable genetic correlations between fleece weight and fibre diameter, fibre diameter and staple strength, and eye muscle depth and greasy fleece weight/fibre diameter, can be overcome with use of appropriate selection indexes
- Regional variation in wool and meat trait EBVs provides opportunities for breeders and producers to source improved genetics
- Selection for lower coefficient of variation in fibre diameter from OFDA2000 profiles is the best tool to use for improvement in staple strength
- Values for the new wool trait curvature from OFDA2000 can be used to predict the other new wool traits of crimp frequency and resistance to compression.
- Pasture growth data and fibre diameter profiles can be used retrospectively for improved feeding during periods of pasture shortage to improve staple strength

Acknowledgements

Grateful acknowledgement is made to the following: the 27 co-operating Merino breeders; MLA and AWI for financial and technical support; AWTA and IWG for in-kind laboratory support; provision of Pastures from Space data by Graham Donald, CSIRO Chiswick; skilled technical input from Grant Uphill, Christine Dennis, Judi Kenny and Heather Brewer, CSIRO Chiswick.

Novel Merino Wool Quality Traits

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Summary

The project was conducted in conjunction with Sheep CRC Project 1.2.6, in which wool samples representing some 29 Sheep Genetics Australia (SGA) flocks were tested for a range of novel traits including resistance to compression, crimp frequency and measured and assessed style traits.

Genetic variation in novel traits:

- The novel traits of crimp frequency, resistance to compression, crimp definition, wool colour and staple size were moderately to highly heritable and therefore could be easily improved through selection.
- The genetic correlation between mean fibre curvature and crimp frequency was 0.84 to 0.93 suggesting that there is little need to measure crimp frequency to change it genetically.

Trueness to Type:

- The results also indicate that there is significant variation between Merino strains / flocks in their diameter and crimp relationships. That is some flocks have a measured fibre diameter consistently different to that predicted from their crimp frequency.
- A "Trueness to Type" score was calculated for each sheep which indicated its FD relative to that expected based on its crimp frequency.
- Given the strong genetic relationships between crimp frequency and fibre curvature it is also possible to predict a crimp frequency measurement from the standard fibre curvature measurement. This predicted crimp frequency measurement can also be used to calculate a Trueness to Type score. Trueness to Type classification could be made available in the near future following industry consultation and validation.

Prediction of resistance to compression:

- Measurements of resistance to compression can be predicted with moderate accuracy from the other wool measurements made in this study.
- At the genetic level, resistance to compression was significantly related to fibre diameter (0.36), fibre diameter coefficient of variation (0.21), fibre curvature (0.79), crimp frequency (0.52), variation in crimp frequency (0.96) and staple size (0.41). Therefore resistance to compression could easily be included in the breeding objective without the need for direct measurements.

Introduction

The focus of this project is to extend the scope of traits measured for SGA across-flock genetic evaluation, by developing the basis for trait definitions for several traits presently considered important to sheep classer and wool buyers – namely those relating to the visual 'style' and the tactile appeal of wool.

"Trueness to type" is a term used is the wool industry to define whether a fleece's crimp frequency matches its fibre diameter. Across flocks there is a strong relationship between these traits, with finer wools displaying a much higher crimp frequency and curvature than broader wools. Nevertheless, at any given fibre diameter, flocks are often under or over crimped, and therefore not "true to type".

Novel wool traits

Historically, trueness to type has been used by the wool trade as an integral component of a system allowing the prediction of processing performance to the yarn stage of greasy wool, using a system of "quality numbers". In assigning a quality number, trueness to type was combined with assessment of handle, colour, length and strength to estimate the number of 560 yard hanks of yarn able to be spun from per imperial pound of scoured wool. While the prediction of processing performance based on objective raw wool measures has advanced substantially over the years, trueness to type is still an important price determinant in some wool markets.
The compression characteristics of wool represent an important aspect of wool quality with requirements depending upon end use and processing conditions. Resistance to compression has also been shown to be significantly related to fibre curvature and crimp frequency.

This study will develop the preliminary basis for the estimation of breeding values for:

- Crimp frequency: new measurement technology has been used which enables a routine and objective measurement of crimp frequency.
- Trueness to type: the relativity of fibre curvature and crimp frequency with fibre diameter.
- Compressibility: as estimated using the measurement of resistance to compression and other raw wool traits.

The Data Used

This project was conducted in conjunction with Sheep CRC Project 1.2.6, whereby wool samples representing some 29 client flocks of Sheep Genetic Australia were tested for a range of wool parameters by IWG using OFDA2000 and AWTA using Laserscan and other measurement technology. Samples were also measures for style traits using the Style Machine and the same samples were visual assessed/scored for a similar range of style related traits.

The data set contained 12,085 animals (7,130 females and 4,951 males) with data and 22,397 animals in the pedigree. There were 374 sires and 6,000 dams with recorded progeny. The data originated from 29 SGA flocks and all animals measured were born in 2003, 2004 and 2005. All animals were measured at either at yearling or hogget ages. Some flocks also shore / tipped their sheep as lambs where others did not.

Genetic variation in novel traits

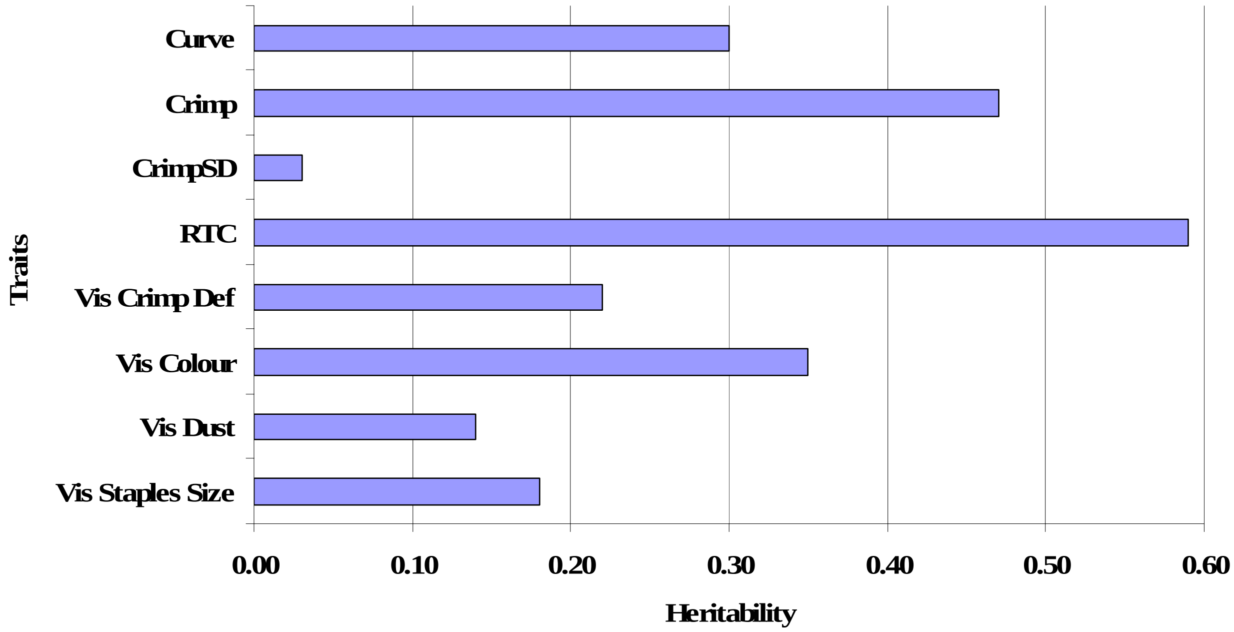
- The heritabilities of the standard wool traits agree with previous estimates from SGA data.
- As shown in Figure 1 below, the heritabilities for the novel traits were generally moderate to high except variation in crimp (CrimpSD) and dust penetration (Vis Dust).
- Visually assessed colour, crimp definition and dust were more highly heritable than the equivalent Style Machine traits.
- Fibre diameter measurements from Laserscan and OFDA were genetically and phenotypically the same traits, with genetic and phenotypic correlations of 0.98 and 0.89 respectively.
- Laserscan and OFDA fibre curvature had a high genetic correlation of 0.92, although the phenotypic correlation was only 0.53.
- Crimp frequency from AWTA was also genetically correlated with;
  - ✓ Greasy fleece weight -0.37
  - ✓ Staple length -0.43
  - ✓ Fibre diameter -0.15
  - ✓ Laserscan curvature 0.84
  - ✓ OFDA curvature 0.93

  The high genetic correlation between crimp frequency and curvature indicates that there is little need to measure crimp frequency directly in breeding programs. To put this in context, the genetic correlation between the traits of around 0.9 is much higher than the genetic correlation between CV of fibre diameter and staple strength (-0.5). CV of fibre diameter is regularly used as a proxy trait for staple strength.
- Some other interesting genetic correlations were;
  - ✓ Smaller staple size is associated with better crimp definition (0.83)

Novel wool traits

- ✓ Smaller staple size is associated with greater staple length (0.43)
- ✓ Higher crimp frequency was associated with short staple length (-0.44)

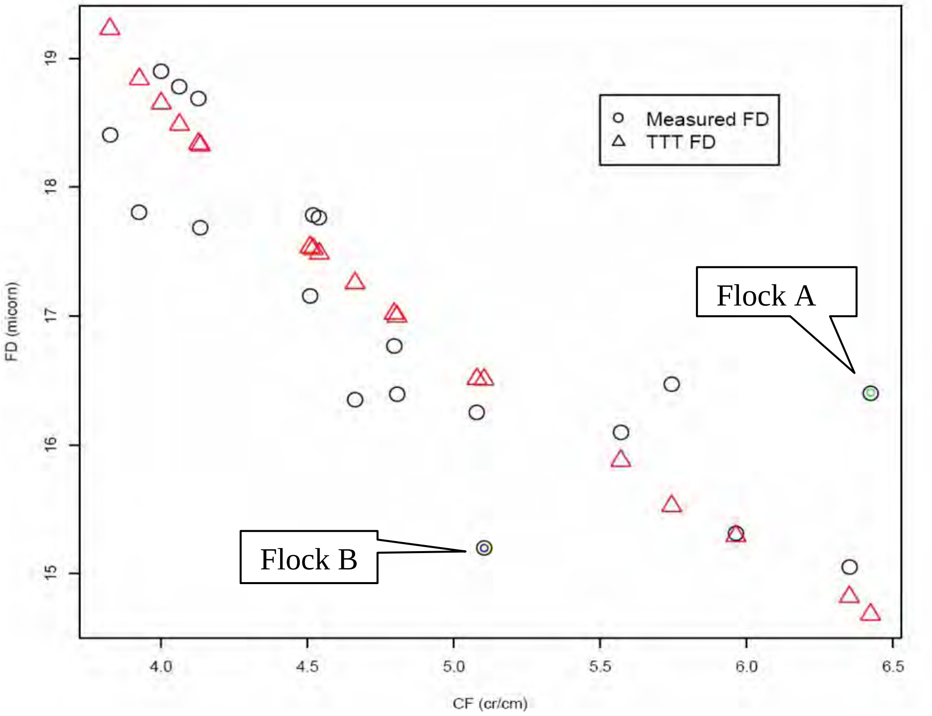
Figure 1: Heritabilities for selected novel wool traits



Trueness to Type

Trueness to type fibre diameter (TTT FD) was derived for each animal using crimp frequency and a modified version of published formulae. The deviation of each of these from the measured Laserscan FD was taken as the TTT score. Furthermore given the strong genetic relationship between crimp frequency and fibre curvature it is also possible to predict a crimp frequency measurement from the standard fibre curvature measurement and then derive TTT FD. Because breeding values for fibre diameter and curvature are currently available from SGA, the TTT classification could be implemented using current information, without the need to directly measure crimp frequency. Delivery could occur quite rapidly following industry consultation and validation.

Figure 2 Average Laserscan fibre diameter (AWTA FD), predicted "trueness to type" fibre diameter (TTT FD) and Crimp Frequency (CF) for each flock



The relationship between crimp frequency and fibre diameter in Figure 2 shows the effects we were trying to model. For example Flock A in figure 2 has an observed mean fibre diameter much higher than expected from its crimp frequency. Alternatively Flock B has a much low measured fibre diameter than expected from its crimp frequency.

Across all the animals there is a moderate negative relationship between fibre diameter and crimp frequency (correlation of -0.51). However, within flocks there are variable correlations ranging from low negative to low positive, hence the small genetic correlation between fibre diameter and crimp shown above. Other results suggest that the prediction function fits the data well at low to moderate crimp frequencies, but not so well at high crimp frequencies (>6 cr/cm).

The data set used in this study only contained animals with mean fibre diameters from approximately 14 microns to 19 microns. As this is not representative of wider industry the results need to be tested more with a data set which included more broader wools.

The results also demonstrated that the practice of tip/even-up shearing of lambs/weaners also affected the relationship between fibre diameter with crimp and curvature measurements.

Prediction of resistance to compression

Phenotypic Prediction

The ability to phenotypically predict RTC from the other measured traits was examined using both the Laserscan and OFDA data separately. The table below shows how much variation in RTC each trait explained.

	Laserscan	**OFDA**
Mean fibre curvature	33%	21%
Mean fibre diameter	8%	19%
Crimp frequency	7%	1%
Fibre diameter coefficient of variation	1%	1%
Variation in crimp frequency	1%	1%

Novel wool traits		
Total	**50%**	**43%**

Previous research has also demonstrated that the function of $D^2 * R^{-1.5}$ explained 91.2% of the variation in RTC where D is fibre diameter and R is the radius of fibre curvature. In the current study this prediction equation explained 41% and 38% of the variation in RTC based on Laserscan and OFDA measurements respectively. The accuracy of this prediction was also variable across each flock.

Genetic Prediction

Genetically resistance to compression was significantly related to fibre diameter (0.36 $\pm$ 0.05), fibre diameter coefficient of variation (0.21 $\pm$ 0.06), fibre curvature (0.79 $\pm$ 0.03), crimp frequency (0.52 $\pm$ 0.07), variation in crimp frequency (0.96 $\pm$ 0.25) and staple size (0.41 $\pm$ 0.09). Thus resistance to compression could easily be included in the breeding objective without the need for direct measurements.

Conclusions

- The novel traits of crimp frequency, crimp definition, wool colour and resistance to compression were moderately to highly heritable and therefore could be improved through selection.
- Curvature is significantly genetically and phenotypically related to crimp frequency such that there is little need for direct measurement of crimp frequency.
- The results also indicate that there is significant variation between Merino flocks in their diameter and crimp relationships. That is, some flocks have a measured fibre diameter consistently different to that predicted from their crimp frequency.
- A trueness to type score was able to be derived for each sheep which indicates its fibre diameter relative to that expected based on crimp frequency.
- As curvature and crimp frequency were significantly correlated a TTT score was also generated using fibre curvature rather than measured crimp frequency.
- This scoring system requires further consultation and validation by industry but could be implemented using existing information from SGA.
- Phenotypically, resistance to compression could be predicted with moderate accuracy from the other wool measurements made in this study.
- Genetically, resistance to compression was significantly related to many traits, therefore resistance to compression could be included in the breeding objective without the need for direct measurements.

Acknowledgements

This project involved the successful collaboration of several organisation including, AWI, AWTA, AGBU, CSIRO, Sheep CRC and IWG. The author would like to thank all parties for the valuable contributions but in particular Dr Paul Swan, Dr Trevor Mahar and David Crowe.

More Information

To obtain additional information about this project please contact Daniel Brown on email at dbrown2@une.edu.au or phone 02 6773 2160.

Information Nucleus

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Introduction

The Cooperative Research Centre for Sheep Industry Innovation (Sheep CRC), the successor to the Australian Sheep Industry CRC, will transform wool and meat products and the sheep that produce them with new research to 2014. A key program of the Sheep CRC is the *Information Nucleus*.

The *Information Nucleus*, a world first innovation for sheep, provides next-generation genetic and new trait information to industry and supports the three core research programs of the Sheep CRC:

- Transforming sheep and their management
- Next generation wool quality
- Next generation meat quality

Each year 5000 ewes in diverse *Information Nucleus* flocks across Australia will produce progeny by 100 Merino, maternal and terminal sires chosen from across industry. The progeny will be extensively measured and assessed for current and new traits in meat and wool quality, parasite resistance and reproduction.

Through the Sheep CRC's unique partnership with SGA Sheep Genetics Australia and SheepGenomics the information will be used to:

- Improve accuracy of Australian Sheep Breeding Values (ASBV) for current traits
- Contribute to development of ASBVs for new traits
- Validate molecular markers for current and new traits
- Develop breeding values that combine quantitative and molecular information.

Breeders and commercial producers will be able to quickly use the developments in new genetic technology and molecular information to advance their chosen breeding objectives. Both individual flocks and sheep across industry will achieve more rapid genetic gain.

What is the *Information Nucleus*?

The *Information Nucleus* is a series of flocks located at research sites around Australia that are directly linked to breeders and industry through SGA. The *Information Nucleus* uses key young and proven industry sires to progeny test for an extensive range of traits in widely differing environments.

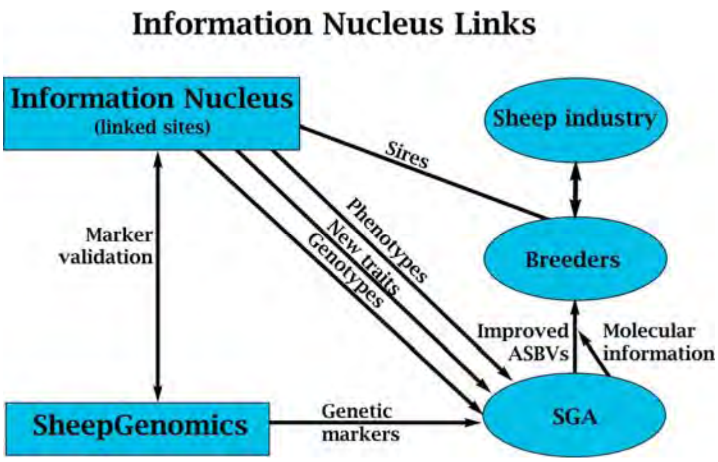
Working closely with SheepGenomics, the *Information Nucleus* will provide information on genetic markers and validate their usefulness for industry sheep.

With the information on phenotypes and genotypes generated from the *Information Nucleus*, potential genetic markers will be validated and the results from the other CRC research programs will be applied.

The genetic information will flow directly and rapidly to breeders and industry via SGA through more accurate Australian Sheep Breeding values (ASBVs) that will eventually be enhanced by the incorporation of molecular information.

What will the *Information Nucleus* do?

The *Information Nucleus* will generate genetic information about new and novel traits as well as traits that are difficult or expensive to measure commercially on-farm. These may be related to wool and meat quality, internal parasite resistance and reproductive performance. This will provide genetic parameters for traits such as staple strength, wool quality, meat eating quality, nutritional content, carcase yield and feed efficiency.



The *Information Nucleus* will also assess genetic variation and opportunities for improvement of new and novel traits such as wool UV-colour stability, traits of meat relating to human nutrition and characteristics that result in easier care and management of sheep.

Gene marker and SNP (single nucleotide polymorphism) discoveries will be tested and validated in sheep with different genetic backgrounds, sex and age in a range of environments.

The SheepGenomics program is developing new molecular technology that will allow animals to be quickly and cheaply tested for thousands of genetic markers and SNPs that will be validated in the *Information Nucleus*. The *Information Nucleus* will also be the focus of sheep management, wool and meat research being undertaken in the other CRC research programs.

How will the *Information Nucleus* help breeders?

Key sires from industry flocks are selected annually for mating in the *Information Nucleus*. Their progeny phenotype information will be included immediately in the SGA database and will contribute to ASBVs for the sires and to overall linkage of the SGA analyses. For most sires, the additional progeny will increase the accuracy of the sire ASBVs as well as the accuracy of the ASBVs for other related animals because of the greater across-flock linkage.

New traits that prove valuable to industry will be added directly to SGA if they are commercially applicable. A major advance will be the validation of gene markers and SNPs that will contribute to the development of molecular breeding values. These may eventually be incorporated into enhanced ASBVs that can be used to more accurately select sheep at a very young age and further increase the rate of genetic improvement.

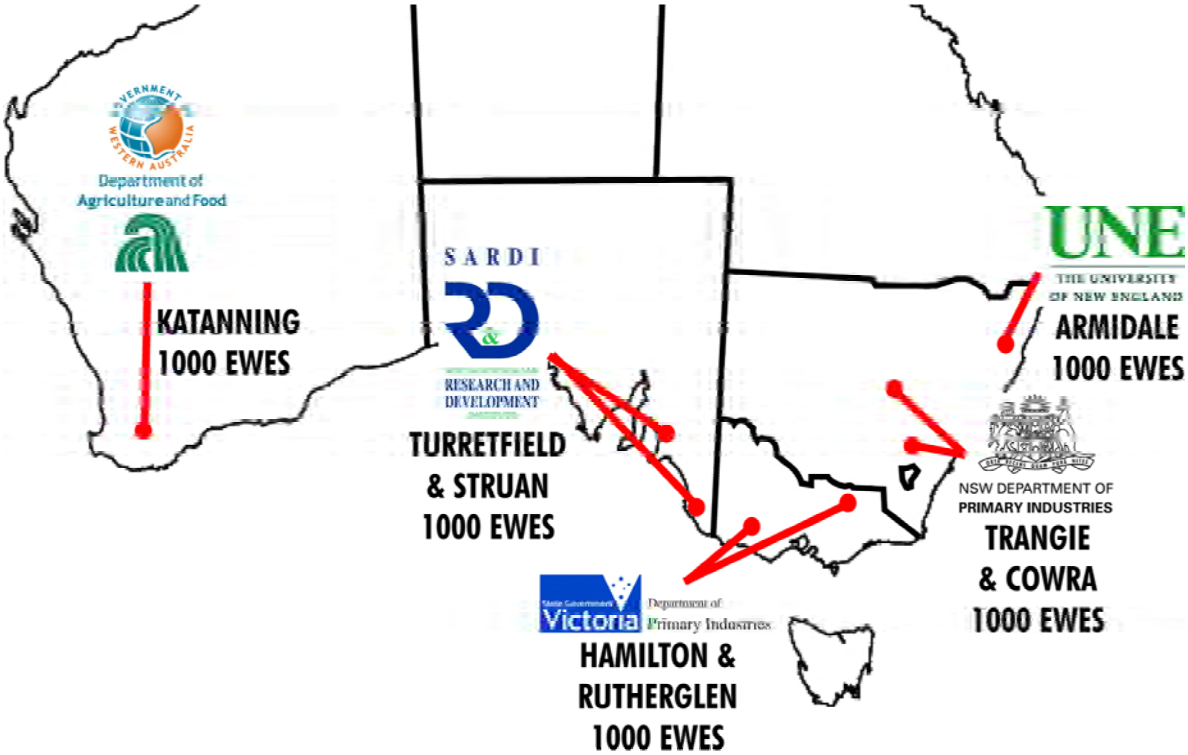
Selection of Sires

The *Information Nucleus* has been structured to provide genetic information for the most widely used production systems across Australia. The sires are selected on a combination of several attributes:

- High genetic merit for key production traits, including divergence for some other traits
- Genetic diversity of the selected team, so that a broad range of bloodlines, strains and breeds are sampled
- Linkage to the SGA database including potential for influence on future generations *(including some prominent bloodlines that have not yet been evaluated within SGA)*

How will the *Information Nucleus* work?

The *Information Nucleus* will operate at eight research sites covering a wide range of sheep environments in Australia:



Each year approximately 100 young sires will be selected and mated to 50 ewes each using artificial insemination and frozen semen. The first matings of the *Information Nucleus* occurred in early 2007 so that progeny will be available for evaluation in the first year of operation of the CRC for Sheep Industry Innovation (from July 2007).

The 5000 matings represent the major sheep types in the industry and generate Merino (MxM), Border Leicester X Merino (BLxM) and Terminal first (TxM) and second cross progeny (TxBLM) (see Table).

Approximate annual numbers of sires, ewes mated and progeny in the *Information Nucleus*

Sires	Ewes	Progeny	Retained (ewes)	Slaughter
40 Merino (M)	2000 M	1500 MxM	750	750
20 Border Leicester (BL)	1000 M	750 BLxM	375	375
40 Terminal (T)	1000 M	750 TxM	-	750
	1000 BLM	750 TxBLM	-	750
Total	5000	3750	1125	2625

The progeny will be evaluated for phenotypes for a large number of growth, carcase, meat, wool, reproduction and internal parasite resistance traits, which are not practical or economical to do on commercial farms. The crossbred lambs will be grown out and slaughtered in processing plants with industry partners. Detailed information on carcase and meat traits, meat yield and samples for laboratory testing will also be collected.

The MxM progeny will be evaluated for a wide range of wool traits and half the wethers will subsequently be slaughtered for carcase and meat evaluation. The MxM and BLxM ewes will be retained and mated naturally for two joinings to evaluate reproduction and maternal traits. Blood and tissue samples will also be collected for genotyping and molecular genetic studies.

It is planned that all *Information Nucleus* sites will have regular field days to enable industry to view progeny of sires and to keep up-to-date with the outcomes of the Sheep CRC programs.

Sheep Enterprise Comparisons – Using the GrassGro DSS to compare sheep enterprises run under optimal management.

Doug Alcock
Livestock Officer (Sheep and Wool) NSW DPI, Cooma.

Summary

GrassGro was used to compare the economic output of a range of sheep enterprises at 4 specific localities in southeastern Australia. It was found that stocking rate had the largest bearing on the enterprise gross margin (GM) $/ha. It was also determined that lambing from mid winter to mid spring was most profitable depending on enterprise and locality. Dual-purpose enterprises based on fine Merino Ewes were consistently the most profitable (prices averaged over 1999-2003 & adjusted for CPI) and seemed to be quite resilient in the face of changes in commodity prices. Most importantly there appears considerable scope for many sheep producers to improve their gross margin through attention to fine tuning stocking rate and lambing time regardless of their chosen enterprise.

Introduction

Many farmers regularly question whether changing enterprises would make them more profitable. Often the question relates to more dramatic shifts between cropping and grazing or between sheep and cattle enterprises, but in recent times the question is increasingly pertinent in deciding between the various sheep enterprise options. *"Would the farm make more money if I ran meat sheep rather than merinos"?*

More subtle is the question "what proportion of my merino ewes should I join to maternal or terminal sires"? To answer these questions the starting point is to determine the relative profitability of different sheep enterprises over the long term, under average market conditions and running in the same environment.

Project 1.2.6 of the Sheep CRC (1) was an "analysis of the profitability of sheep wool and meat enterprises in southern Australia". The project modelled grazing systems to determine the long term economic output of a large range of sheep enterprises run at a range of localities across south eastern Australia.

Project Outline

The GrassGro decision support system was used to model the productivity and economic output from a range of sheep enterprises under optimal management. Optimal management was judged on the basis of gross margin (GM) in dollars per hectare since land represents both the primary resource limitation and also the greatest capital investment.

Simulations were run at four localities (Mortlake, Rutherglen, Naracoorte and Cowra) across the 37 years from 1965 to 2002. GrassGro (Moore et al 1998) uses daily historical weather data to drive a pasture growth model that involves both soil and plant characteristics. Animals then graze the pasture and their intake physical performance and harvestable product calculated based on herbage intake and quality (Freer et al 1998).

The enterprises analysed include

1) merino wethers
2) self relacing merinos
3) 1^{ST} cross lambs (dual purpose flocks)
4) 2^{nd} cross lambs (prime lamb).

Pure merinos (1,2 & 3) were simulated for three different reference weights and corresponding fibre diameters (superfine, fine and medium). While first and second cross enterprises were simulated for three target markets including store lambs, trade lambs (44kg) and export lambs (53kg).

The critical management decisions of lambing time (LT) and stocking rate (SR) were varied in order to determine optimal economic management of each enterprise. Lambing times ranged from April to October and stocking rates from 4 to 20 sheep per ha depending on enterprise. Each enterprise was then compared under optimal management at each locality.

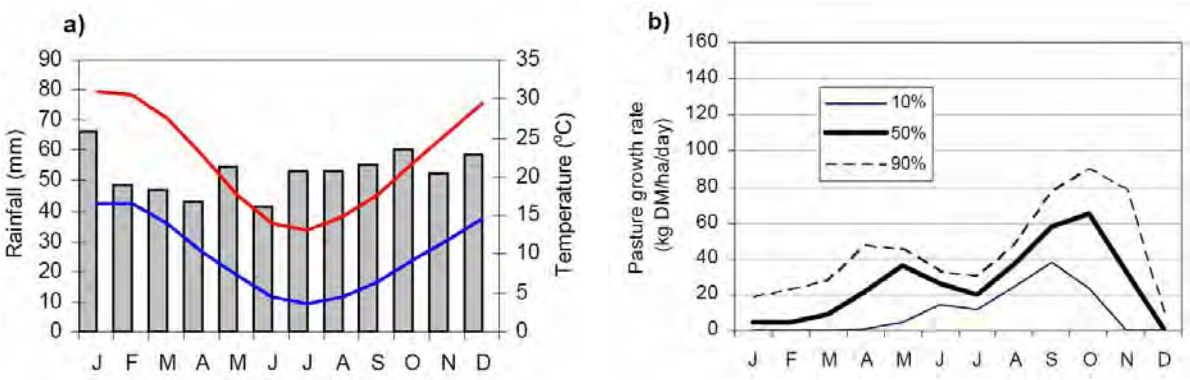
Project Results

For complete detail on every site and enterprise simulated I refer to the full project report available from the Sheep CRC (Warn et al 2006). In this paper I will draw mainly on the Cowra simulations but reference will be made to other localities in order to draw out specific points.

Simulation of Pasture Growth

Cowra simulations were of an annual pasture, grass dominant with 30% legume. Cowra is a non seasonal rainfall environment tending toward greater seasonal reliability in spring (figure 1. a). Winters are cool with regular frost incidence in June, July and August. Pasture growth is bimodal with both spring and autumn spikes in growth. The dark line in figure 1 b) represents the median growth rate averaged for each month of the year (for any given month the average growth rate has been above this line in 18 of the 37 years of the simulation). For example the median growth rate for July is 20 kg DM/ha/day while for October the median growth rate is 65 kg DM/ha/day. The pasture growth curve sets boundaries for the potential performance of the enterprises evaluated in the project.

Figure 1. Monthly climate and pasture growth rate percentiles for Cowra.

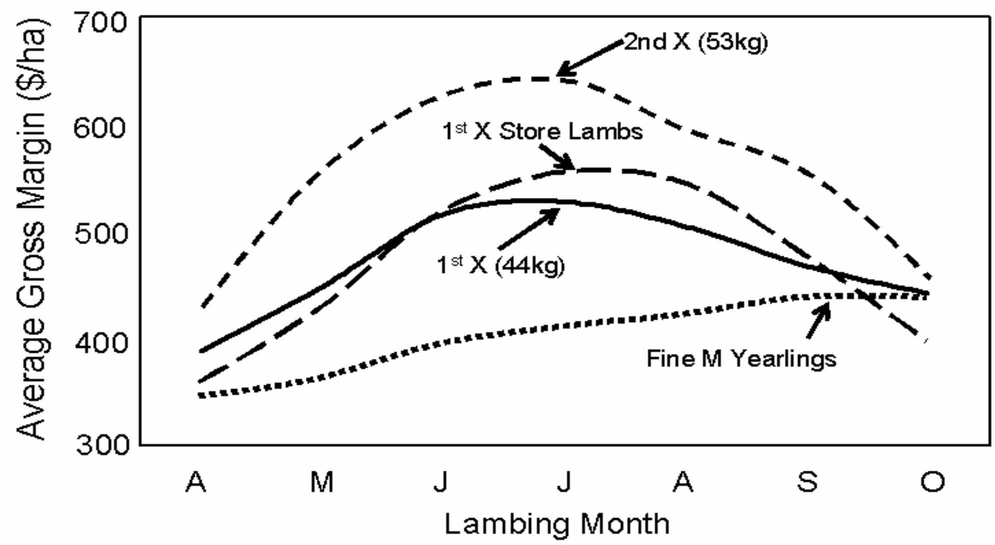


The Lambing Time x Stocking Rate Interaction

Analysis of the interaction between stocking rate and time of lambing determines the combination of these two factors that gives the greatest economic output per hectare.

Figure 2 illustrates the variation in GM by lambing date for four enterprises at Cowra. Given the shape of the pasture supply curve, enterprises that produce animals for sale as lambs give optimal returns by lambing in July.

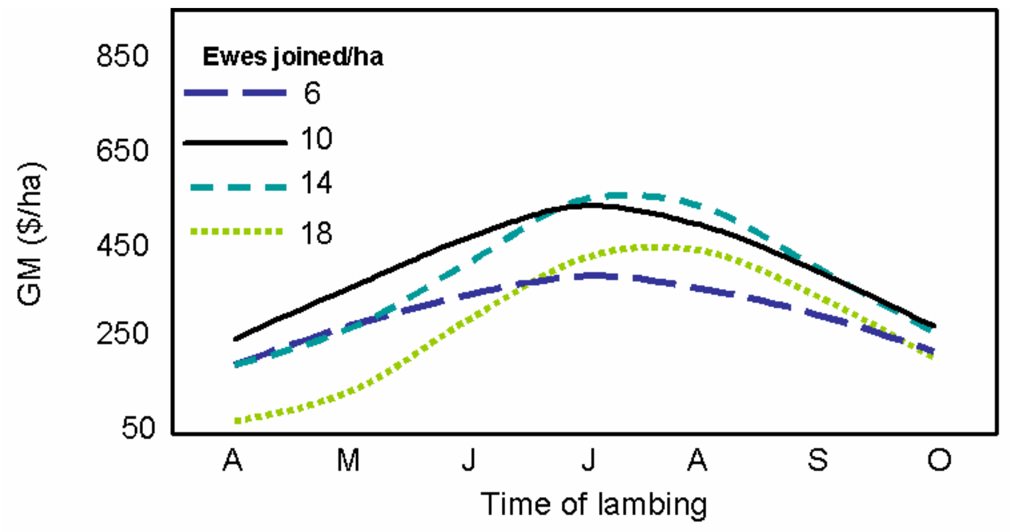
Figure 2. Change in average annual gross margin with lambing date for 4 breeding enterprises run at 10 ewes/ha on annual pastures at Cowra.



Contrasting this, a pure merino enterprise with sale of surplus young animals as yearlings (hoggets) which shows best returns with a September lambing. This timing allows sale animals the benefit of growth through a second spring season before sale. The optimal timing is a result of combining high live-weight at sale (kg/ha) with low cost of supplementation.

To derive the optimal combination of lambing time and stocking rate, simulations for every combination of these factors were run for each enterprise at each locality. Figure 3 summarises this exercise for a 2nd cross store lamb enterprise. Maximum GM is generated by lambing in July at 10 to 14 ewes per ha.

Figure 3. The interaction between lambing time (LT) and stocking rate (SR) for a 2nd cross store lamb enterprise at Cowra



Optimal scenarios were then screened using two other rules.

1) Ground cover > 70% from 1st of Jan to the 30th of Apr, at least 8 years in 10. (minimise risk of erosion and pasture degradation)

2) Ewes not fed > 30 kg of grain/head (wethers > 20 kg/head) more than 4years in 10. (only feed heavily in drought years)

Table 1. GM ($/ha) for stocking rate (SR) x lambing time (LT), highlighting constraints of ground cover and supplementary feeding.

Stocking Rate (ewes/ha)	Time of Lambing						
	April	May	June	July	Aug	Sept	Oct
4	146	195	236	259	249	214	166
6	198	274	338	373	355	299	224
8	234	334	417	464	437	358	256
10	243	356	460	527	492	393	271
14	196	281	420	550	525	406	257

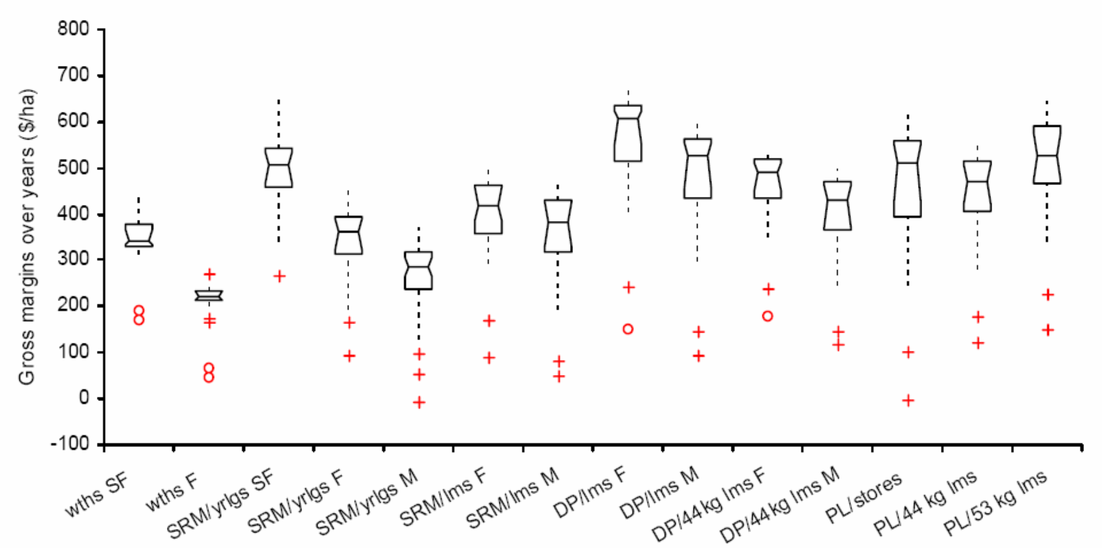
Feeding rule broken   Ground cover rule broken   Both rules broken

In Table 1, when these rules are met the optimum LT remains at July but the optimal SR is only 8 ewes per ha. Unshaded cells in the table show combinations of LT and SR that meet all necessary criteria. With all criteria met the expected average annual GM for this enterprise is $464/ha. This process has been repeated for all enterprises to enable a comparison of enterprise economic performance under optimal management.

The Comparisons

With a single set of assumptions regarding costs and prices there will always be one enterprise that, on average, generates more profit than all others. Figure 4 shows the distribution of gross margins for the years 1965 to 2002. The hourglass represents the middle 50% of the distribution while the dotted lines represent the probable statistical extremes. The symbols (+ and o) represent outliers (extreme droughts). For the defined Cowra locality the most profitable enterprise over the long run is a dual purpose flock (fine Merinos producing 1st cross store lambs). However a similar median GM can be achieved from dual purpose (medium merinos), self replacing super fine merinos and prime lambs (store and export).

Figure 4. Range in annual GM ($/ha) for simulated sheep enterprises at Cowra from 1965 -2002.



All enterprises can generate significant profits if managed optimally. Assuming farm overheads of $130/ha the average profit ranges from $84/ha up to $430/ha.

Comparison with industry benchmarks and Ag Census data suggests that in fact very few real farms are operating close to optimal levels. Adoption of simple technologies to increase

production per hectare (improved pastures, increased stocking rates and appropriate lambing time) can lead to large increases in net farm income (Webb Ware 2002, Lean etal 1997)

Reproductive Efficiency

The GrassGro simulations were also used to assess the economic impact of weaning more lambs. The results indicate it is important to first ensure that stocking rate and lambing time are optimised before focusing on weaning percentage as a profit driver. This is not to say that weaning rate is unimportant, indeed on farms already running at their carrying capacity (optimum stocking rate) it may even be profitable to run fewer ewes/ha in order to wean more lambs. Under-stocked farms should focus on lifting stock numbers closer to carrying capacity rather than simply on increased weaning rate.

Discussion

Valuable methodology not definitive results.

This work by the CRC represents a robust framework for comparison of enterprises in the context of the physical production system. It is especially useful in relation to quantifying production risks arising from climate variability. But it is only a snapshot of the production that might be expected under a very specific set of assumptions. It does not show there is a single optimal enterprise on any particular farm and certainly not that any one enterprise is the most profitable across any of the districts simulated. Nonetheless it does provide a robust methodology for exploring the productive potential of pasture systems for a range of pastures, soil types and climates.

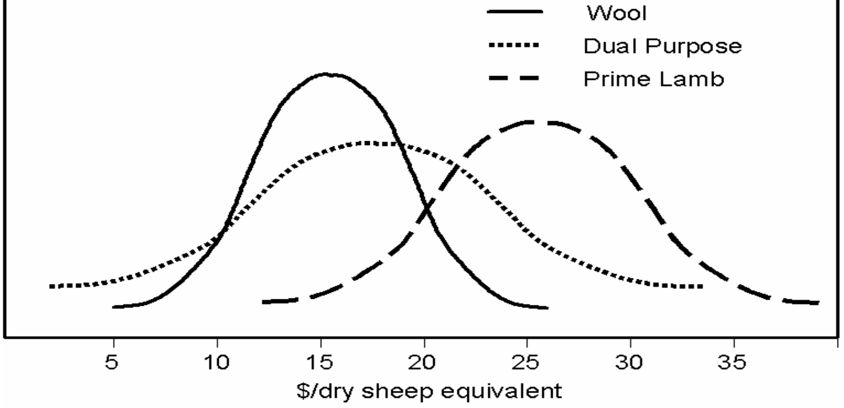
Salmon (2006) illustrates the power of modelling to reveal the spatial differences between farms in a search for the optimal stocking rate. GrassGro simulation for two properties in the Yass district showed that even at similar rainfall (710mm vs 760mm) shallower top soil and higher elevation reduced sustainable carrying capacity by one third (12 vs 18 wethers/ha). Similar differences between individual farms might be expected in most districts.

Variation within farms can be equally important. On any particular farm soil types and even climate characteristics may vary across the farm. On the Monaro average annual rainfall can vary by as much as 200mm within large properties due to the effects of elevation and topography. Despite this simulation modelling can provide the principles needed to make better decisions about stocking rate and lambing times and also give some clues as to optimal enterprise mix based on the mix of land capability and climate within the property.

Good management is a valuable as good enterprise choice.

One message is very clear, **"do what you do do, well"**. Benchmarking data illustrates the range in how well enterprises groupings are conducted in the real world (HSA 2005)

Figure 5. A graphical representation of the distribution of GM ($/dry sheep equivalent) for wool, dual purpose and prime lamb enterprises in AgInsights 2005 (HSA 2005)



Although the average gross margin per DSE differs between enterprises there are significant overlaps and the best performers for the worst enterprise are still better than the worst performers for the best enterprise (Figure 5). This reinforces it is more important to be good at whichever enterprises you choose to run. It is also important to acknowledge the costs involved when changing enterprises. Table 2. shows that in changing from Merinos to 1st cross ewes the time to break even depends of the price of replacement ewes. In recent years with 1st cross ewes making over $150/head it could take at least 5 years before the cumulative cash-flow would exceed that accrued by staying with the original Merino enterprise.

Table 2. Time to break even in the transition from a Merino enterprise to a 2nd cross store lamb enterprise as affected by 1st cross ewe purchase price (Rutherglen simulations).

Option	Ewe Cost ($/head)	Mean GM ($/hectare)	Break Even Time (Years)
Keep Merinos		$429	
Sell Merinos for $80 & Purchase first cross ewes.	$100	$631	1
	$130	$578	2
	$150	$542	5
	$180	$490	13
	$200	$454	40

Good genetics is equally important.

While the GrassGro modelling uses average animal genetics, there is clearly much to be gained through sourcing better than average genetics. In Table 3. a Merino genotype with 22% higher fleece weight at the same micron yields a GM almost 20% higher and the gap between the self replacing Merino enterprise and the dual purpose enterprise narrows considerably.

Table 3.Effect of improved genetics on economic output for a fine wool self replacing merino enterprise at Rutherglen.

Genotype	SR (ewes/ha)	Reference Wt. (Kg in CS 3)	Ewe FD (micron)	Wool Cut (greasy Kg/hd)	GM ($/ha)
Fine wool	8.5	50	19	4.1	$398
1st X lambs (fine wool)	9.5	50	19	4.1	$583
Fine Wool (22% more wool)	8.5	50	19	5.0	$474

This is reinforced by data from Merino bloodline comparisons (Atkins et al 2005). The most profitable bloodline yields a GM ($/dse) almost 40% higher than the average of all bloodlines while the lowest GM was almost 13% lower than the average.

The effect of genetics is equally important for meat enterprises. Fogarty et al (2005) reported the sire effect on GM ($/DSE) recorded by the Maternal sire Central Progeny Test (MCPT). The most common maternal sire breed (Border Leicester) ranged in GM from $28.32/dse to $39.77/dse for sires that were significantly better than the industry average (based on LAMPLAN figures), so it could be assumed that the potential range in GM due to genetics is even greater in the commercial industry.

Conclusion

The GrassGro analyses clearly showed that the most important economic drivers for sheep enterprises are optimising stocking rate and lambing times. In areas similar to those simulated there is considerable opportunity for sheep producers to increase their profits by refining their stocking rates and lambing times. Regardless of enterprise the focus should be on optimising the amount of meat and wool produced per hectare.

The strong performance of dual purpose enterprises and the relatively small difference in profit between self replacing Merinos and prime lamb flocks supports the option that many producers have taken in joining a proportion of their merino ewes to maternal or terminal sires. This option enables the producer to maintain important control over the flock genetics and greatly reduces the risk of introducing disease.

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BREEDING MERINO SHEEP FOR WORM RESISTANCE INCREASES PROFIT IN A MEDITERRANEAN ENVIRONMENT

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INTRODUCTION

Gastro-intestinal parasites (worms) are increasingly becoming more resistant to the available drenches and the only long term solution is to breed worm resistance sheep as it appears that no new drenches will become available in the near future.. The Rylington Merino flock have been bred for worm resistance but in spite of the success of this work, Merino ram breeders are reluctant to adopt breeding for worm resistance because it has not been clearly demonstrated that sheep that are resistant to worms are more profitable sheep. To quantify and to demonstrate the benefits of worm resistant sheep, it is important that resistant and susceptible animals should be managed in separate groups where there is no cross contamination.

ECONOMIC BENEFITS OF BREEDING FOR WORM RESISTANCE

A trial was conducted at the Mt Barker Research station in Western Australia to investigate the economic benefits of breeding for worm resistance. Three hundred Merino ewes of which 150 were sourced from the Rylington Merino selection line and 150 ewes from the unselected control line were allocated to six paddocks of approximately 5 hectares each, with 50 ewes per paddock to ensure a stocking rate of about 12 DSE under a set-stock management system. The resistant groups were mated to 6 rams from the Rylington Merino resistant line and the control groups with six rams from the unselected control line.

The lambs were born in July/August 2004 and weaned in November 2004. After weaning all the lambs were drenched and placed in separate paddocks to prevent any cross contamination between groups. None of the groups were drenched because the faecal worm egg count (WEC) of each group did not exceed 250 eggs per gram. The production data were collected and analysed, and the income from wool production was calculated using the Woolcheque prediction tool of Australian Wool Innovations (http://www.wool.com.au/). Income from meat production was calculated by using a standard price of $1.20 per kg live weight after hogget shearing.

RESULTS

Table 1 shows that the resistant line had significantly lower WEC at weaning. There were no significant WEC differences at 14 months of age and the low WEC (52 vs 35 eggs per gram) indicates that the challenge during the year was very low. However, the resistant line had a significantly lower dagscore and it was also consistently heavier and had a higher condition score than the control line. The resistant line produced 0.2 kg more clean wool per sheep that was also 0.4 micron finer but with a lower SS. These differences resulted in a 9.5% higher income for the resistant group than that for the control group (Table 2).

Table 1. Differences in production traits between the resistant and control line.

Traits	Control	Resistant	Difference	P
WEC weaning	1093	373	-720	<0.001
WEC 14 mnths	52	35	-17	0.05
Dagscore 14 mnths	1.16	0.35	-0.8	<0.001
Weaning weight (kg)	18.7	22.9	4.2	<0.001
Live weight at 7 months (kg)	22.5	25.5	3.0	<0.001
Live weight at 9 months (kg)	23.2	26.3	3.1	<0.001
Live weight-shearing (kg)	49.0	53.9	4.9	<0.001
Condition score at weaning	2.08	2.36	0.3	<0.001
Condition score at 7 months	2.23	2.37	0.1	0.03
Condition score at 9 months	2.14	2.56	0.4	<0.001
Condition score at shearing	3.17	3.38	0.2	<0.001
Fibre diameter (mic)	20.6	20.2	-0.4	<0.01
CV of fibre diameter (%)	24.4	20.4	-4.0	<0.001
Yield (%)	70.4	71.6	1.2	<0.001
Staple Strength (N/Ktex)	22.8	21.9	-0.9	0.28
Clean fleece weight (kg)	2.6	2.8	0.2	<0.001

Table 2. Differences in income from wool and meat production between the resistant and control line.

$ Income from	Control	Resistant	Difference
Meat @ $1.20/kg live weight after shearing	$58.82	$64.68	$5.86
Wool	$18.07	$19.51	$1.43
Total income	$76.89	$84.18	$7.29

DISCUSSION

These results indicate that the reduced worm burden contributed to large differences in production traits between the resistant and control groups. Adjusting the data for differences in breeding values still resulted in the resistant group more than $6 per sheep more profitable than the control groups even though there was no drenching during the year. Thus drenching and labour costs were not included in this estimate. These results show that breeding for worm resistance improves production significantly where there is no cross contamination between resistant and control flocks. Therefore ram breeders should consider including worm resistance in their breeding objectives because of the economical benefits that the increase in productivity can provide alone.

ANALYSIS OF THE PROFITABILITY OF SHEEP WOOL AND MEAT ENTERPRISES

FINAL REPORT FOR PROJECT 1.2.6

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JULY 2005

CORE PARTIES Australian Meat Processor Corporation • CSIRO • Department of Agriculture, Western Australia • Department of Primary Industries & Fisheries, Queensland • NSW Department of Primary Industries • The University of New England

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THE AUSTRALIAN SHEEP INDUSTRY CRC IS A JOINT VENTURE ESTABLISHED AND SUPPORTED UNDER THE AUSTRALIAN GOVERNMENT'S COOPERATIVE RESEARCH CENTRES PROGRAM

CONTENTS

SUMMARY

Analyses were undertaken to compare the profitability of a range of sheep meat and wool enterprises and to investigate the impact that management variables had on production and gross margins. The computer program, GrassGro™, was used to model fourteen different sheep enterprises at 4 different locations in south-eastern Australia. Simulations were run over 37 years (1965-2002), using historical weather data for each location and relevant soil types and pasture species. The enterprises modelled were: Merino wethers (both super-fine and fine fibre diameter); self-replacing Merino ewes (both fine and medium) turning off store merino lambs or yearlings; Dual purpose - Merino ewes (fine and medium) turning off 1st cross store lambs or lambs finished to 44kg; Prime lamb - first-cross ewes turning off 2nd cross stores, 44kg or 53 kg lambs. The management of all enterprises was optimised prior to making any comparisons.

- **The dual purpose enterprise using fine Merino ewes was consistently the most profitable**. It was followed by prime lambs, then the self-replacing Merino enterprises, with the Merino wethers the least profitable enterprise, at all 4 locations and at 2 commodity price scenarios. In general, the self-replacing Merino enterprises were slightly less profitable than the prime lamb enterprises. However, when a large price premium existed for super-fine wool (i.e. 5 year average price, 1999-2003), the super-fine Merino yearling enterprise was as profitable as the dual purpose enterprise.

- **The enterprises in which replacement ewes were purchased, rather than bred, were more profitable**. This was because more joined ewes could be run per ha allowing more meat/ha to be produced. However, the enterprise gross margin was sensitive to the price paid for replacement ewes. In reality, most producers of 1st cross lambs are doing so as an adjunct to their self-replacing Merino enterprise. The self-replacing Merino flock turning off store lambs was able to run more ewes/ha and turn-off similar quantities of meat but slightly less wool per ha, to the enterprise turning off Merino yearlings. The higher gross margins for the self-replacing Merino lamb enterprise were mainly due to higher prices for Merino lamb compared with yearlings (2-tooth) and lower supplement requirements. If there was no price discount for yearling meat (i.e. 30%) than the yearling enterprise would be slightly more profitable.

- **The results highlight that there is considerable scope for all sheep producers to improve the gross margins of their current enterprise by refining their time of lambing and stocking rates.** The focus should be on optimising the amount of meat and wool produced per ha and not on maximising per head animal performance.

- **Guidelines for the optimum time of lambing for each enterprise were developed**, and could be related to the length of the average growing season at each location. For a given enterprise and stocking rate (in ewes/ha), the time of lambing with the highest gross margin was that with the greatest production for the lowest total supplementary feed costs (maintenance and production). At a given stocking rate, time of lambing had no impact on wool produced per ha. The trends were as follows: For Merino yearling enterprise – lamb 3 months before the end of the growing season; store lamb enterprise (Merino, 1st cross, 2nd cross) enterprise – lamb 4 months prior; Trade lamb (44 kg liveweight) enterprise (1st cross or 2nd cross) or Export lamb (53 kg) enterprise – lamb 4-5 months prior. There was no benefit in lambing prior to June for any of the enterprises evaluated, due to reduced meat/ha and increased supplementary feeding costs.

- **Stocking rate had the largest bearing on enterprise gross margin.** Optimum stocking rates for each enterprise were selected on the basis of environmental and production risk criteria (relating to pasture mass and probability of feeding supplements), and generally were below the level where gross margin/ha was maximised. This indicated that, at the grain price used ($150/t) and if environmental and production risks were not considered, it was profitable to run much higher stocking rates and increase the probability of feeding supplements for maintenance.

- **A range of other production factors were investigated, such as ewe frame size, weaning percentage, lamb carcase weight, and price differentials for time of sale and carcase weight** as they are often quoted as having a large impact on profitability. Increasing Merino ewe frame size, while increasing lamb growth rate marginally, did not necessarily lead to increased meat/ha, as this reduced the numbers of ewes/ha that could be run. Using the 5 year price scenario, if an increase in ewe frame size was associated with an increase in fibre diameter, then gross margins decreased.

- **Increasing ewe fertility and the number of lambs weaned per ewe by 10%, increased gross margin by approximately 10%** (i.e.$ 50-70/ha or $3.50 - 5.00/ewe). This also increased grazing pressure. Producers who are understocked, will get greater benefits from increasing ewes/ha run rather than focussing on just increasing weaning percentage. For producers who are running an optimum stocking rate of ewes/ha, an increase in weaning percentage will be profitable, even after allowing for a small decrease in ewes/ha.

- **Lambing in late winter or spring was most profitable.** Increasing lamb sale weight by lambing in June and keeping lambs until the end of the growing season, was not as profitable as lambing later (as outlined above). Lambing earlier resulted in increased maintenance feed costs for ewes, so less ewes/ha could be sustained on the pasture. The increase in lamb sale weight did not compensate for the reduction in stocking rate and meat produced per ha. Price premiums for heavier carcase weights have generally not been high enough to make the earlier lambing time profitable. However, lambing at the optimum time (as per guidelines above), maintaining higher ewe numbers/ha and finishing 2^{nd} cross lambs to target weights using grain, was profitable at the grain price used. Finishing 1^{st} cross lambs to 44 kg was not always as profitable as producing 1^{st} cross stores. In this finishing system, to optimise the gross margin, the optimum time of lambing was slightly earlier and the optimum ewes/ha slightly lower, than for the store system. The small gain in meat/ha by producing heavier lambs, did not compensate for loss in wool income, but feeding to a target weight did reduce the economic risk.

- **Running a dual purpose enterprise offers producers some resilience against changes in commodity prices**, but producers doing so should still pay close attention to the genetic merit (wool cut per head and fibre diameter in relation to live weight) of the ewes they purchase to reap full benefits. The results also support the option that many producers with self-replacing Merino flocks have been taking, that is joining a portion of ewes to terminal sires. Producers contemplating changing over to 1^{st} cross ewes, need to exercise caution as they may not be any better off, particularly if paying very high prices for ewes. In high rainfall environments where producers often experience feet problems with Merinos or difficulty managing internal parasites, cross-bred ewe enterprises have some advantages. Although a self-replacing flock may not be as profitable as enterprises where replacement ewes are purchased (under the price scenarios modelled), purchasing ewes has the risks of introducing disease, lack of control with genetics, and exposure to high ewe prices.

INTRODUCTION

Large changes have occurred to the Australian sheep flock over the last decade. The total sheep and lamb numbers are now around 100 Million, the lowest level since 1948 (ABS 2003). Over the past decade, wool production has declined in Australia as sheep numbers have fallen, but lamb production has increased. Sheep numbers have declined in response to recent, widespread drought conditions. However, over the longer term the relative price of wool and sheep meats compared with grain and beef cattle have also had a large impact on sheep numbers (Barrett *et al*. 2003). However, wool is still the major product from the sheep industry in Australia. In fact, almost of third of Australia's commercial farms continue to produce wool and the wool industry remains one of Australia's most important agricultural industries with $ 2.5 billion export income (Barrett *et al*. 2003).

The number of Merino sheep in Australia has fallen at a faster rate than crossbred sheep numbers over the past decade, and the national flock is now younger and contains a higher proportion of ewes (Barrett *et al.* 2003). ABARE surveys of producers involved in prime lamb production (ABARE 2004), indicate that the number of Merino ewes joined to Merino rams decreased from 40.7 million in 1996/1997 to 31.8 million in 2004/05, while the numbers joined to short wool rams (terminal sires) or long wool rams increased from 9.7 million to 11.4 million in the same period. The number of crossbred Merino or other breeds of ewes has increased from 4.5 to 7.6 million over that 8 year period.

For many farmers, revenue from lamb sales is contributing a greater proportion of farm receipts, and prime lamb production is now considered by a growing number of sheep producers to be their primary activity (Connell and Hooper 2001). Wool producers are becoming more interested in running dual purpose Merino flocks, for wool and meat production, as a hedge between price fluctuations of either commodity. Only 30% of wool producers sold lambs for slaughter in 1992, however by 2002, this had risen to 47% (Barrett et al. 2002). Specialist prime lamb producers have become more focussed on producing larger carcase weights to meet specifications of processors, and capture price premiums. All of these changes are a reflection of the relative price of meat to wool.

The increased interest in meat production by woolgrowers has led to management changes, such as joining Merino ewes to terminal sires, lambing earlier (ie. autumn or early winter) to produce heavier lambs, altering breeding programs to breed larger frame Merino ewes or injection of SAMM or Dohne genetics, and more focus on increasing lambs weaned per ewe. Many producers who have traditionally run self-replacing Merino flocks are switching over to first-cross ewes for prime lamb production. The price of replacement first-cross ewes has increased as a consequence of the increased demand. The changes being made to enterprises may not be the most profitable options. Producers appear to be focused on price/kg meat not meat/ha and many may be running less ewes/ha as a consequence.

Benchmarking studies indicate that dual purpose flocks have been performing better than wool (pure Merino) or prime lamb flocks over past few years (Holmes, Sackett and Associates, 2003). One analysis of the relative profitability (profit after interest, $/ha) of different grazing enterprises over the last 5 years, indicates that beef trading has been more profitable than running a beef herd or a sheep flock, but it was much more volatile (i.e.more variation in returns and hence higher risk) (Holmes, Sackett and Associates, 2002). The data also shows that beef herds had similar profitability and variation in profit (risk) to dual purpose sheep flocks, prime lamb flocks were next most profitable with wool flocks least profitable. Based on the last 3 years data, dual purpose flocks (Merino ewe joined to terminal sire) have stood out as an enterprise having a high level of profit and acceptable volatility. An analysis of farms in south-western Victoria by Beattie (2002), show similar trends to those of Holmes, Sackett and Associates (2003). For 2001-02, average gross margins for prime lamb flocks (1^{st} and 2^{nd} cross enterprises) were $ 421/ha, beef herds were $335/ha, while wool flocks had the lowest gross margins of $284/ha.

While the benchmarking studies allow a comparative analysis of profitability between enterprises and farms, which allow producers to focus on the areas of their business where they can improve, there are a number of limitations when trying to extrapolate about optimising production systems. For example, they do not allow specific recommendations about the most profitable management practices for different environments to developed (eg. time of lambing). The analysis of financial data-bases highlight the strong linear relationship that exist between kg meat/ha or kg wool/ha and gross margin or profit, with stocking rate identified as the main driver of these. However, the relative contribution of other variables such as weaning % or genetics to this animal output /ha, or optimum ranges for other variables in the production system are not determined. Modelling the biology of farm systems and price/cost sensitivity analysis may allow a better understanding of the interaction between components, and the conditions under which variables may or may not be profit drivers.

Given that an increasing number of producers are starting to integrate wool and meat production into their systems in response to price signals, it is critical they have a better understanding of the profit drivers and risks associated with different enterprises and combinations.

The modelling work in this project was undertaken to evaluate the profitability of a range of sheep meat and wool enterprises and more specifically to answer the following questions:

1. Which production factors in each enterprise have the biggest impact on profitability (what are the key profit drivers)?

2. How do the enterprises compare (in the same environment) when the management is optimised (i.e. time of lambing, appropriate stocking rate)?

3. What impact do commodity prices have on the relative profitability of the enterprises?

An additional aim was to develop guidelines (biological and economic) for sheep producers to optimise profit and minimise risk, which can be adapted to suit a range of environments. The intention being that producers use this information to make better decisions about the management of their sheep enterprise, to improve the profitability and sustainability of their business.

METHOD

The profitability of a range of sheep enterprises was modelled using the computer program *GrassGro* (Moore *et al.,* 1997). *GrassGro* versions 2.4.3 and 2.4.4 (for self-replacing flocks) were used and simulations were run from 1st January 1965 to 31st December 2002. The first year's data were not used. A batch processing program, "Batch Gro" (version 6/7/04) was developed by CSIRO, and used to create and execute the factorials of the simulation experiment.

Four case study locations, where wool and sheep meat production are major industries, were selected for the analysis. The locations chosen were:

Mortlake region in south-western Victoria,
Rutherglen region in north-eastern Victoria,
Cowra region in Central West of NSW,
Naracoorte region in south-eastern South Australia.

A wide range of enterprises were selected which were based on enterprises currently run by producers in the 4 locations. The impact of a range of management options on profitability, were also analysed. These were: breed, genotype (fibre diameter, fleece weight), time of lambing, stocking rate, and time of sale/finishing system for slaughter lambs. Details of all systems investigated for each locality are presented in Table 1. Two options for selling Merino lambs were included; as 18 week old weaned lambs or as 12 month old hoggets/yearlings. Although selling Merino lambs at 4 months old is not practised in all 4 localities, this option was included to allow comparisons with the cross-bred lamb enterprises. Merino lambs were first shorn as yearlings. The timing of husbandry practices are summarised in Table 2, and ewe conception rates used are summarised in Table 3. Standard weights and conception rates of ewes varied with seasonal conditions.

A supplement of wheat was fed to maintain liveweight whenever livestock body condition (Jeffries, 1961) fell below a threshold. The supplementary feeding rules used for each class of stock were:

- Wethers – fed when average condition was 1½ (lowest 1)
- Ewes – fed when average condition was 2 ½ (lowest 2)
- Weaners – fed when average condition was 2 (lowest 1½)
- Lamb finishing – weaners production fed to reach a "Trade" liveweight of **44 kg/20 kg carcase weight** (1st and 2nd cross lambs) or to an "Export" liveweight of **53 kg/ 24kg carcase weight** (2nd cross lambs only).

The quality specifications for the wheat used in the simulations were: 89% dry matter, 14% crude protein, 90% digestible dry matter, 92% rumen degradable protein, and 13.8 MJ/kg DM metabolisable energy.

A production feeding rule was also used to finish first cross and second cross lambs to a target liveweight. Production feeding with wheat took place after weaning, in the paddock, in any year it was required.

The effect of pasture type and soil fertility on productivity and profitability was not investigated. This analysis assumed that the pasture species composition and soil fertility were not limiting factors in each system. The pasture types and soil types used for each location are summarised in Table 4. A fertility scalar of **0.9** was used for all simulations. Also, the legume content was fixed at **30%** to remove this as a source of error. A paddock size of 1000 ha was used to minimise rounding errors.

The assumptions used for prices and costs are shown in Table 5. Both 5 year (1999-2003) and 1 year (July 2003-June 2004) average wool and meat prices were used to investigate the impact of changes in commodity prices on gross margins. Average 5 year prices for wool were similar to the 12 year average, i.e. post reserve price scheme.

For each enterprise, profitability was calculated as gross margin/ha and per 100mm of rainfall, these being 2 common indices used in farm financial benchmarking studies. Gross margins for the first year of the simulations were not used. Physical benchmarks such as stocking rate (DSE/ha), and clean wool and meat produced per ha were also extracted. Risks (economic, production and environmental) associated with the enterprises and management options were also assessed. The key financial and physical performance indicators, or benchmarks, extracted from each run in *GrassGro* are summarised in Table 6.

In order to compare the profitability of a wide range of sheep enterprises, a stocking rate was selected for each enterprise which took into consideration risks of supplementary feeding and low pasture mass in late summer/autumn (Mason *et al.* 2003). The following two "rules" were developed:

(i) *Pasture mass rule: Maintain more than 800 kg dry matter/ha (dead/total) on paddock from 1st January through to 30th April for at least 8 out of 10 years (i.e. will tolerate reducing kg DM /ha below this target in 2 out of 10 years).*

(ii) *Supplementary feeding rule: Prepared to feed ewes > 30 kg/head per year in only 4 out 10 years. Prepared to feed wethers >20 kg /head per year in only 2 out of 10 years (i.e. only feed heavily in drought or very dry years).*

The upper limit for stocking rate for each enterprise was defined as the highest that could meet these 2 rules.

Table 1. Sheep Enterprises and management variables used in GrassGro simulations

Enterprise	Liveweight of ewe[B] in average condition[A] (kg)	Ewe fibre diameter[A] (µm)	Ewe greasy wool cut[A] (kg/hd)	Stocking rates (sheep/ha)[C]	Time of lambing[D]	Time of sale - cast for age sheep	Time of sale - lambs
Merino wethers	45	17.5 (SUPER-FINE)	3.6	6 – 20	-	6 years, after Dec shearing	-
	50	19 (FINE)	4.1	6 - 20	-	6 years, after Dec shearing	-
	55	21 (MEDIUM)	4.5	6 - 20	-	6 years, after Dec shearing	-
Self replacing flock (Merino ewe X Merino ram)	45	17.5	3.6	6 - 18	April - Oct	6 years, after wean/ vary with lambing	**1. Lambs**/ weaners (18 weeks old) and **2. Yearlings** (12 mths old), time varies with lambing
	50	19	4.1	6 - 18	April - Oct	6 years, after wean/ vary with lambing	As above
	55	21	4.5	6 - 18	April - Oct	6 years, after wean/ vary with lambing	As above
First cross lambs (DUAL PURPOSE ENTERPRISE) (Purchased Merino ewes X terminal sire)	50	19	4.1	6 - 18	April - Oct	6 years, after wean/ vary with lambing	**Store lambs** Sell at 44 kg LWT (20 kg CWT) or by 18 weeks of age.
	55	21	4.5	6 - 18	April - Oct	As above	As above
First cross lambs FINISH	50	19	4.1	6 - 18	April - Oct	6 years, after wean/ vary with lambing	**Finish lambs**: Production feed & sell at 44 kg LWT/20 kg CWT or by 26 weeks of age.
	55	21	4.5	6 - 18	April - Oct	As above	As above
Second cross lambs (PRIME LAMB ENTERPRISE) (Purchased 1st cross ewes X terminal sire)	60	29	4.0	4 - 18	April - Oct	6 y.o. after shear/ vary with lambing	**1. Store lambs** Sell at 44 kg LWT (20 kg CWT) or by 18 weeks of age **2. Finish lambs (Trade):** Prod. feed & sell at 44 kg LWT/20 kg CWT or by 26wks **3. Finish lambs (Export):** Prod. feed & sell at 53 kg LWT/24 kg CWT or by 26 wks.

[A] Alex Ball (2004). "Average" genotypes used based on data in Merino Genetic Services (MGS) and LAMBPLAN databases.
[B] Liveweight, fleece weight and fibre diameter are for the ewe of the nominated breed.
[C] "Sheep" are wethers in wether enterprises and ewes in breeding flocks.
[D] The mean date of lambing is the start of the month specified.

Table 2. Timing of husbandry operations for flocks simulated in GrassGro

Enterprise	Lamb	Shear[A]	CFA[B] (6-7 years)	Replace/ purchase	Mate	Wean	Sell lambs
Merino wethers	-	15 Dec	31 Dec	1 Jan	-	-	-
Merino lambs – self-replacing flock	April	1 Mar	2 Jul	15 Oct	1 Nov	1 Jul	1 Aug (18 wks) or 27 Mar (52 wks)
	May	1 Apr	2 Aug	15 Nov	1 Dec	1 Aug	1 Sept/ 26 Apr
	June	1 May	2 Sept	15 Dec	1 Jan	1 Sept	1 Oct/ 27 May
	July	1 Jun	2 Oct	15 Jan	1 Feb	1 Oct	1 Nov/ 27 June
	Aug	1 Jul	2 Nov	15 Feb	1 Mar	1 Nov	1 Dec/ 26 July
	Sep	1 Aug	2 Dec	15 Mar	1 Apr	1 Dec	1 Jan/ 26 Aug
	Oct	1 Sep	2 Jan	15 Apr	1 May	1 Jan	1 Feb/ 25 Sep
First cross lambs (purchased Merino ewes)	As above	As above	As above	As above	As above	As above	1. At 44 kg LWT (20 kg CWT)/ or by 18 weeks 2. Prod. Feeding - At 44 kg LWT (20 kg CWT)/ or by 26 weeks.
Second cross lambs (purchased 1st X ewes)	As above	As above	As above	As above	As above		1. At 44 kg LWT (20 kg CWT/or by 18 weeks 2. At 53 kg LWT (22 kg CWT/ or by 26 weeks.

[A] Shearing date for ewes is the month pre-lambing to allow the Merino yearlings to be shorn prior to sale.
[B] CFA = cast for age

Table 3. Relative conception rates used for Merino[A] and cross-bred[B] ewes simulated in GrassGro

Ewes	Lamb date	Mating date (day of year)	Conception rate %	Singles %	Twins %
Merino	April	1 Nov (300)	80	70	5
	May	1Dec (330)	90	80	5
	Jun	1 Jan (1)	110	90	10
	Jul	1 Feb (32)	120	80	20
	Aug	1 Mar (60)	130	70	30
	Sep	1 Apr (90)	130	70	30
	Oct	1 May (120)	120	80	20
Crossbred					
	April	1 Nov (300)	105	65	20
	May	1Dec (330)	120	60	30
	Jun	1 Jan (1)	135	55	40
	Jul	1 Feb (32)	148	48	50
	Aug	1 Mar (60)	156	40	58
	Sep	1 Apr (90)	156	40	58
	Oct	1 May (120)	145	45	50

[A] Freer *et al*. (1997).
[B] Neal Fogarty (2004) personal communication.

Table 4. Site details, and pasture and soil types used in simulations

	Mortlake[A]	Rutherglen[E]	Naracoorte[F]	Cowra[G]
Pasture species				
Legume (Fixed at 30%)	-	-	-	-
Grass & root depth	Perennial ryegrass (480 mm)	Phalaris (700 mm)	Phalaris (700 mm)	Annual ryegrass (450 mm)
Soil type				
Northcote description[B]	Dy 3.43 (yellow duplex)	Dr 2.22 (red duplex)	Dy 5.43 (yellow duplex)	Gn 2.15 (red earth)
Cumulative depth (mm)				
Topsoil	275	500	300	500
Subsoil	800	1000	850	1000
Average annual rainfall (mm)[C]	663	619	567	633
Rainfall pattern[D]	Winter dominant	Winter dominant	Winter dominant	Uniform
Median length of growing season[H] (months)	9 (early April –end Dec)	8 (mid Apr –end Nov)	7 (May – end Nov)	7 (mid April-mid Nov)

[A] Unless otherwise indicated, Mortlake locality details from Steven Clark (2003) pers. comm. Victorian Department of Primary Industries, Hamilton, and Graeme Ward (2003) pers. comm. Victorian Department of Primary Industries, Warnambool,.
[B] Northcote (1965).
[C] 1965-2002 *(GrassGro)*
[D] 1965-2002 *(GrassGro)*
[E] Unless otherwise indicated, Rutherglen locality details from Angela Avery and Charlie Showers (2003) pers. comm. Victorian Department of Primary Industries, Rutherglen.
[F] Unless otherwise indicated, Naracoorte locality details from Andrew Craig and Jock McFarlane (2003) pers. comm. South Australian Research and Development Institute (SARDI), Struan.
[G] Unless otherwise indicated, Cowra locality details from Doug Alcock (2004) pers. comm., NSW Department of Primary Industries, Cooma.
[H] Median length of the growing season, is the number of months in which pasture growth occurs in at least half the years.

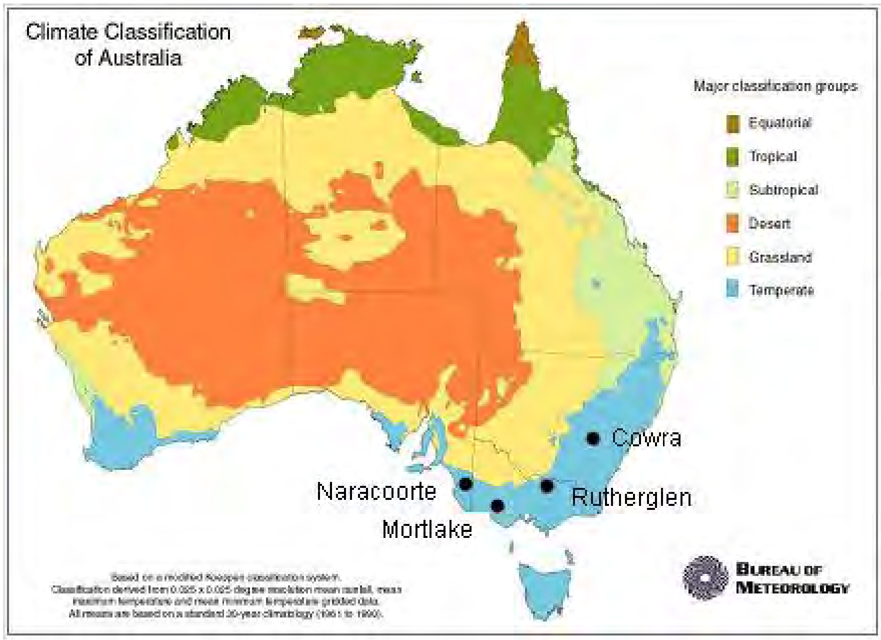


Figure 1. Location of 4 case study sites in relation to climate classification (Bureau of Meteorology, 2004).

Table 5. Commodity prices and inputs costs used in GrassGro simulations

Inputs		*5 year average price: Jan 1999 - Dec 2003 (adjusted for CPI)*	*Average price: July 2003 - Jun2004*
Pasture management (cost of phosphorus/sulphur fertiliser).		$ 30/ha (i.e.140kg /ha superphosphate@ $220/t spread)	
Merino rams		$ 500	$ 500
Merino ewes		$ 50	$80
First cross ewes		$ 80	$150
Merino wethers		$40	$45
Shearing		$ 5/head ($3/head lambs)	
Husbandry		$2/head (wethers, lambs), $3/hd (ewes)	
Livestock commission		5%	
Wool commission		5%	
Other sale costs		$1.20/head	
Supplementary feed (wheat)		$150/t	
Prices Received		***5 year average: Jan 1999 - Dec 2003 (adjusted for CPI)***	***Average: July 2003 - Jun2004***
WOOL [A] (AWEX[B])	**Fibre Diameter**	**c/kg clean**	**c/kg clean**
	17 µm	2301	1242
	18 µm	1521	1047
	19 µm	1223	983
	20 µm	910	943
	21 µm	798	925
	22 µm	759	911
	23 µm	732	891
	28 µm	526	569
	29 µm	526	527
MEAT (NLRS[C])	**Carcase weight[D]**	**$/kg (CWT)**	**$/kg (CWT)**
Merino hoggets	18-24 kg	1.66	2.11
Merino lambs	< 16 kg	2.03	2.61
	16-18 kg	2.29	2.10
	> 18 kg	2.59	2.40
1^{st} X lambs	< 16 kg	2.42	1.91
	16-18 kg	2.61	2.13
	> 18 kg	3.07	3.77
2^{nd} X lambs	< 18 kg	2.72	1.93
	18-22 kg	3.17	2.26
	>22 kg	3.20	3.84
Lamb skin		$5/head	$10/head
Cast for age sheep		$ 0.64/kg (LWT)	$ 0.80/kg (LWT)

[A] *Assume all wool is sound.*
[B] *Wool prices from AWEX = Australian Wool Exchange.*
[C] *Meat prices from NLRS = National Livestock Reporting Service.*
[D] *Assume dressing % of 45%.*

Table 6. Parameters extracted from GrassGro simulations to use as indicators of financial and physical performance and risk

Financial	*Physical*	*Risk*
Average gross margin ($/ha)	Wool - clean kg/ha Meat - liveweight kg/ha	Average gross margin Range in gross margin over years: median, lower and upper quartiles
Gross margin ($/ha)/ 100 mm rainfall	No. lambs /ewe (weaning %)	
	Average sale weight of wether lambs (kg)	Probability of feeding supplements (>30 kg/mature ewe per year or >20kg mature wether per year)
Percentage of income from wool & meat (%)	Average DSE/ha Winter DSE/ha (1 Jul)	
Cost of supplement for maintenance ($/ha) Cost of supplement for production feeding ($/ha)	Average annual supplement fed (kg/head per ewe/wether and weaner)	Soil erosion/soil health risk: Probability of falling below target pasture mass (800 kg DM/ha total mass) during January -April
	Pasture utilised (%)	

RESULTS

CLIMATE AND PASTURE GROWTH CHARACTERISTICS OF LOCALITIES

The four localities selected all fall within the temperate pasture zone (Figure 1) but the macro-climate varies markedly between sites. Naracoorte, Rutherglen and Mortlake all have a winter dominant rainfall pattern (Figure 2), and average annual rainfall of 567mm, 619 mm and 663 mm, respectively (Table 4), while Cowra has a uniform rainfall pattern and average annual rainfall of 633 mm. Rutherglen and Cowra have a more continental influence to the climate, with a greater range in minimum and maximum temperatures than Naracoorte and Mortlake (Figure 2).

The three winter rainfall dominant sites had a similar seasonal pattern of pasture growth (Figure 2). That is, there was an obvious autumn break, a winter trough (the extent of which depends on the minimum winter temperatures), and a spring peak (the duration of which is dictated by the amount of November and December rainfall, and soil type). Based on the 50th percentile for pasture growth (Figure 2), the length of the growing season for Mortlake, Rutherglen and Naracoorte, was 9 months (early Apr- end Dec), 8 months (mid Apr-end Nov) and 7 months (May-end Nov) respectively. In contrast, the annual pasture simulated at Cowra, had greater autumn growth but less spring production than the other sites where a perennial pasture was simulated. The period of pasture growth at Cowra was 7 months (mid Apr- mid Nov). Although this site received almost twice the amount of summer rainfall compared with the other sites, there were no summer-active perennials simulated in this pasture.

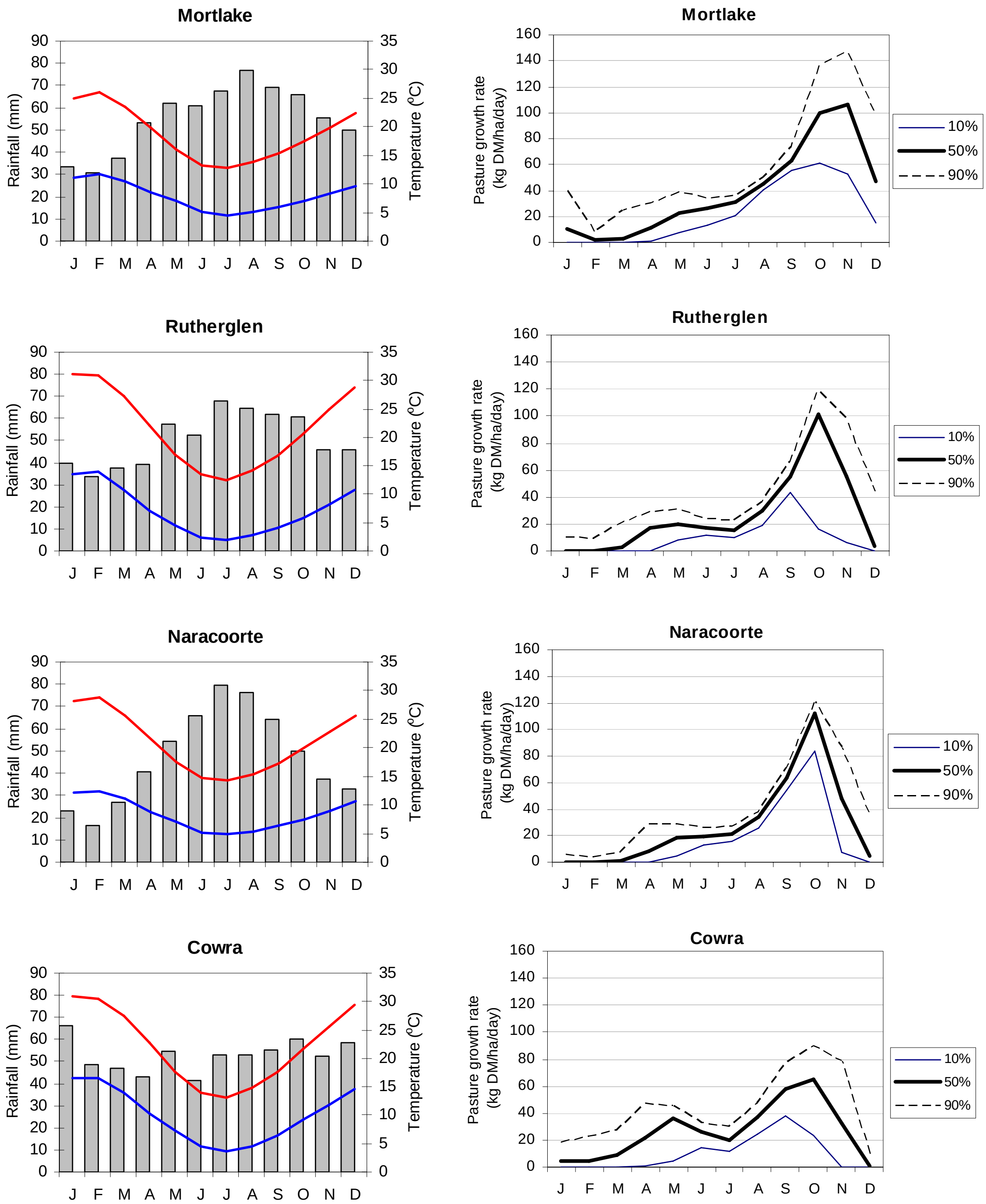


Figure 2. Average monthly rainfall, average minimum and maximum temperatures and percentiles for pasture growth (from 1965 - 2002), for the 4 localities studied.

EFFECT OF MANAGEMENT VARIABLES ON GROSS MARGIN AND RISK

(I) TIME OF LAMBING

The optimum time of lambing for each enterprise was defined as the time where the average gross margin was maximised (Figure 3). Lambing date was investigated in monthly increments from April through to October. For each month of lambing simulated, the mean date of lambing (when most lambs born) was the start of the month. In effect, some ewes would have started lambing 10 days before the mean date of lambing.

For a given stocking rate (in terms of number of ewes/ha), the optimum time of lambing occurred when meat production per ha was maximum and supplement costs per ha was minimum. Time of lambing did not affect wool production (kg per ha). The same relationships between time of lambing, meat production and supplement costs were observed at each locality, but the lambing date varied depending on the length of the growing season and the extent of the spring peak (Figure 3). For example, the optimum time of lambing for all store lamb enterprises was around August/September for Mortlake, August for Rutherglen and Naracoorte, and July/August for Cowra (Figure 3a). The optimum time of lambing was around a month earlier if the lambs were kept for longer and fed, to achieve higher sale weights (Figures 3c and 3d). The optimum time of lambing for the Merino yearling enterprise was October for Mortlake, September/October for Rutherglen and Naracoorte, and August/September for Cowra (Figure 3b).

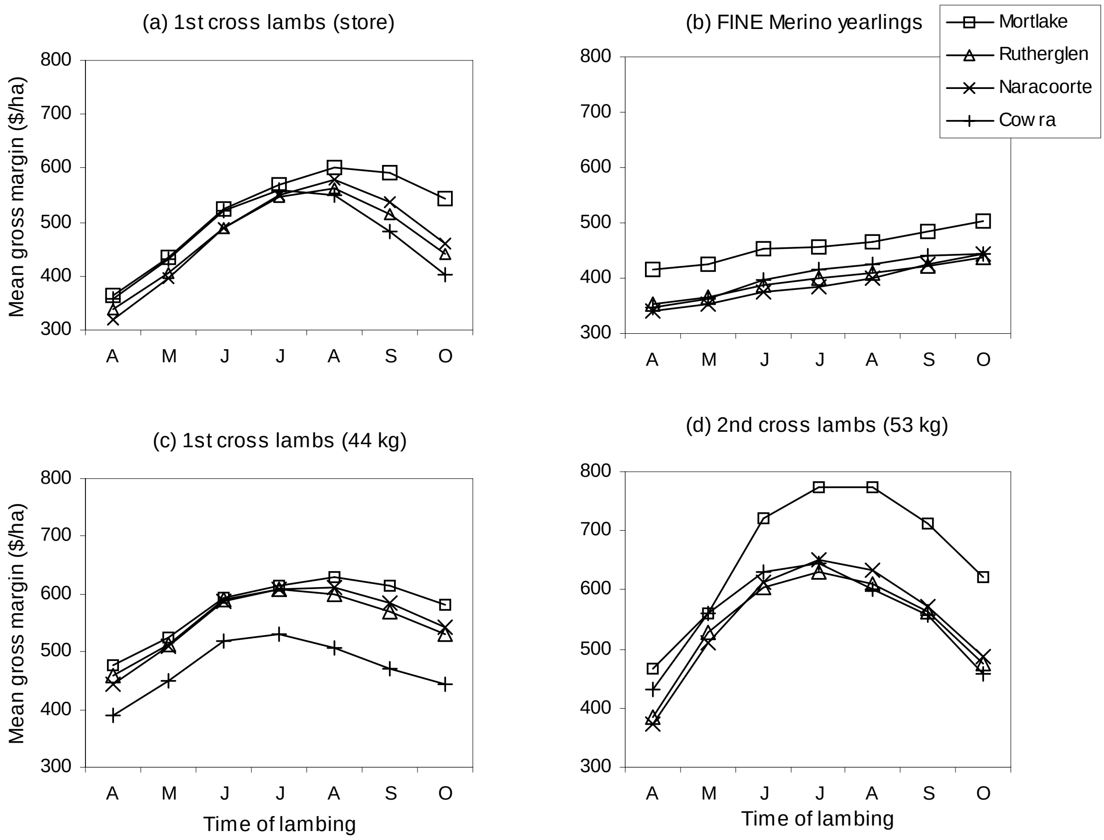


Figure 3. Effect of time of lambing on mean gross margin ($/ha) for 4 locations at a stocking rate of 10 ewes/ha. (At each location the same number of ewes/ha does not represent equivalent grazing pressure between enterprises). (a) FINE Merino ewes producing store 1st cross lambs, (b) FINE self-replacing flock, turning off Merino yearlings, (c) FINE Merino ewes, finishing 1st cross lambs to 44kg liveweight, d) 1st cross ewes joined to terminal sire, finishing 2nd cross lambs to 53 kg.

For the store lamb and yearling systems, in which no production feeding occurred, the major variable cost was supplement for maintenance of ewes. The time of lambing with the highest gross margin ("optimum") was that with the greatest meat production/ha and the least supplement cost (Figure 4). For the store lamb enterprise, lambing beyond August/September, reduced ewe supplementary feed costs marginally but also reduced sale weight of lambs (Figure 5). For the yearling enterprise, lambing later in the year (September - October) meant that ewe supplement costs were lowest and sale weight was also highest (Figure 5). Lambing earlier meant 12 month old yearlings were sold when pasture availability and live weight gain were low. Lambing later than September/ October also resulted in increased costs of supplementation to ewes and weaners.

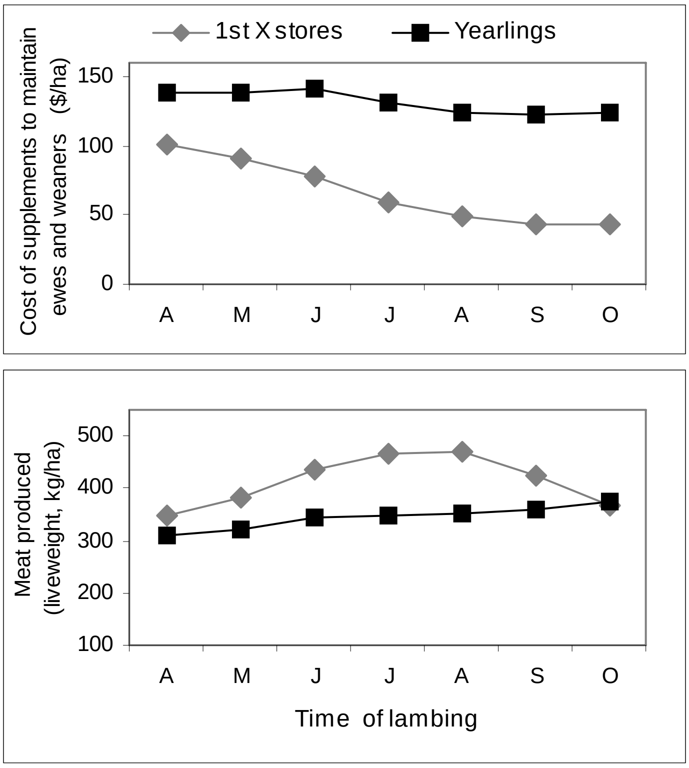


Figure 4. Effect of time of lambing on annual supplement cost (to maintain ewes and weaners) and meat produced (live weight, kg/ha), for a 1st cross store lamb (FINE Merino ewes) and a FINE Merino yearling enterprise at Rutherglen, for a stocking rate of 10 ewes/ha.

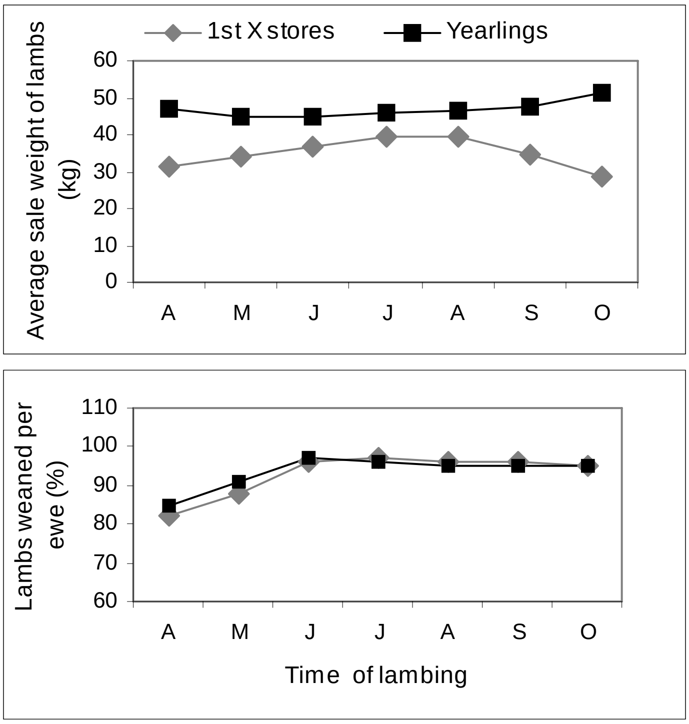


Figure 5. Effect of time of lambing on the number of lambs weaned per ewe and the average sale weight of wether lambs for a 1st cross store lamb (FINE Merino ewes) and a FINE Merino yearling enterprise, at Rutherglen for a stocking rate of 10 ewes/ha.

At a given stocking rate, meat (live weight) per ha was the product of the number of lambs weaned per ewe and the average sale weight of lambs. The impact on time of lambing on these two variables is shown in Figure 5. Although only data for Rutherglen are shown, the same trend was apparent at all locations. Conception rates were higher for both Merino and first-cross ewes lambing from June through to October, and peaked in August and September (Table 3). Lamb mortalities due to wind chill tended to increase after July, and were most extreme at Mortlake (data not shown). The net result was a similar weaning percentage from Merino ewes lambing in June to October (Figure 5) and from first-cross ewes lambing from June to September (Figure 6).

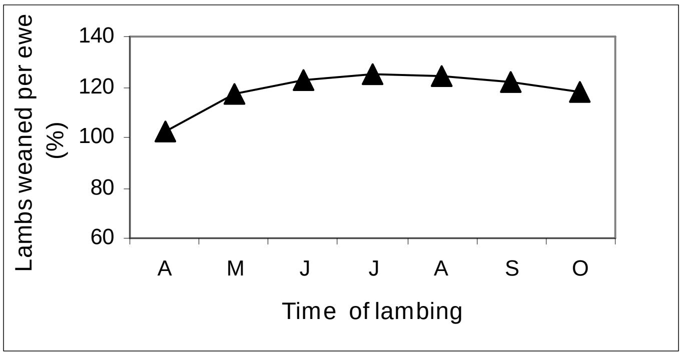


Figure 6. Effect of time of lambing on the number of lambs weaned per ewe for a 2nd -cross store lamb enterprise, at Rutherglen for a stocking rate of 10 ewes/ha.

For the systems where lambs were supplemented to reach a target weight, the optimum time of lambing was that with lowest total supplement costs (maintenance and production) (Figure 7). The heavier the target weight, or the shorter the growing season, the earlier the optimum time of lambing. This time occurred, of course, within the range of lambing dates in which meat/ha was highest. Lambing very early in April or May was the least profitable time for all enterprises, because the number of lambs weaned per ewe (due to lower ewe fertility at joining) was lowest (Figures 5 and 6) and supplementary feed costs (for maintenance) the highest (Figures 4 and 7). Lamb sale weight was not a variable in this instance, as lambs were sold after they reached a target weight.

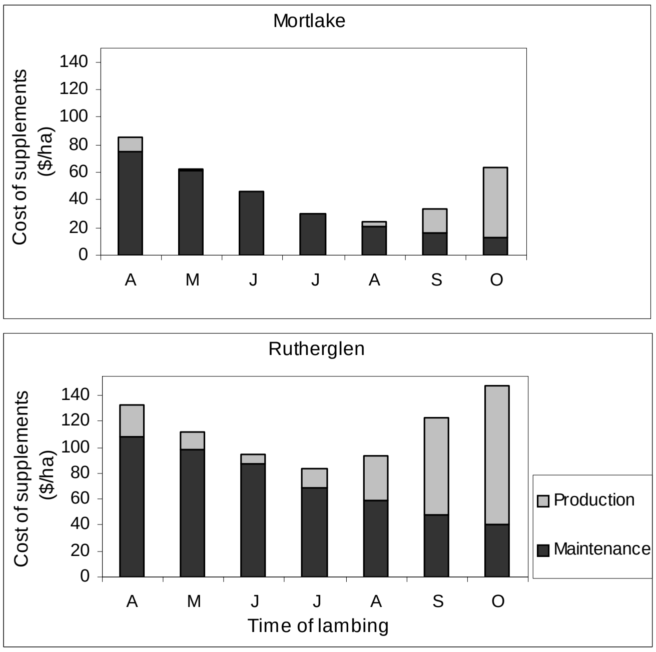


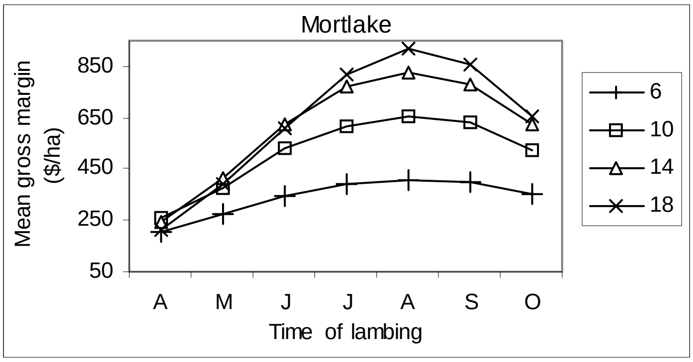
Figure 7. Effect of time of lambing on cost of supplements (maintenance and production) for a 1st cross lamb enterprise (finishing lambs to 44 kg) using FINE merino ewes, stocked at 10 ewes/ha, at Mortlake and Rutherglen.

(II) STOCKING RATE

Simulations were run at a range of stocking rates for each enterprise, time of lambing and location (Appendices 2, 3, 4 and 5). The highest stocking rates tested were 20 wethers/ha and 18 ewes/ha. A response curve was obtained for time of lambing versus mean gross margin for each stocking rate (Figure 8).

Gross margins increased as stocking rate increased for the Merino wether enterprises and all the Merino ewe enterprises at all 4 locations. Gross margins decreased at the highest stocking rate tested (18 ewes/ha) for the first-cross ewe enterprises (producing store, trade or export 2nd cross lambs) at Rutherglen, Naracoorte and Cowra because of high supplement costs (Figure 8). At Mortlake, gross margins decreased at the highest stocking rate, only for the 1st cross ewe/2nd cross store lamb enterprise lambing in April May or June (Figure 8). Gross margins increased as stocking rate increased for the 2nd cross trade and export lamb enterprises at Mortlake.

The length of the growing season and winter pasture growth rates at the different locations gave rise to different potential carrying capacities. Mortlake had a longer growing season, greater spring pasture growth and relatively good winter growth rates compared with the other sites. Hence Mortlake had higher gross margins, due to lower supplement costs, for a given number of ewes/ha compared with the other 3 locations (Figure 8).



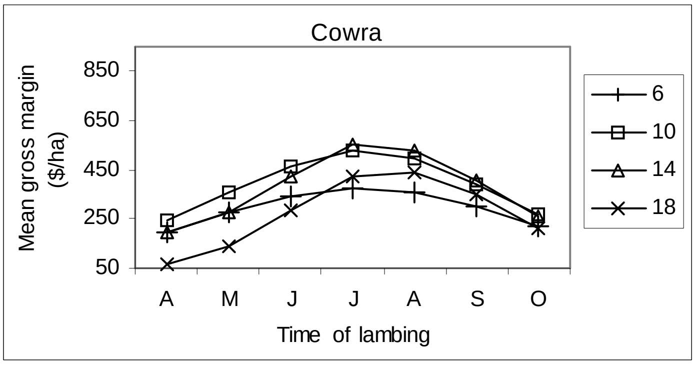


Figure 8. Effect time of lambing on gross margin for a 2nd cross store lamb enterprise at 4 stocking rates (6, 10, 14 or 18 ewes/ha) at Mortlake and Cowra.

The year to year variation in gross margin increased with stocking rate, indicating higher risk. However, the analysis indicated that it was profitable to increase supplementary feeding (at the grain price of $150/t) to maintain stocking rates above those generally considered acceptable in these locations (Figure 9). For all lambing times, stocking at 18 ewes/ha was more profitable than stocking at 6 ewes/ha (Figure 9). This indicates that stocking rate is a more important driver of profit than time of lambing. However, there are likely to be interactions with high stocking rates being more profitable at the later lambing dates. Figure 9 shows that optimising time of lambing can increase gross margin at a low stocking rate, but as stocking rate increases the benefits become larger. Even though risk increased with the higher stocking rate, the downside risk could be minimised if the time of lambing was optimised. Data for all enterprises, depicting the economic risk for various time of lambing and stocking rate combinations, is presented in Appendices 1.1, 1.2, 1.3 and 1.4.

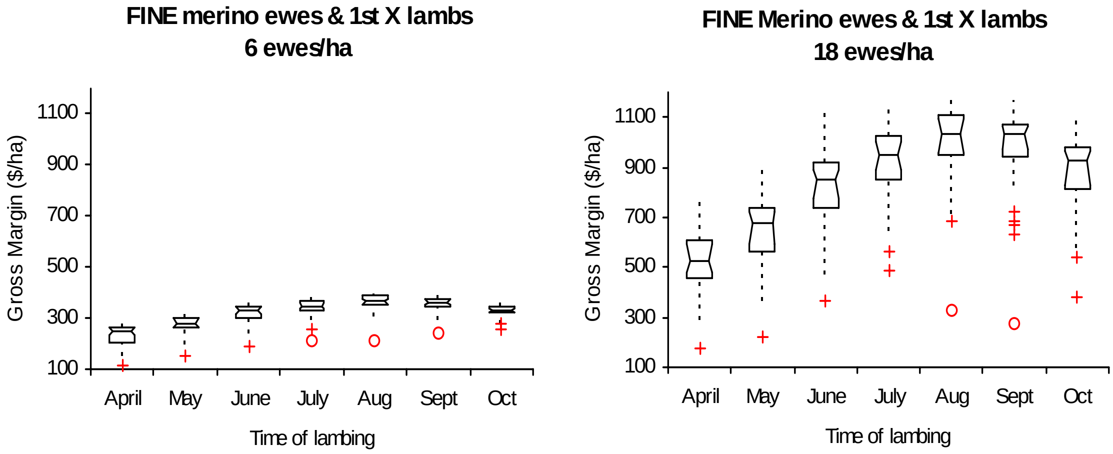


Figure 9. Effect of time of lambing and stocking rate on average gross margin and the variation in gross margin (risk) from 1966-2001, for a 1st cross lamb enterprise (FINE merino ewes) at Mortlake. The box plots show the spread/scatter in gross margins over the years. The notched box shows the median (middle line), the upper quartile (top of box) and the lower quartile (the bottom of box). The dotted-line connects the nearest values within 1.5 times the inter-quartile ranges of the lower and upper quartile. Exceptional values (severe droughts) are shown by the cross and open circle.

(III) TIME OF LAMBING AND STOCKING RATE INTERACTIONS – CONSIDERATION OF RISK FACTORS

In this study, enterprises were compared at the time of lambing and stocking rate which was most profitable. However, selecting the stocking rate on the basis of maximum gross margin does not account for production and environmental risks encountered by producers. Selecting the stocking rate on the basis of maintaining a similar winter DSE/ha for each enterprise does not fully capture the different risks of the enterprises. Hence, the highest sustainable stocking rate was selected for each of the enterprises on the basis of whether it met the 2 key risk criteria – i.e. the pasture mass (ground cover) and supplementary feed rules.

These additional criteria modified the choice of stocking rate and lambing dates at each location. For example, at Mortlake, the initial optimum time of lambing for 1st cross store lamb (FINE Merino ewes) enterprise was August/September, with August having marginally higher gross margin (Figure 3a). When the risk criteria was overlaid on these times of lambing, the highest sustainable stocking rate that could be carried for August lambing was 17.5 ewes/ha with a gross margin of $966/ha compared with 20 ewes/ha for September lambing with a gross margin of $1042/ha. Lambing later, reduced the probability of feeding ewes and the sale of lambs as stores, reduced the grazing pressure on the pasture over summer and autumn. This allowed more ewes to be safely carried. In enterprises in which wool is of high value (eg. super-fine and fine wools at the 5 year price scenario), it was more profitable to lamb at the later end of the optimum range, and run more ewes per ha, as the marginal return per ewe was still substantial (i.e. extra $30 gross margin per additional ewe). If the extra return per additional ewe/ha is small, then there is little benefit lambing at the later end of the range and running additional ewes. There would be a risk, or opportunity cost, from having capital invested in additional ewes with a low return.

A table was prepared for each enterprise at each location, to highlight the effect of time of lambing and stocking rate on average gross margin (Appendices 2, 3, 4 and 5). Examples of the gross margin tables for a Merino yearling and 1st cross lamb enterprise for Mortlake are shown in Tables 7 and 8. The tables highlight the additional risks of managing the enterprise under the different combinations of stocking rate and time of lambing, using the criteria relating to supplementary feeding and maintaining adequate pasture cover. The risk of supplementing ewes decreases (i.e. pale shaded cells in Tables) as lambing occurs later in the year, to coincide with the increase in pasture availability (Tables 7 and 8). Hence more ewes/ha can be carried and higher gross margins obtained. More ewes/ha can be run for the store lamb enterprise than for the yearling enterprise, as lambs are sold at 4 months of age and grazing pressure over winter is reduced. Lower grazing pressure at the end of the growing season, also reduced the risk of pastures falling below the target 800 kg DM/ha (dead) in summer and early autumn. This is demonstrated for the yearling enterprise in Table 7, where the dark shaded or dotted cells indicate the "pasture cover" rule has been exceeded.

Table 7. Effect of lambing and stocking rate combinations on average gross margin ($/ha) and risk (sustainable stocking rate criteria), for a FINE Merino yearling enterprise at Mortlake. Average 5 year prices used. Pale shaded cells indicate combinations where maintenance supplementary feeding rule cannot be met. Dotted cells indicate where ground cover rule cannot be met. Dark shaded cells indicate combinations where both rules cannot be met.

Ewes/ha	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**
6	279	281	293	298	305	311	316
10	416	426	452	456	467	485	502
14	516	538	568	569	584	611	647
15	540	564	597	596	616	643	680
16	565	588	619	619	638	668	708
17	586	608	640	638	661	690	734
18	604	627	658	658	678	710	754

Table 8. Effect of lambing and stocking rate combinations on average gross margin ($/ha) and risk (sustainable stocking rate criteria), for a FINE Merino ewes/1st cross store lamb enterprise at Mortlake. Average 5 year prices used. Pale shaded cells indicate combinations where maintenance supplementary feeding rule cannot be met.

Ewes/ha	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**
6	235	276	323	344	361	357	331
10	363	436	523	569	600	592	544
14	456	563	692	766	812	796	724
17	506	628	784	885	947	928	836
18	518	644	809	920	986	967	873
19	529	657	835	954	1025	1008	905
20	540	670	856	984	1062	1042	937

The optimum time of lambing for each enterprise and locality could be further refined when the interactions between stocking rate and risk were considered. The broad guidelines for the optimum time of lambing is summarised diagrammatically in Figure 10.

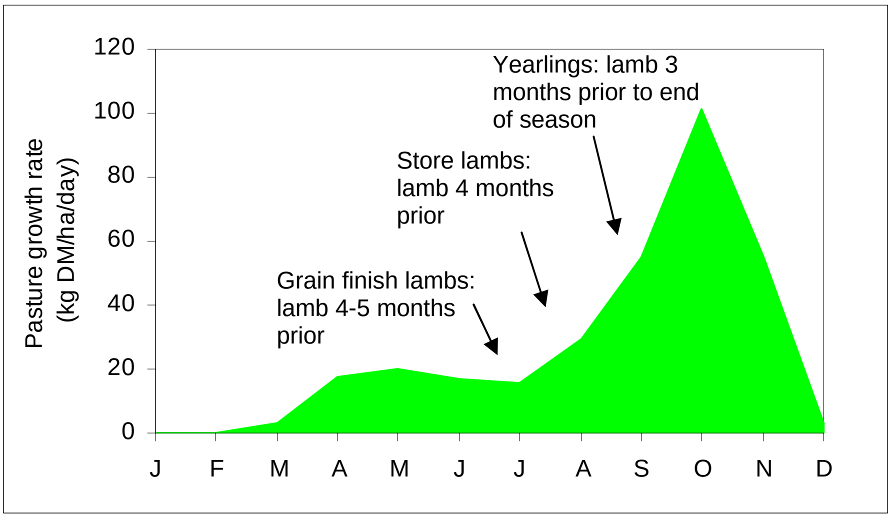


Figure 10. Guidelines for the optimum time of lambing can be related to the length of the growing season for a given pasture and environment.

(IV) GENOTYPE

The genotypes (average live weight, wool cut per head, fibre diameter) for each breed used for the main simulations were based on "average" sheep from Lambplan and Merino data bases (A. Ball pers. com. 2004). Given the wide genetic variation that exists within breed and between breeds (Fogarty *et al.*, 2005), the impact of using "superior" animals on gross margins was also investigated.

FIBRE DIAMETER AND FLEECE WEIGHT

When Merino ewes with a different "average" genotype were stocked at their optimum rate (using both economic and sustainability criteria), the amount of wool and meat produced per ha were similar (Table 9). However, when premiums were paid for the finer Merino wools, such as during 1999 -2003 (i.e. average 5 year price scenario) then the enterprises with the SUPER-FINE and FINE ewe genotypes had higher gross margins than the MEDIUM ewe enterprises (Table 9). Without price premiums, then there would be little difference in gross margins for the 3 genotypes. (The impact of changing commodity prices will be discussed in a later section). The wool cut per head of the "average" sheep was around 8.2% of their live weight (when in average condition). If more productive sheep are run, for example, ewes capable of producing a wool cut around 10% of their live weight (but with similar live weight and fibre diameter to "average" sheep), then the wool production per ha and gross margins will increase accordingly (Table 9). In this simulation, a 22 % increase in wool cut per head and per ha resulted in around a 19% increase in gross margin. If selection for higher fleece weight is accompanied by increased ewe live weight, the number of ewes run per ha will decrease.

Table 9. Effect of fibre diameter and fleece weight on the profitability of a Merino yearling enterprise, lambing in October, at Rutherglen.

Genotype	Stocking rate (ewes/ha)	Ewe live weight (kg) (in average condition)	Ewe fibre diameter (µm)	Ewe greasy wool cut (kg/head)	**Gross Margin[A] ($/ha)**	Wool produced (kg/ha)	Meat produced (kg/ha)
SUPER-FINE	9.5	45	17.5	3.6	**569**	38	334
FINE	8.5	50	19	4.1	**398**	38	333
MEDIUM	8.0	55	21	4.5	**311**	39	344
Superior genetics FINE plus (22% more wool)	8.5	50	19	5.0	**474**	47	331

[A] 5 year average (1999-2003) prices used

EWE LIVEWEIGHT / FRAME SIZE

Increasing the frame size (live weight) of the ewe, (but maintaining similar conception rates), will result in higher lamb birth weights and growth rates (Table 10). Hence it is a variable in which producers, who are focused on meat production, are interested. However, if ewe live weight is increased, the number of ewes/ha that can be carried has to be reduced, if grazing pressure is to be kept constant. Increasing ewe frame size may not necessarily result in an increase in meat/ha or gross margins, particularly if fibre diameter also increases (Table 10). The exceptions would be if the larger ewes also had greater feed conversion efficiency or greater fertility.

Table 10. Effect of ewe frame size on the profitability of a 1st cross store lamb enterprise, lambing in August, at Rutherglen.

Genotype	Stock rate[A] (ewe/ha)	Ewe live weight (kg) (in average condition)	Ewe fibre diameter (µm)	Ewe greasy wool cut (kg/head)	**Gross Margin[B] ($/ha)**	Average lamb growth rate (g/day)	Lamb sale weight (kg)	Meat (kg/ha)
FINE	10.5	50	19	4.1	**584**	245	39	489
MEDIUM	9.7	55	21	4.5	**506**	258	41	480
FINE – heavier ewe	9.7	55	19	4.5	**587**	258	41	480

[A] Stocking rate was adjusted for each genotype to achieve same winter grazing pressure (17.1 DSE/ha at 1 July) and meet risk criteria
[B] 5 year average (1999-2003) prices used in this simulation

(V) NUMBER OF LAMBS WEANED PER EWE (WEANING %)

The effect of increasing the fertility of the Merino ewe on gross margin was investigated for a first- cross store lamb enterprise at Mortlake (Figure 10). In this example, it was assumed that the increase in fertility was the effect of genotype, and not due to options with additional costs to the enterprise (eg. feeding ewes more supplements prior to joining). The costs of any additional supplements required by the ewes, during pregnancy or lactation, have been included in the simulation.

Gross margin increased as weaning percentage increased, for all 4 stocking rates tested (Figure 11). For every 10% increase in weaning %, the gross margin increased by around 8 - 10% for the 4 stocking rates, using the 5 year average price scenario. This equated to an additional $24, $50, $61or $74 per ha for the 5, 10, 15 or 20 ewes/ha stocking rates, respectively. On a gross margin per ewe basis, a 10% increase in weaning equated to an additional benefit of around $4.00 -$5.00/ewe.

Increasing the stocking rate from 5 to 10 ewes/ha or from 10 to 20 ewes/ha had a much greater impact on gross margin than increasing weaning percentage. Doubling the stocking rate effectively doubled the gross margin (Figure 11).

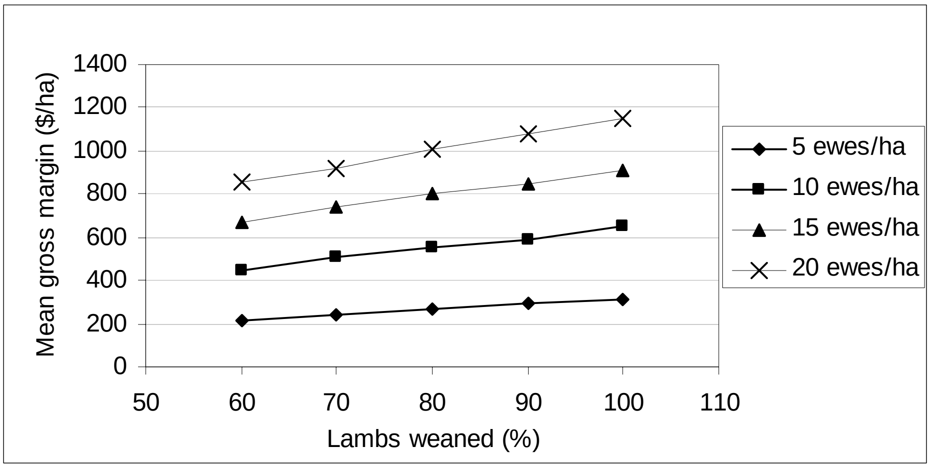


Figure 11. Effect of weaning % on Gross Margin for a 1st X store lamb enterprise, with FINE Merino ewes lambing in September, at Mortlake, at 4 stocking rates.

Increasing the number of lambs weaned per ewe also increased the grazing pressure, in dry sheep equivalent (DSE) terms. At Mortlake, 20 ewes/ha was the maximum number of ewes that could be run for this enterprise, when the “pasture mass” and the “supplementary feeding” rules were applied. When the standard conception rates were used (Table 3), stocking ewes at 20/ha, resulted in a weaning rate of 85%. Increasing the weaning % above this level by increasing the proportion of twins conceived/born (Figure 11), meant that the “supplementary feeding” rule could not be met. The paddock would be overstocked and the ewes/ha would need to decrease to compensate. The number of ewes per ha that could be run for the different weaning percentages (assuming the grazing pressure measured on the 1st July is kept constant and the 2 stocking rate rules are met) is shown in Table 11.

For the fully-stocked farm scenario, it was more profitable to wean more lambs per ewe and run slightly less ewes/ha, if there were no additional costs associated with the increase in fertility. For the under-stocked farm scenario (10 ewes/ha), there would be greater benefit from increasing the stocking rate first rather than focusing on increasing weaning %.

Table 11. Effect of weaning percentage on the number of ewes/ha that could be carried[A] and the associated gross margins, for a 1st cross store lamb (FINE ewes) enterprise, lambing in September, at Mortlake.

Weaning %	Stocking rate (ewes/ha)	Winter DSE/ha[B] (1 July)	Gross margin ($/ha)
50	21.0	28	814
60	20.5	28	868
70	20.0	28	920
80	20.0	28	1006
90	19.5	28	1059
100	19.0	28	1105

[A] Stocking rate was adjusted to maintain similar winter grazing pressure and meet the sustainable stocking rate rules. Stocking rate was rounded off to nearest 0.5 ewe/ha.
[B] DSE/ha = dry sheep equivalents. A 50 kg dry sheep in average condition is equivalent to 1 DSE in *GrassGro.*

Simulations were also run to investigate the effect of increasing the fertility of first-cross ewes on gross margin (Figure 12). Similarly to the results for the Merino ewes, for every 10% increase in weaning %, the gross margin increased by around 8 -10%, using the 5 year average price scenario. This equated to an additional $40 or $73 per ha for the 7 and 14.5 ewes/ha stocking rates, respectively. On a gross margin per ewe basis, a 10% increase in weaning equated to an additional benefit of around $5.00 -$6.00/ewe.

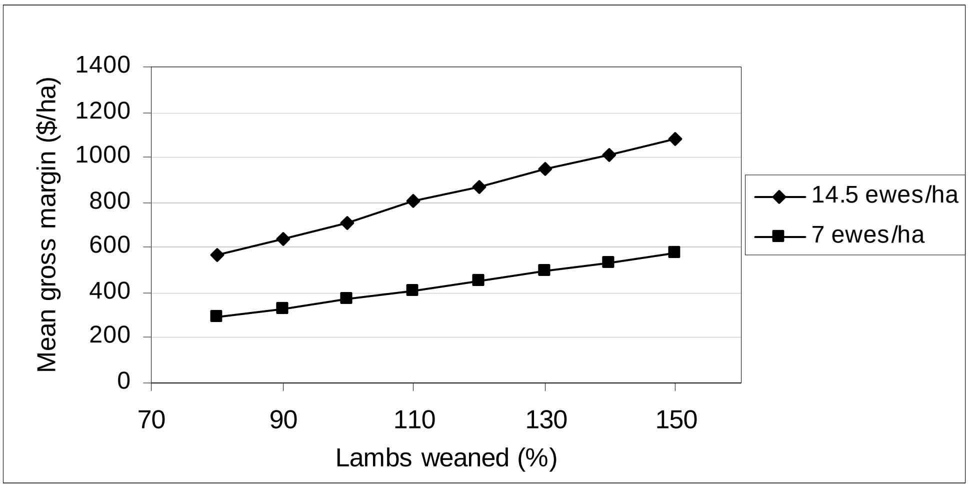


Figure 12. Effect of weaning % on gross margin for a 2nd-cross trade lamb enterprise, with 1st -cross ewes lambing in August, at Mortlake, at 2 stocking rates.

Weaning percentage was more important for the profitability of the 2nd cross lamb enterprise compared to the 1st cross lamb enterprise. For the 1st cross lamb enterprise, stocked at 20 ewes/ha (optimum using pasture mass and supplementary feeding rules), and using the standard conception rates (Table 3) the weaning rate was 85% and the gross margin $1042/ha. For the 2nd cross lamb enterprise, stocked at 14.5 ewes/ha, and using the standard conception rates, the weaning rate was 120% and the gross margin was $870/ha. Figure 13 shows the effect of varying weaning percentage, while keeping the number of ewes/ha constant, for the 1st cross store lamb (FINE Merino ewes) and the 2nd cross trade lamb (first-cross ewes)enterprises. For the 2nd cross lamb enterprise to generate a similar gross margin to the 1st cross lamb enterprise, a weaning rate of 145% was required (Figure 13).

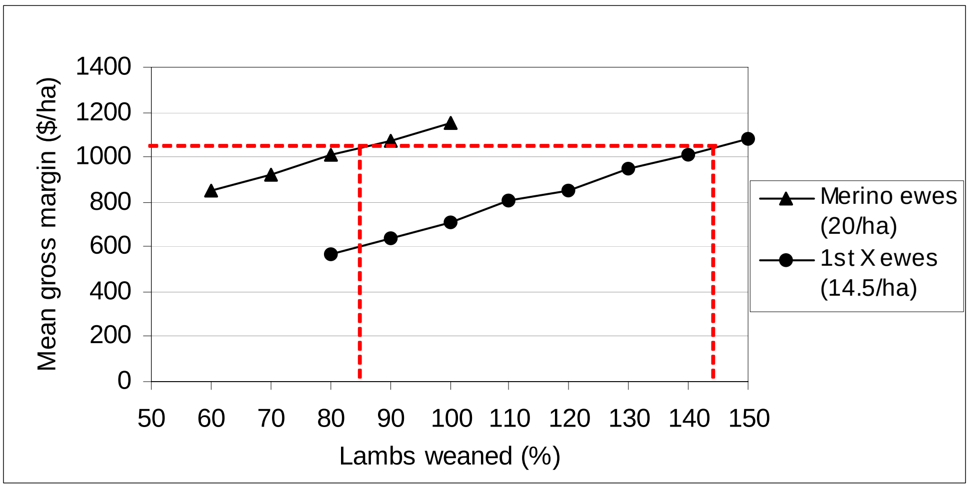


Figure 13. Comparison of the effect of weaning % on gross margin for a 1st -cross store lamb (FINE ewes) and a 2nd-cross trade lamb enterprise, at Mortlake. (1999-2003 average prices).

(VI) CARCASE WEIGHT & KG MEAT/HA

The effect of producing heavier lambs on gross margin, was investigated for a 1st cross lamb enterprise at Mortlake (Table 12). In this example, rather than feed lambs grain to increase sale weight, the option of lambing earlier (in June) and keeping lambs for a longer time (until the end of December or until they reached 44 kg live weight) was explored. This option was compared with the store lamb option which lambed in September and sold lambs at 4 months of age (end of December), at a stocking rate of 20 ewes/ha. The upper sustainable stocking rate for the earlier lambing option (based on the pasture mass and supplementary feeding rules) was 12 ewes/ha. Lambing earlier meant lambs were sold at an older age and higher average live weight. However, as 40% less ewes/ha could be carried this resulted in around 30% less live weight/ha and 40% less wool/ha produced, and a reduction in meat and wool income per ha.

A price grid was used in the simulation, which allowed lambs of different sale weights over the 37 years to receive the appropriate sale price. Although the 44 kg lambs would have attracted a price premium of 20c/kg (live weight) on average, compared with the 38 kg lambs, this was not high enough to compensate for the lower meat and wool production per ha (Table 12).

Table 12. Effect of time of lambing and lamb sale age on the number of ewes/ha that can be carried, and the associated gross margins, for a 1st cross lamb (FINE ewes) enterprise at Mortlake.

System	Stocking rate[A] (ewes/ha)	Gross margin ($/ha)	Average lamb live weight when sold (kg)	Wool income ($/ha)	Meat income ($/ha)	Maintenance supplement cost ($/ha)
Lamb June/sell end Dec	12	704	44	323	797	71
Lamb Sept/sell end Dec	20	1042	38	593	1086	101

[A] Stocking rate adjusted using pasture mass and supplementary feeding rules.

Following on from the above example, the effect of keeping lamb sale date constant (lambs sold by end December or when reach 44 kg live weight) but varying time of lambing from April through to October was investigated. Stocking rate was adjusted using the pasture mass and supplementary feeding rules as above. Lambing in September, running more ewes/ha and selling lambs at a younger age and lighter live weight was more profitable than all earlier times of lambing (Figure 14). Although lambing in October allowed more ewes/ha to be run, the meat income was less than from lambing in September due to lower average lamb sale weights (i.e. 30 kg).

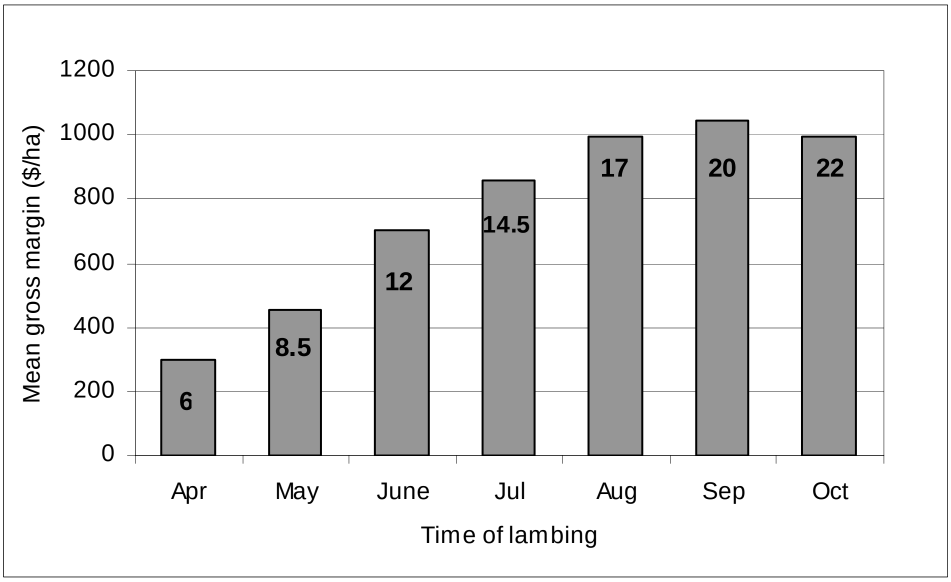


Figure 14. Effect of time of lambing and lamb sale age (lambs sold by end December or when reach 44 kg live weight) on the number of ewes/ha that can be carried (figures in bold), and the associated gross margins, for a 1st cross lamb (FINE ewes) enterprise at Mortlake.

(VII) TIME OF SALE - SEASONAL VARIATION IN MEAT PRICE

Wool can be stored in order to manage price risk but producers selling lambs have less flexibility with the timing of lamb sales. This exposes them to the risk of seasonal price fluctuations, which could affect gross margins. So far in the analysis average yearly meat prices for each weight category have been used for simplicity. The 5 year average, monthly variations in 1st cross lamb prices are shown in Figure 15. Prices vary from $0.50 -1.00 /kg carcase weight, depending on the carcase size category, and there is a tendency for prices to be slightly higher from January to June. Since the times of lambing investigated ranged from April through to October, store lambs were sold from August to January, finished lambs sold from August to March, and yearlings sold from March to September. So there is potential for large differences in the price of lambs based on time of sale.

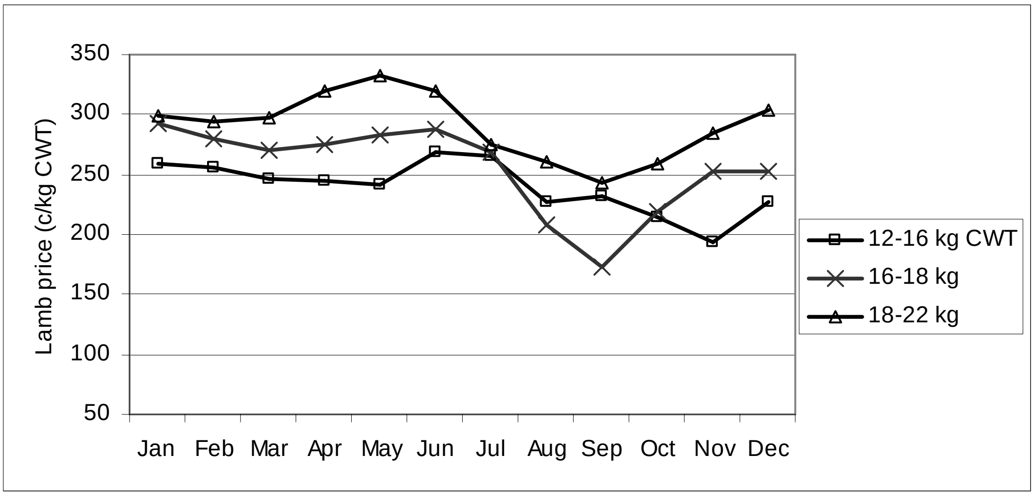


Figure 15. Effect of month of sale on price received for 1st cross lambs (5year average: July 1999- June 2004) (National Livestock Reporting Service, 2004).

The impact of seasonal price variation was investigated for a 1st cross store lamb (FINE ewes) enterprise at Mortlake, stocked at 10 ewes/ha (Figure 16). Using the actual monthly prices reduced gross margins for the April to July lambing times (selling lambs from August to November), but had little impact for the later lambing/selling times. In this case, using the monthly prices did not affect the optimum time of lambing previously determined. Lambing in October or later, meant an escalation in maintenance feeding costs for the lambs and ewes and less meat produced per ha. The price premiums which are evident in January and June are not high enough to compensate for this.

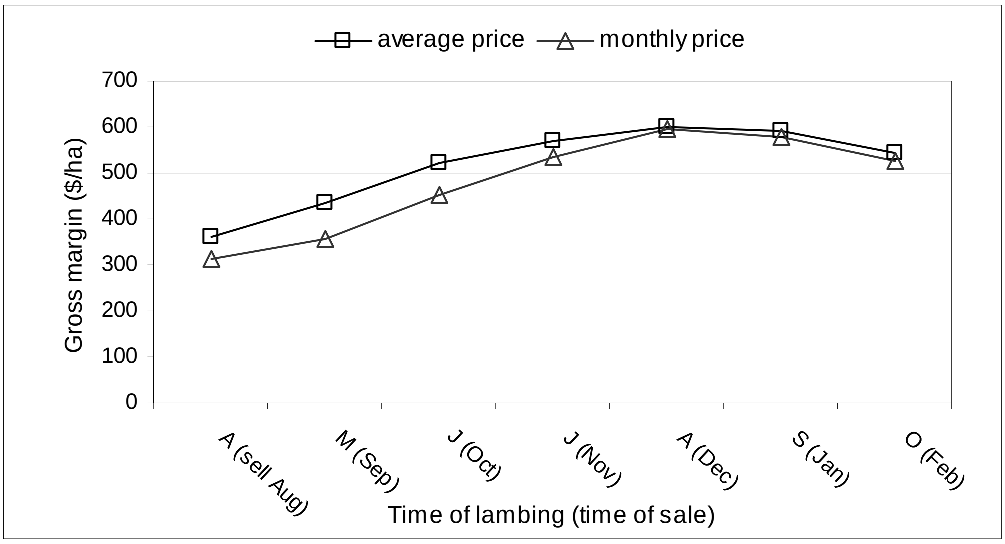


Figure 16. A comparison of using actual monthly lamb sale price versus a yearly average on the gross margins, for a 1st cross lamb enterprise at Mortlake, stocked at 10 ewes/ha.

The effect of lambing in spring, but holding lambs over to sell the following winter, on gross margin, was also investigated for a 1st cross lamb enterprise. This is a tactic that some lamb producers undertake in an attempt to sell lambs when prices are higher. Table 13 compares Merino ewes lambing in September, selling 1st cross store lambs at the end of December, and run at the optimum stocking rate (based on the pasture mass and feeding rules) with selling lambs the following June. While delaying selling lambs increased the average sale weight and sale price (using actual average monthly prices from 1999-2004), the additional grazing pressure over summer and autumn reduced the number of ewes that could be carried. The result was less meat and wool income per ha and a lower gross margin.

Table 13. Effect of time of sale/lamb sale age on the number of ewes/ha that can be carried, and the associated gross margins, for a 1st cross lamb (FINE ewes) enterprise at Mortlake.

System	Stocking rate[A] (ewes/ha)	Gross margin[B] ($/ha)	Average lamb live weight when sold (kg)	Wool income ($/ha)	Meat income ($/ha)	Maintenance supplement cost ($/ha)
Lamb Sept/sell mid June	14.5	782	42	431	856	105
Lamb Sept/sell end Dec	20	1032	38	593	1075	100

[A] Stocking rate adjusted using pasture mass and supplementary feeding rules.
[B] Actual monthly price used for time of sale

ENTERPRISE COMPARISONS UNDER "OPTIMUM MANAGEMENT" CONDITIONS.

In this study, "optimum management" related to the time of lambing and stocking rate selected for each enterprise. The optimum time of lambing was selected and the highest sustainable stocking rate was selected for each of the enterprises on the basis of whether it met the 2 key risk criteria as described above (i.e. the pasture mass and supplementary feed rules). The stocking rates selected and the associated financial and production data are summarised in Appendices 6.1, 6.2, 6.3 and 6.4, for each location.

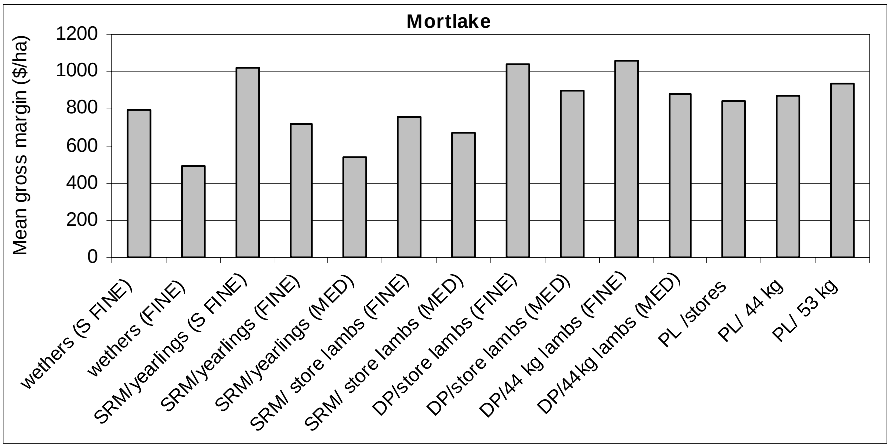
A comparison of gross margin (using 5 year average prices) for each enterprise when run under "optimum management" is shown for Mortlake, Rutherglen, Naracoorte and Cowra in Figure 17. The relative profitability of each enterprise at the 4 locations was similar. The dual purpose (1st cross lambs) enterprise was most profitable, followed by prime lambs (2nd cross lambs), with the self-replacing flocks (lambs and yearlings) least profitable, the exception being the SUPER-FINE yearling enterprise. FINE wethers were less profitable than ewes, but the SUPER-FINE wethers compared favourably with the FINE Merino lamb enterprise. The effect of micron premiums was apparent for the Merino enterprises when the 5 year average prices were used.

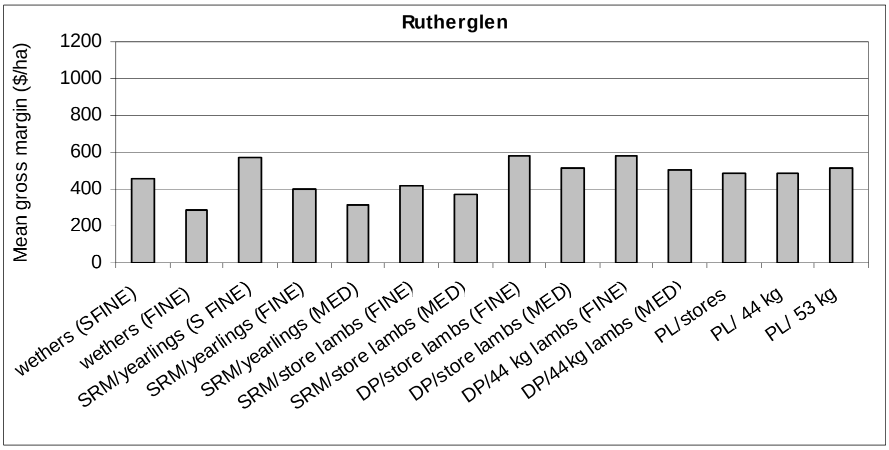
There was no advantage in keeping Merino lambs to shear and sell as yearlings. Slightly more wool/ha was produced in the yearling system, and similar meat/ha was produced. A 30% price discount for yearling meat, compared with lamb, reduced meat income. If Merino yearlings received the same meat price (c/kg) as Merino lambs, then this enterprise would be marginally more profitable than the Merino lamb enterprise (Appendices 6.1, 6.2, 6.3 and 6.4).

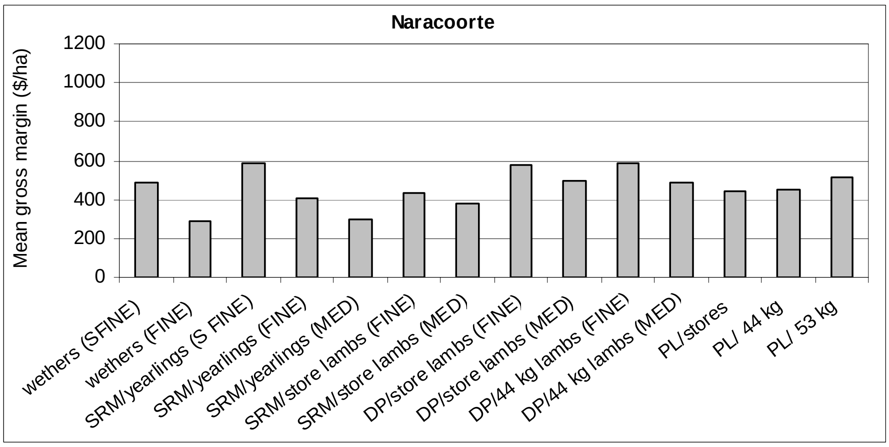
The magnitude of the gross margins at the different locations was largely a function of the different stocking rates that could be carried. The Mortlake perennial pasture had the highest carrying capacity, and the Cowra annual pasture had the lowest.

Finishing first cross lambs to 44 kg live weight was not as profitable as producing stores, and this was most obvious at Cowra. The length of the growing season and the size of the spring peak in pasture supply also had a bearing on the relative value of finishing lambs. Finishing 1st cross lambs (MEDIUM ewes) to a live weight of 44 kg (compared with lambing later, running more ewes and turning off store lambs), returned, on average, a loss of \$7/ha at Mortlake, \$6/ha at Rutherglen, \$7/ha at Naracoorte, and a loss of \$77/ha at Cowra. At the 4 locations, the average sale weight of 1st cross store lambs ranged from 39 kg (Cowra) to 41kg (Rutherglen). Feeding grain reduced production risk by adding on average, an additional 4-6 kg live weight to the lambs. However, the small decrease in ewes/ha, meant wool production per ha was reduced at the expense of a small or no net gain in meat production per ha.

Finishing 2nd cross, prime lambs to a live weight of 44 kg (compared with turning off stores), increased gross margin by \$26/ha at Mortlake, \$6/ha at Rutherglen, \$3/ha at Naracoorte, and a loss of \$20/ha at Cowra, for the grain price used in this analysis. Finishing 2nd cross lambs to a heavier live weight of 53 kg (compared with 44kg), increased gross margin by \$61/ha at Mortlake, \$28/ha at Rutherglen, \$61/ha at Naracoorte, and \$65/ha at Cowra.







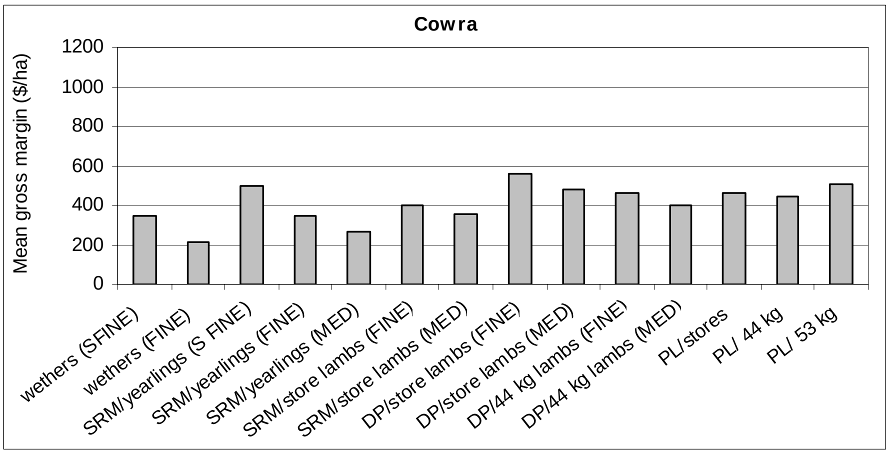


Figure 17 . Comparison of gross margins for a range of sheep enterprises at Mortlake, Rutherglen, Naracoorte and Cowra (5 year average prices used). SRM =self replacing merino flock. DP = dual purpose flock, merino ewes joined to terminal sire. PL = prime lamb flock, 1st X ewe joined to terminal sire.

The dual purpose and prime lamb enterprises produced more meat per ha than the self-replacing Merino enterprises and correspondingly received more meat income/ha (Table 14, Figure 18). This is because more joined ewes could be run per ha, as all ewe replacements were purchased, and not bred. The FINE and MEDIUM dual purpose enterprises also had a higher wool income than the prime lamb enterprises, due to the higher value of the wool.

Table 14. Comparison of meat (live weight) and wool produced per ha for the sheep enterprises simulated at Rutherglen.

Enterprise	Clean wool (kg/ha)	Live weight (kg/ha)
Wethers (FINE)	42	158
SRM/ yearlings (FINE)	38	333
SRM/ store lambs (FINE)	32	325
DP/ store lambs (FINE)	33	489
DP/44 kg lambs (FINE)	30	503
PL/store lambs	26	537
PL/44 kg lambs	24	543
PL/53 kg lambs	21	552

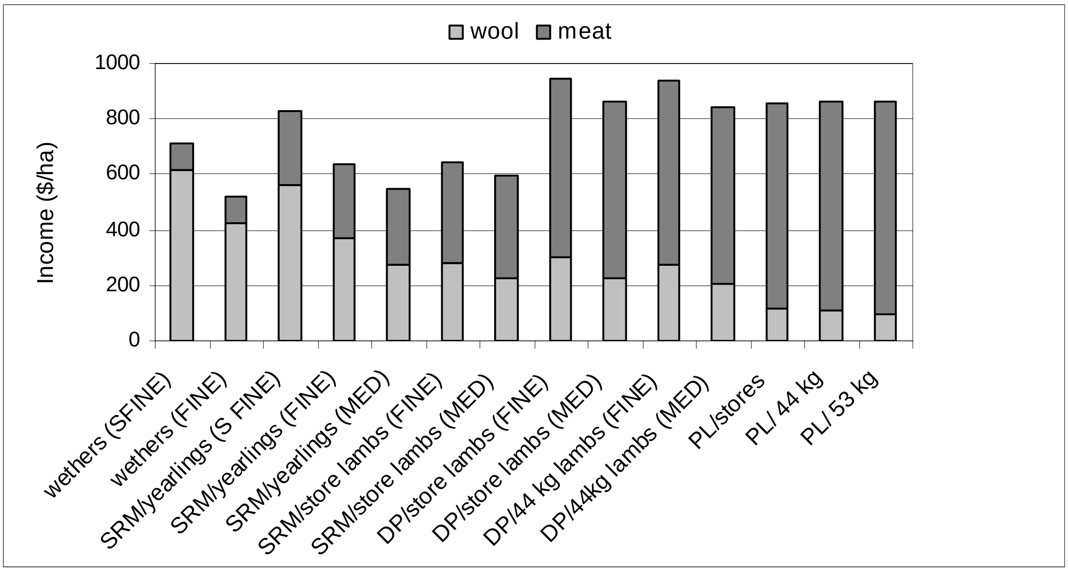


Figure 18. Proportion of income derived from wool or meat for a range of sheep enterprises at Rutherglen (5 year average prices used). SRM =self replacing merino flock. DP = dual purpose flock, merino ewes joined to terminal sire. PL = prime lamb flock, 1st X ewe joined to terminal sire.

The economic risk associated with each enterprise can be represented by the variation in gross margins over the 37 years the simulations were run. Although FINE wethers were less profitable than ewe enterprises, there was less variation in gross margins (Figure 19). The ewe enterprises with the SUPER-FINE and FINE wool, had less range in gross margins than those with the MEDIUM genotype. Feeding lambs, when required, to achieve a target live weight of 44 kg or 53 kg, reduced economic risk. The trends were similar at each location.

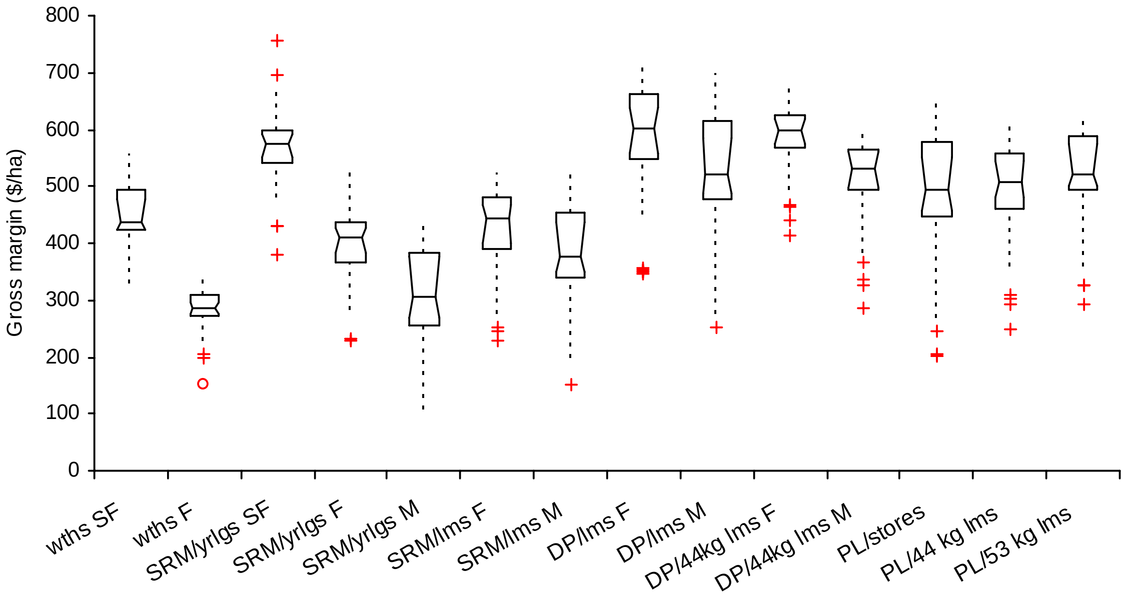


Figure 19. Range in enterprise gross margins from 1966 -2001, at Rutherglen (5 year average prices). The box plots show the spread/scatter in gross margins over the years. The notched box shows the median (middle line), the upper quartile (top of box) and the lower quartile (the bottom of box). The dotted-line connects the nearest values within 1.5 times the inter-quartile ranges of the lower and upper quartile. Exceptional values (severe droughts) are shown by the cross and open circle.

SENSITIVITY OF GROSS MARGINS TO CHANGES IN COMMODITY PRICES

Over 2003-04 the micron premium fell, while meat prices remained relatively high (Table 5). The impact of using the past year's (July 2003-June 2004) prices on the profitability of the sheep enterprises at Rutherglen and Mortlake is shown in Figure 20. The relative ranking of the enterprises on the basis of gross margin was similar to that pattern described for the 5 year average price scenario, for each location. The main difference was that the advantage of the SUPER-FINE and FINE ewe genotypes disappeared, with the demise of the micron premiums. The average gross margins for the dual purpose and prime lamb enterprises increased with the increase in meat income.

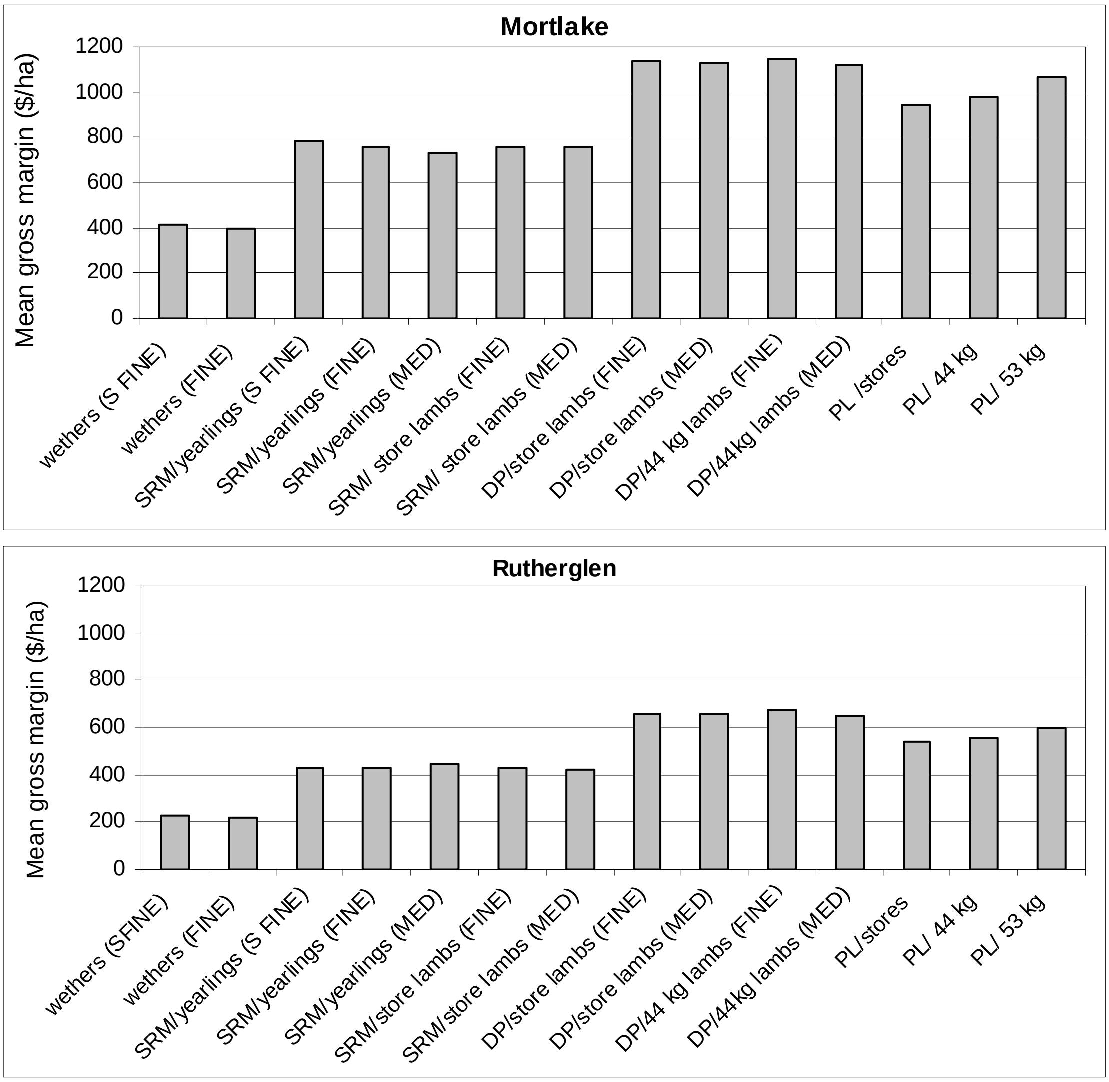


Figure 20. Comparison of gross margins for a range of sheep enterprises at Mortlake and Rutherglen (2003-04 average prices used). SRM =self replacing merino flock. DP = dual purpose flock, merino ewes joined to terminal sire. PL = prime lamb flock, 1st X ewe joined to terminal sire.

SENSITIVITY OF GROSS MARGIN TO WEANING % WITH 2003-04 AVERAGE PRICES

The effect of weaning % on the relative profitability of a 1st cross lamb and a 2nd cross lamb enterprise was demonstrated in Figure 13, using the 5 year average prices for meat and wool. The relative profitability of the 2 enterprise was also compared using the 2003-04 average prices, for a range of weaning percentages (Figure 21).

Using the 2003-04 average prices, the 1st cross lamb enterprise, stocked at 20 ewes/ha (optimum using pasture mass and supplementary feeding rules), and using the standard conception rates (Table 3) the weaning rate was 85% and the gross margin $1139/ha. For the 2nd cross lamb enterprise, stocked at 14.5 ewes/ha, and using the standard conception rates, the weaning rate was 120% and the gross margin was $981/ha. Figure 21 shows the effect of varying weaning percentage, while keeping the number of ewes/ha constant, for the 1st cross store lamb (FINE Merino ewes) and the 2nd cross trade lamb (first-cross ewes) enterprises. For the 2nd cross lamb enterprise to generate a similar gross margin to the 1st cross lamb enterprise, a weaning rate of 135% was required (Figure 21). This was a slightly lower break-even weaning rate (145%) than that generated using the 1999-2003 average prices (Figure 13). These results indicate that for a 2nd cross lamb enterprise to be as profitable as a 1st cross store lamb enterprise, a weaning rate of 135 -145% needs to be achieved, based on the 2 commodity price scenarios investigated.

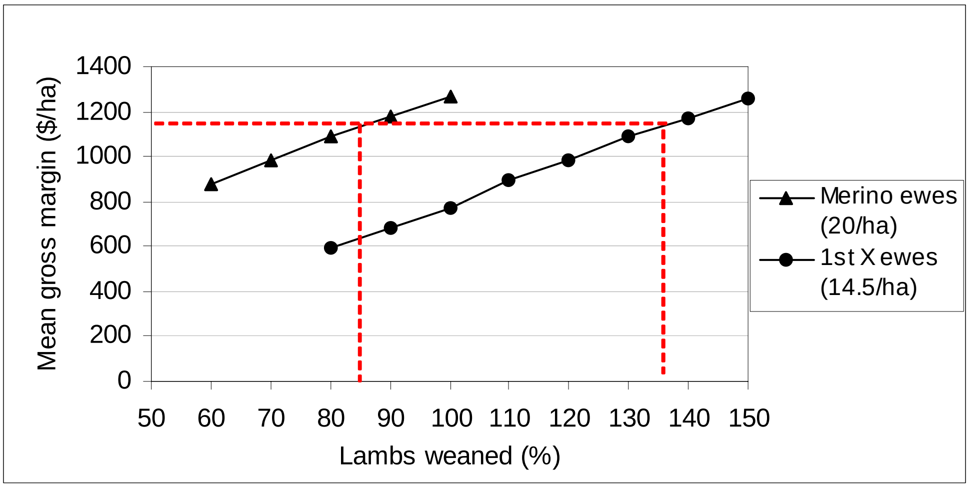


Figure 21. Comparison of the effect of weaning % on gross margin for a 1st -cross store lamb (FINE ewes) and a 2nd-cross trade lamb enterprise, at Mortlake. (2003-04 average prices).

SENSITIVITY OF GROSS MARGIN TO EWE PURCHASE PRICE

The purchase price of replacement Merino or crossbred ewes was an important variable affecting the relative profitability of the 1st and 2nd cross lamb enterprises. Using the 2003-04 average prices for wool and meat, but varying ewe price, Figure 22 shows that if ewe purchase price was similar for both enterprises, gross margins would also be similar. However, average prices for 2003-04 were around $80 for Merino ewes and $150 for 1st cross ewes.

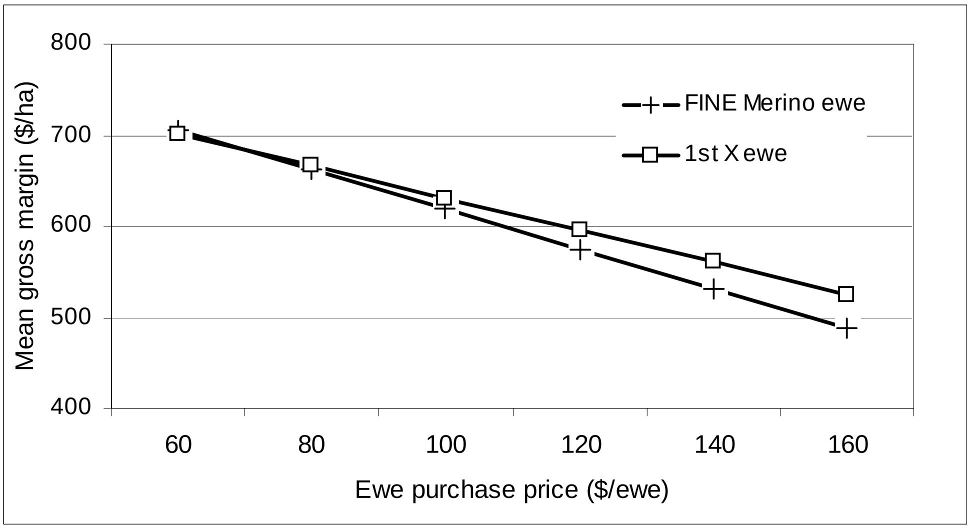


Figure 22. Effect of ewe purchase price on gross margin, for a 1st -cross store lamb (FINE Merino ewes) enterprise lambing in August and stocked at 10.5 ewes/ha, and a 2nd-cross store lamb (1st cross ewes) enterprise lambing in August and stocked at 8.5 ewes/ha, at Rutherglen. (2003-04 average prices). (The stocking rate was based on the pasture mass and supplementary feed rules).

ENTERPRISE CHANGE

The price paid for ewes has a large impact on gross margin and risk associated with changing enterprises (Table 15). The economics of changing from a self-replacing Merino flock to a 1st cross ewe flock was investigated using the 2003-04 commodity prices and a range of 1st cross ewe purchase prices, at Rutherglen. The sale price of Merino ewes (FINE) was kept at $80/head for each 1st cross ewe price scenario. Although the gross margin for the 1st cross ewe enterprise was higher than for the self-replacing Merino enterprise at the range of ewe prices investigated (Table 15), paying more than $150 for a 1st cross ewe would be risky, due to the long the time taken to break-even with the "do-nothing" scenario.

Table 15. Effect of 1st cross ewe purchase price (in a 2nd cross store lamb enterprise) on gross margin and the number of years to break-even (cumulative cash flow) compared with running a self-replacing Merino flock (FINE ewes), producing yearlings, at Rutherglen. (1st cross ewes lamb in August and stocked at 8.5/ha, and Merino ewes lamb in October stocked and at 8.5/ha).

Option	Ewe price ($/head)	Mean gross margin[A] ($/ha)	Time to break even with Merino enterprise (years)
"Do nothing" -Keep self-replacing Merino flock (yearlings)	-	429	-
Sell Merino ewes[B] & Purchase 1st cross ewes	100	631	1
	130	578	2
	150	542	5
	180	490	13
	200	454	40

[A] 2003-04 prices for wool and meat used.
[B] Merino ewes sold for $80/head

DISCUSSION

ENTERPRISE COMPARISONS

The dual purpose enterprise using Merino ewes was consistently the most profitable enterprise, followed by prime lambs, then the self-replacing Merino enterprises, with the Merino wethers the least profitable enterprise, at all 4 localities and at 2 commodity price scenarios. In general, the self-replacing Merino enterprises were slightly less profitable than the prime lamb enterprises. However, when a large price premium existed for super-fine wool (ie. 5 year average price, 1999-2003), the super-fine Merino yearling enterprise was as profitable as the dual purpose enterprise.

In this study, gross margins extracted from *GrassGro* were used as an indicator of profitability of an enterprise. This is of course a simplistic view as differences in labour costs to manage the different enterprises are not considered. However, benchmarking studies indicate that there is a strong correlation between income/ha or gross margin/ha and ultimate net farm income/ha or profit (Webb Ware 2002).

The results for enterprise gross margins from this study agree with data from farm financial benchmarking studies (Holmes, Sackett and Associates,2002; Beattie, 2004). Data from Holmes, Sackett and Associates (2002) highlighted the greater profitability of dual purpose flocks, followed by prime lamb flocks and then wool flocks. Based on their data from 1999 to 2002, dual purpose flocks (Merino ewe joined to terminal sire) stood out as an enterprise having a high level of profit and acceptable volatility. An analysis of 55 farms in south-western Victoria by Beattie (2002, 2004) showed similar trends. For 2001-02, average gross margins for prime lamb flocks were $421/ha, beef herds were $335/ha, while wool flocks had the lowest gross margins of $284/ha. In this analysis prime lambs included 1st and 2nd cross lamb enterprises.

The self-replacing Merino enterprise turning-off store Merino lambs was slightly more profitable than that producing yearlings. The lamb system ran more joined ewes/ha and produced a similar amount of meat per ha but slightly less wool per ha than the yearling system. The meat income was higher for the lamb system as the yearlings received a price discount of around 30%. If there was no price discount for yearlings (2–tooth), then this enterprise would have a marginally higher gross margin than the lamb enterprise. These results differ to those of McEachern (2004), who found that gross margins from a Merino yearling enterprise were higher than from a Merino lamb enterprise. In that study, enterprises were compared at the same time of lambing (September) and the same winter stocking rate of 15 DSE/ha.

The gross margins and relative risk of each enterprise simulated was only compared after variables such as time of lambing and stocking rate were optimised. This was done in order to remove the management variability factor which is so evident in farms involved in benchmarking. An example of this farm variation is shown in Table 14, where the profitability of a range of grazing enterprise, is expressed as profit $/DSE (less interest). As discussed previously, this data set from Holmes, Sackett and Associates (2002) highlights the good performance of dual purpose flocks. It also highlights that for any enterprise there is an enormous range between the bottom 20% of producers and the top 20% of producers within the one year. Expressing profit on a per DSE basis is done to allow a fairer comparison of enterprises which are run in different locations.

Table 14 . Differences in profitability ($/DSE) for four different grazing enterprises for 2001-02 (Holmes, Sackett and Associates 2002).

	Bottom 20%	Average	Top 20%
Wool	$ -2.43	$ 9.38	$ 19.10
Dual purpose sheep	$ 1.13	$ 17.93	$ 34.84
Prime lamb	$ 3.10	$ 11.91	$ 20.21
Beef	$ 1.50	$ 12.34	$ 22.92

Both the simulation and the financial benchmarking data (Table 14) highlight that there is considerable scope for producers with wool flocks, dual purpose flocks or prime lamb flocks to be more profitable without changing enterprise, but simply do a better job of what they are currently doing. The productivity of the farm and efficiency of the operator can make them highly profitable regardless of enterprise or enterprise combinations (Beattie 2002). A recent lamb producer survey (ABARE, 2004) indicates that over the past 8 years the number of crossbred ewes to be joined for 2nd cross lamb production had doubled, even though the benchmarking data shows the dual purpose flocks to be more profitable on a DSE basis, on average.

Producers respond to price signals, as indicated by the trend to production of finer wools (Beattie 2004) and heavier carcase weight lambs (Barrett *et al*. 2003), and the increase in sheep meat production (ABARE 2004). However, price received for product is only one element of the profit equation. If costs increase or product/ha falls, then an increase in profit is not guaranteed. It is important for producers to understand the key factors which drive the profitability of their wool or sheep meat enterprise, so that they can make wise management decisions.

PROFIT/PRODUCTION DRIVERS IN WOOL AND MEAT ENTERPRISES

Meat and wool per ha - Stocking rate

Stocking rate was demonstrated to have a major impact on gross margins. This is because it had the biggest impact on the amount of meat (and wool) produced per ha, compared with other variables evaluated such as weaning percentage, carcase weight, and time of sale. For a given stocking rate, optimising the time of lambing reduced maintenance supplement costs and increased gross margins. However, the greatest advantage of getting time of lambing right is that it enabled stocking rate to be increased while minimising risks. The economic benefit was greater at higher stocking rates.

For a given enterprise, the optimum time of lambing was similar for a range of stocking rates. Sometimes further refinements could be made and lambing could occur at the later end of the optimum range, if the extra returns from each additional ewe run were justified. The optimum time of lambing was not sensitive to commodity or grain prices as the optimum time occurred where supplementary feed costs were the lowest and meat per ha the highest.

An analysis of a farm benchmarking data-base by Holmes, Sackett and Associates (2004), highlighted that for a prime lamb flock, gross margin ($/ha/100 mm rainfall) was highly correlated with kg lamb/ha/100 mm produced and numbers of lambs weaned /ha/100 mm. They indicated that there was no relationship between gross margin and weaning percentage, sale weight of lamb or price received (c/kg dressed weight basis). This analysis was conducted on specialist prime lamb enterprises for the 2001/02 year, and all data was adjusted to allow for the different rainfall zones where farms were located. Although lambs weaned/ha is a function of both stocking rate and weaning percentage, the authors argued that in their study, stocking rate was more important. The results of the simulations are generally consistent with this farm data.

Unlike the results from the analysis of the farm data (Holmes, Sackett and Associates 2004), the simulations showed that there was a linear relationship between weaning percentage and gross margin. When stocking rate (ewes/ha) was held constant, increasing weaning percentage increased grazing pressure (DSEs/ha). Increasing weaning percentage by 10% increased gross margin by approximately 10% for both the 1st and 2nd cross lamb enterprises. This was equivalent to an additional gross margin of $24-74/ha (depending on stocking rate) or $4-5/ewe for the 1st cross lamb enterprise and $5-6/ewe for the 2nd cross lamb enterprise.

In the simulations the costs of any additional supplements required by the ewes, during pregnancy or lactation, were included but any costs associated with obtaining the increase in fertility was not. So, if we assume half of this $4-5/ewe or $5-6/ewe gross margin benefit needs to be kept as profit, then there is $2.00-3.00 available per ewe to spend on increasing weaning rate by 10%. This could be spent on feeding ewes an extra 13-20 kg grain/ewe (i.e.wheat at $150/t) above the maintenance ratio, to increase live weight pre-joining by around 2-3 kg (assuming feed conversion ratio of 7:1) and increase ovulation rates. For every 1kg increase in Merino ewe live weight you can expect 1.5% extra lambs born (Hygate 2003). Therefore, increasing ewe live weight by 2-3 kg would result in an extra 3 to 4.5 more lambs born per 100 ewes. Clearly, this option of feeding extra grain to ewes would not be profitable as it is unlikely to lead to a 10% increase in weaning rate. Alternatively, the extra dollars could be spent reducing lamb mortalities, such as on shelter.

Increasing the stocking rate had a much greater impact on gross margin than increasing weaning percentage. For fully-stocked farms, it would be more profitable to wean more lambs per ewe and run slightly less ewes/ha, if there were no additional costs associated with the increase in fertility. For under-stocked farms, there would be greater benefit from increasing the stocking rate first rather than focusing on increasing weaning %. This of course involves a capital investment to purchase more ewes.

Weaning percentage was more important for the profitability of the 2nd cross lamb enterprise compared to the 1st cross lamb enterprise. For the 2nd cross lamb enterprise to break-even with the 1st cross lamb enterprise in terms of gross margin, the weaning percentage had to be around 60-70% higher.

Genotype and Breed

The importance of genotype of the sheep on production efficiency and gross margins was also demonstrated in this study. The benefit of super-fine and fine wool Merino genotypes was clear when the 5 year average prices were used, as there was a substantial micron premium. The results also highlighted that fibre diameter was important even for a dual purpose enterprise. Increasing ewe frame size could reduce gross margins if fibre diameter increased.

Increasing the fertility of the ewe (by changing genotype) also increased gross margins, but not to the same extent as optimising the stocking rate. Producers who are understocked would benefit more from increasing stocking rate than focusing on weaning percentage. For producers who are fully stocked, increasing weaning percentage would be beneficial, but the number of ewes/ha would have to be reduced.

The value of using superior genetics has also been shown in the Maternal Central Progeny Test (Cummins *et al*. 2002). In that study the choice of maternal sires had a major impact on the profitability of a specialist lamb production system, with differences in returns from lamb meat per ewe of up to $45, between sire groups (Cummins *et al*. 2002).Cummins *et al.* (2002) estimate that for a specialist lamb producer, with 2000 breeding ewes, the choice of sire could result in differences in gross income per year of $80,000. However, it is difficult to determine the full impact of this on farm profit, as the costs associated with the improved per head performances are not evaluated (i.e. do the better progeny cost more to run or are they simply converting pasture more efficiently ?). The potential value of these different breeds and genotypes could be explored through modelling.

Income versus costs

The GrassGro simulations suggested that stocking rate had to be pushed to very high levels before gross margins hit their peak and then declined. The additional income generated from the extra wool and meat produced per ha outweighed the extra costs of supplements. According to Webb Ware (2002) low gross income is a consistent feature of unprofitable farms, which is directly related to low production, inherently unprofitable enterprises or a combination of both (Webb Ware 2002). Farm costs are important on some farms, but usually of much lower priority than low production in terms of driving farm profitability (Webb Ware 2002). Producers who have adopted improved practices (improved pastures and stocking rate, appropriate time of lambing) have been able to demonstrate large increases in net farm income. Increases in gross margins were responsible rather than a reduction in costs (Lean et *al.* 1997).

CONCLUSIONS

The dual purpose enterprise using Merino ewes was consistently the most profitable enterprise, followed by prime lambs, then the self-replacing Merino enterprises, with the Merino wethers the least profitable enterprise, at all 4 localities and at 2 commodity price scenarios. In general, the self-replacing Merino enterprises were slightly less profitable than the prime lamb enterprises. However, when a large price premium existed for super-fine wool (ie. 5 year average price, 1999-2003), the super-fine Merino yearling enterprise was as profitable as the dual purpose enterprise.

The results highlight that there is considerable scope for all sheep producers to improve the gross margins of their current enterprise by refining their time of lambing and stocking rates. The focus should be on optimising the amount of meat and wool produced per ha and not on maximising per head animal performance.

Running a dual purpose enterprise offers producers some resilience against changes in commodity prices, but producers doing so should still pay close attention to the genetic merit (wool cut per head and fibre diameter in relation to live weight) of the ewes they buy in to reap full benefits. The results also support the option that many producers with self-replacing Merino flocks have been taking, that is joining a portion of ewes to terminal sires. Producers contemplating changing from Merino ewes to 1st cross ewes, need to exercise caution as they may not be any better off, particularly if paying very high prices for ewes or obtaining low weaning percentages. In high rainfall environments where producers often experience feet problems with Merinos or difficulty managing internal parasites, cross-bred ewe enterprises have some advantages. Although a self-replacing flock may not be as profitable as enterprises where replacement ewes are purchased (for the prices and costs modelled), purchasing ewes carries risks of introducing disease, lack of control with genetics, and exposure to high ewe prices.

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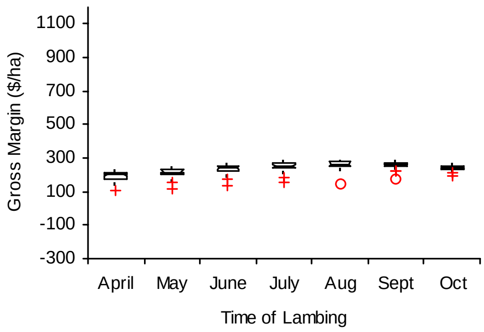
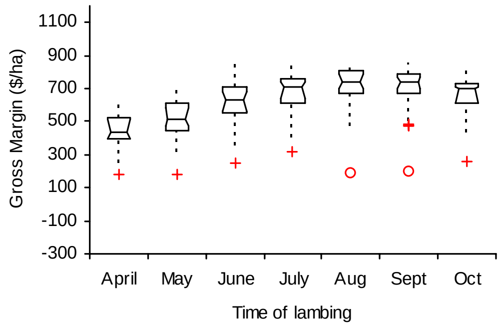
APPENDICES

APPENDIX 1. 1 EFFECT OF TIME OF LAMBING ON VARIATION IN GROSS MARGIN (1966-2001) FOR 2 STOCKING RATES AND A RANGE OF SHEEP ENTEPRISES, AT MORTLAKE. (PRICES: 5 YEAR AVERAGE)

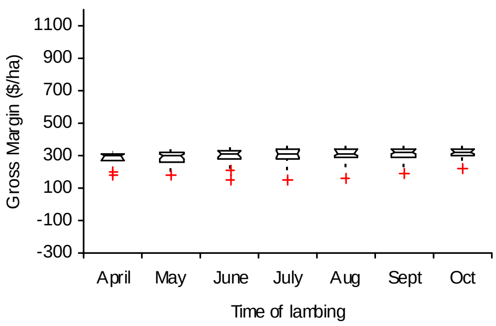
FINE Merino ewes & lambs
6 ewes/ha



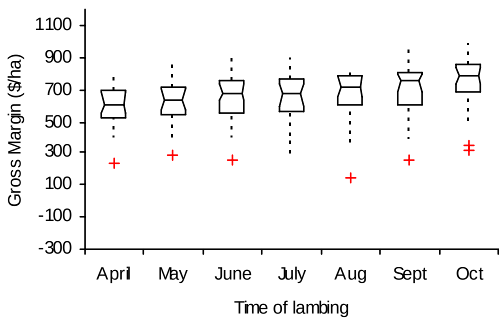
FINE Merino ewes & lambs
18 ewes/ha



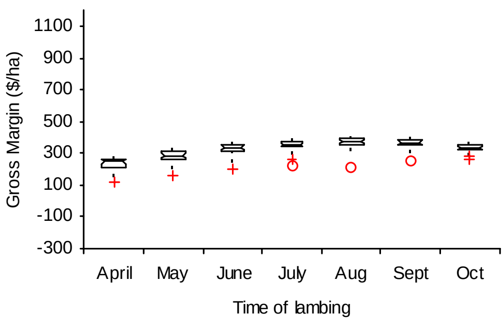
FINE Merino ewes & yearlings
6 ewes/ha



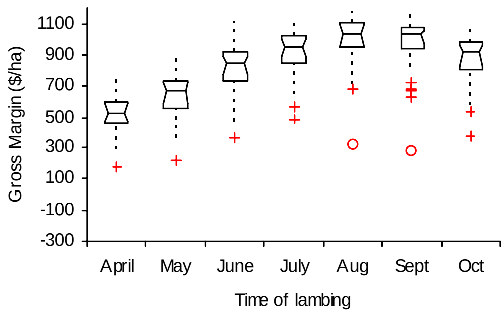
FINE Merino ewes & yearlings
18 ewes/ha



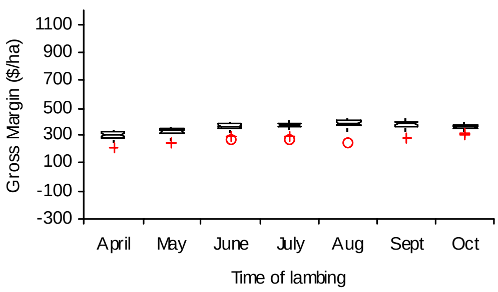
FINE merino ewes & 1st X lambs
6 ewes/ha



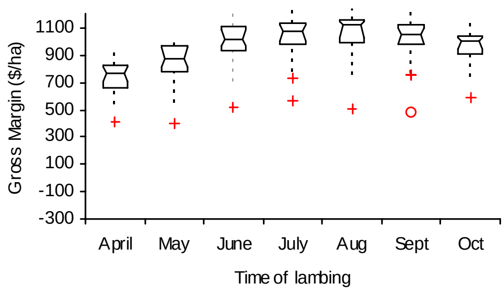
FINE Merino ewes & 1st X lambs
18 ewes/ha

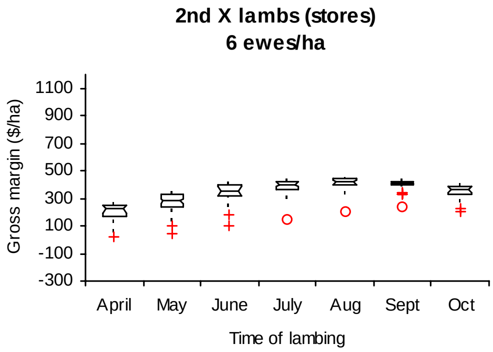


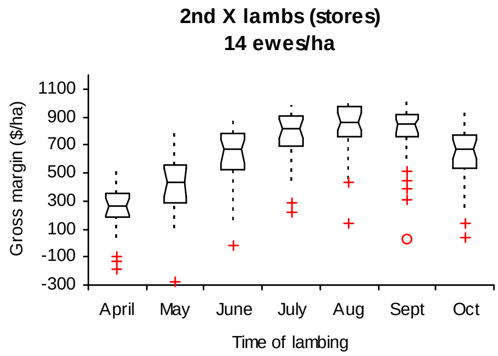
FINE Merino ewes & 1st X lambs (44 kg)
6 ewes/ha

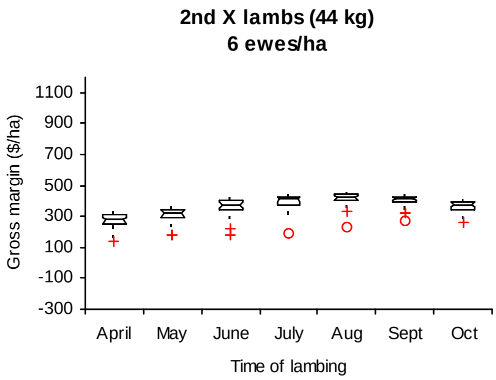


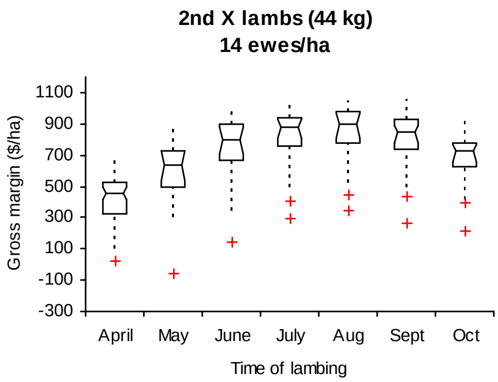
FINE Merino ewes & 1st X lambs (44 kg)
18 ewes/ha

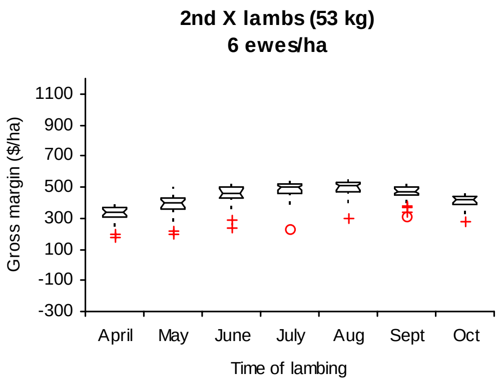


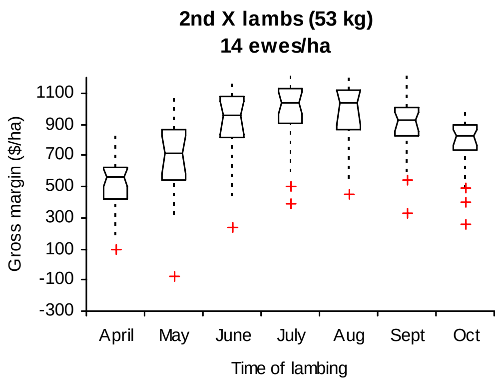

2nd X lambs (stores)
6 ewes/ha
Gross margin ($/ha)
1100
900
700
500
300
100
-100
-300
April
May
June
July
Aug
Sept
Oct
Time of lambing


2nd X lambs (stores)
14 ewes/ha
Gross margin ($/ha)
1100
900
700
500
300
100
-100
-300
April
May
June
July
Aug
Sept
Oct
Time of lambing

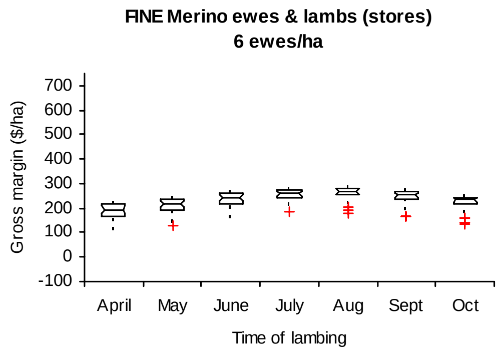

2nd X lambs (44 kg)
6 ewes/ha
Gross margin ($/ha)
1100
900
700
500
300
100
-100
-300
April
May
June
July
Aug
Sept
Oct
Time of lambing

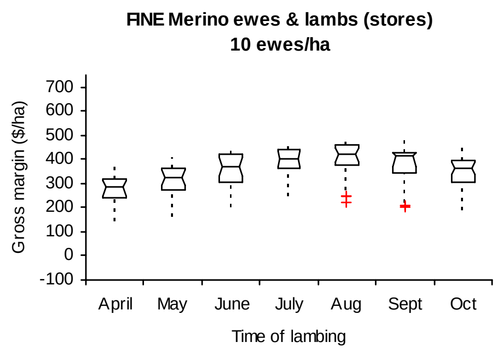

2nd X lambs (44 kg)
14 ewes/ha
Gross margin ($/ha)
1100
900
700
500
300
100
-100
-300
April
May
June
July
Aug
Sept
Oct
Time of lambing

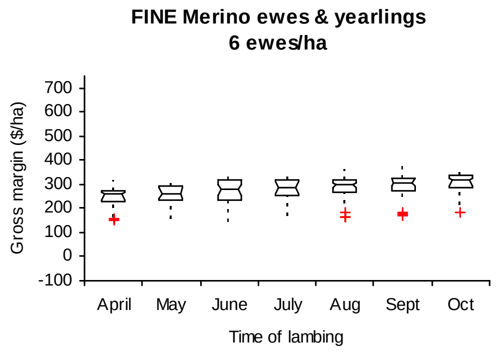

2nd X lambs (53 kg)
6 ewes/ha
Gross margin ($/ha)
1100
900
700
500
300
100
-100
-300
April
May
June
July
Aug
Sept
Oct
Time of lambing

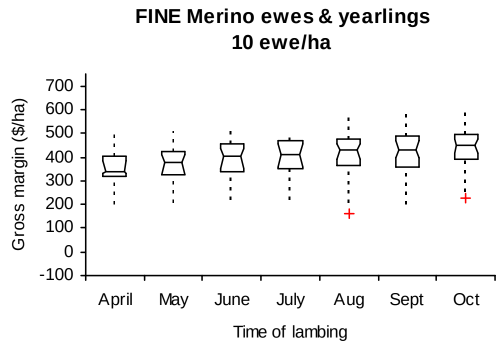

2nd X lambs (53 kg)
14 ewes/ha
Gross margin ($/ha)
1100
900
700
500
300
100
-100
-300
April
May
June
July
Aug
Sept
Oct
Time of lambing

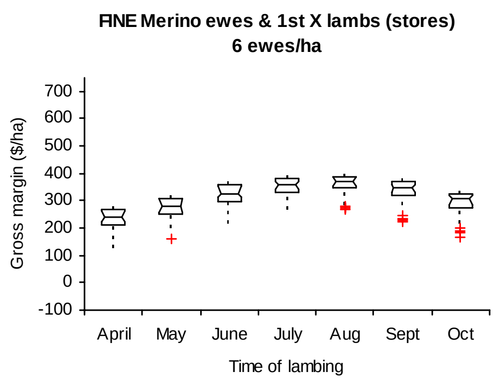
APPENDIX 1.2 - EFFECT OF TIME OF LAMBING ON VARIATION IN GROSS MARGIN (1966-2001) FOR 2 STOCKING RATES AND A RANGE OF SHEEP ENTEPRISES, AT RUTHERGLEN

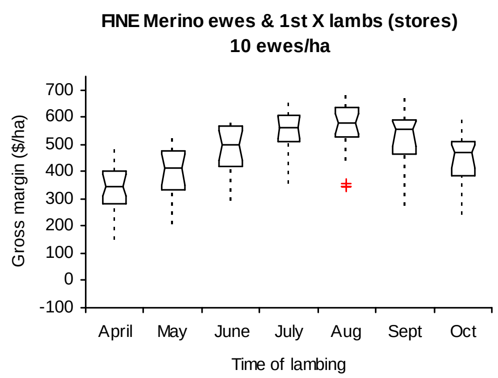


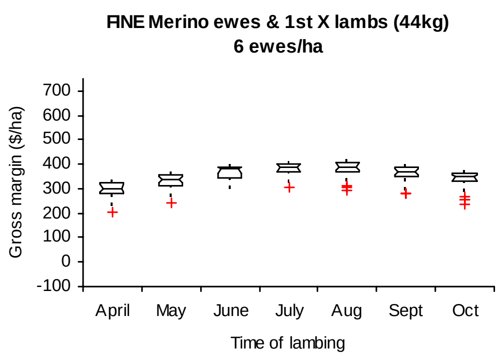


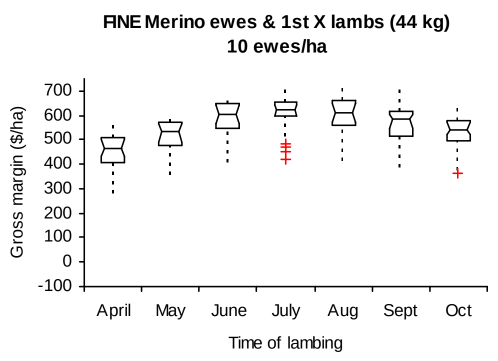


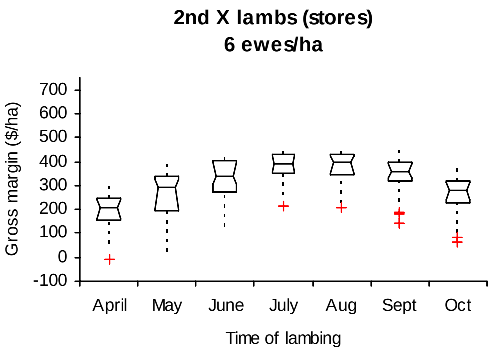


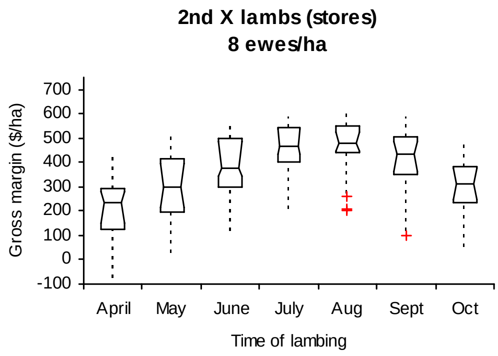


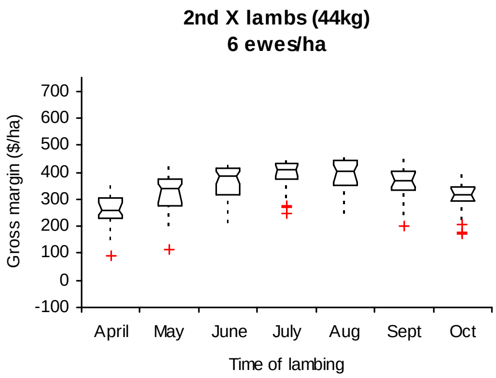


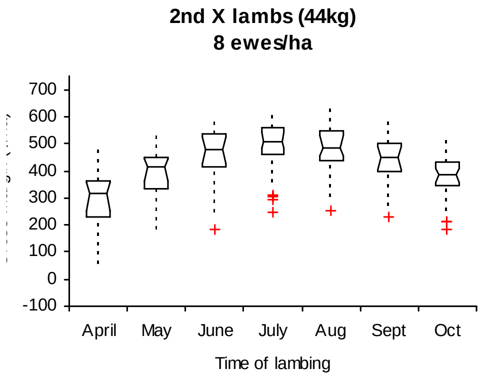


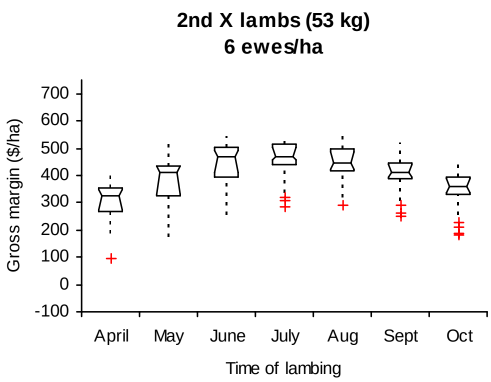


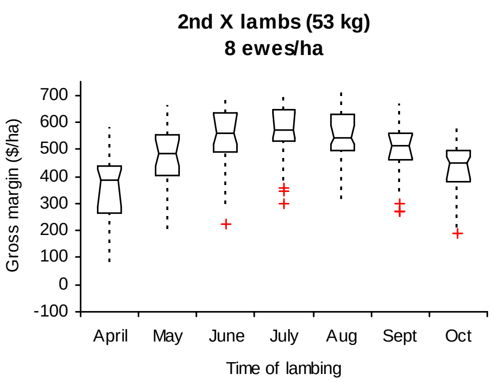

2nd X lambs (stores)
6 ewes/ha
Gross margin ($/ha)
700
600
500
400
300
200
100
0
-100
April
May
June
July
Aug
Sept
Oct
Time of lambing


2nd X lambs (stores)
8 ewes/ha
Gross margin ($/ha)
700
600
500
400
300
200
100
0
-100
April
May
June
July
Aug
Sept
Oct
Time of lambing


2nd X lambs (44kg)
6 ewes/ha
Gross margin ($/ha)
700
600
500
400
300
200
100
0
-100
April
May
June
July
Aug
Sept
Oct
Time of lambing

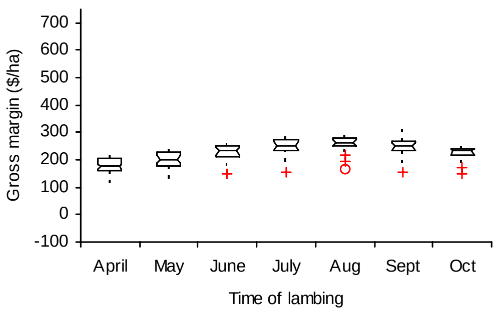

2nd X lambs (44kg)
8 ewes/ha
700
600
500
400
300
200
100
0
-100
April
May
June
July
Aug
Sept
Oct
Time of lambing


2nd X lambs (53 kg)
6 ewes/ha
Gross margin ($/ha)
700
600
500
400
300
200
100
0
-100
April
May
June
July
Aug
Sept
Oct
Time of lambing

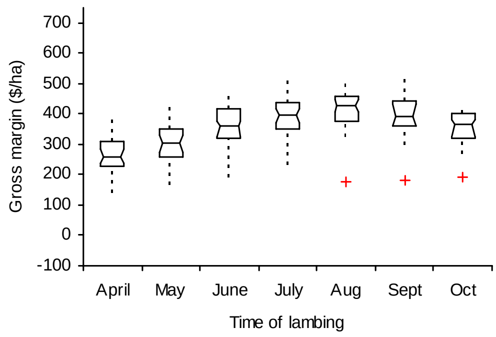

2nd X lambs (53 kg)
8 ewes/ha
Gross margin ($/ha)
700
600
500
400
300
200
100
0
-100
April
May
June
July
Aug
Sept
Oct
Time of lambing

APPENDIX 1.3 - EFFECT OF TIME OF LAMBING ON VARIATION IN GROSS MARGIN (1966-2001) FOR 2 STOCKING RATES AND A RANGE OF SHEEP ENTEPRISES, AT NARACOORTE

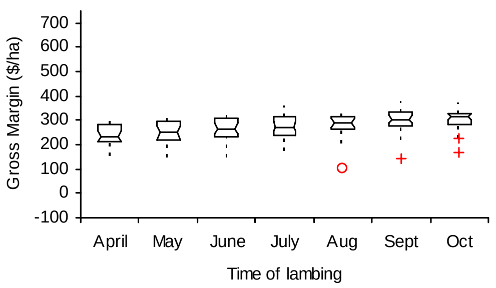
FINE Merino ewes & lambs (stores)
6 ewes/ha



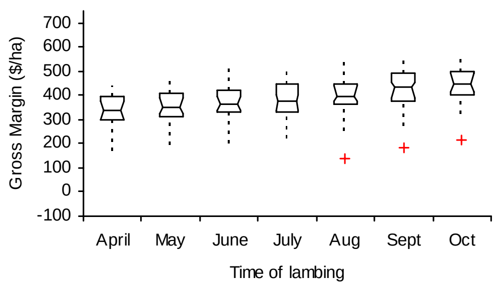
FINE Merino ewes & lambs (stores)
10 ewes/ha



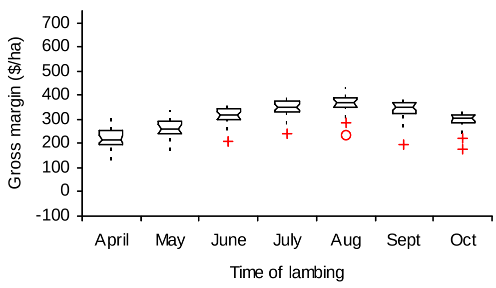
FINE Merino ewes & yearlings
6 ewes/ha



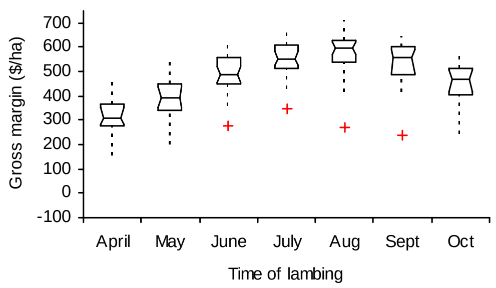
FINE Merino ewes & yearlings
10 ewes/ha



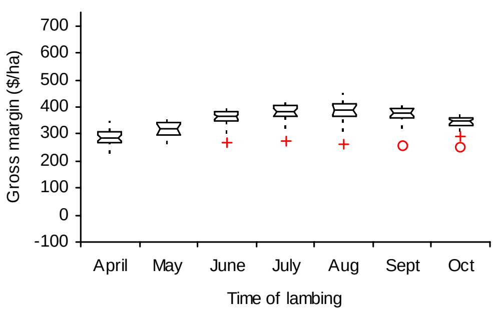
FINE Merino ewes & 1st X lambs (stores)
6 ewes/ha



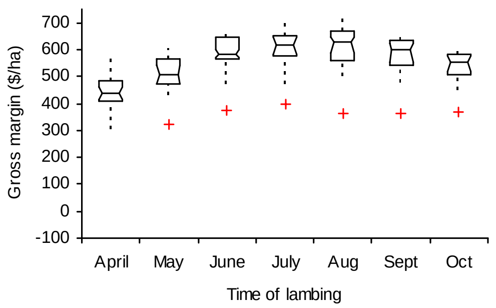
FINE Merino ewes & 1st X lambs (stores)
10 ewes/ha

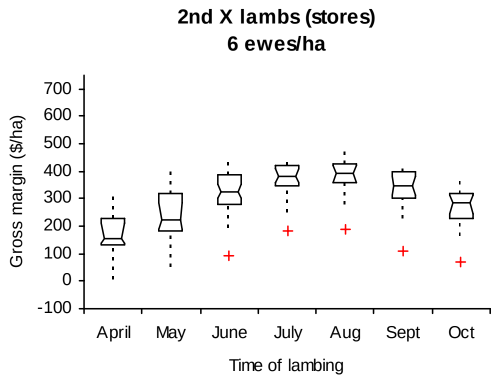


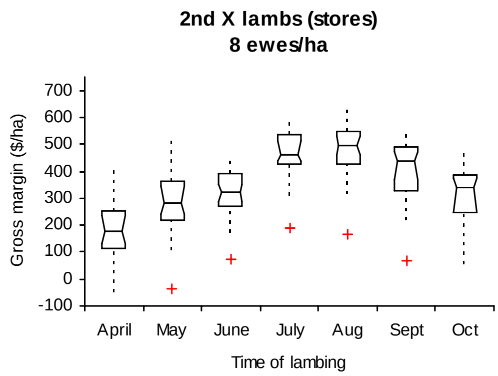
FINE Merino ewes & 1st X lambs (44 kg)
6 ewes/ha

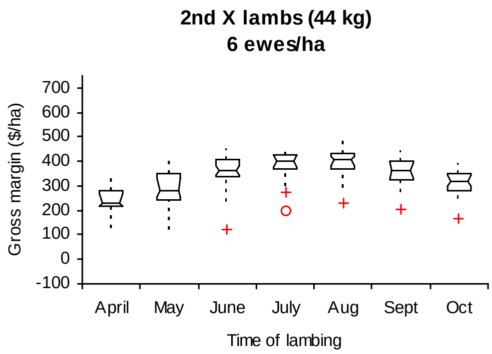


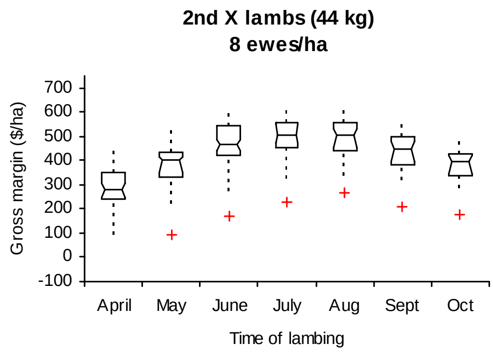
FINE Merino ewes & 1st X lambs (44 kg)
10 ewes/ha

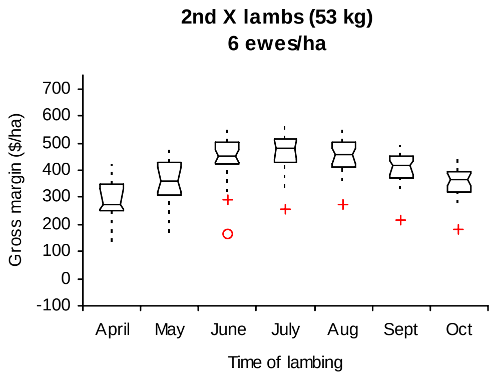


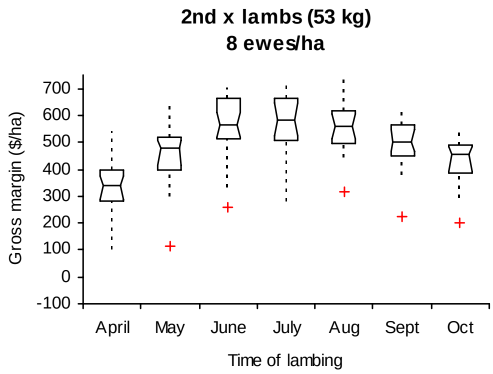

2nd X lambs (stores)
6 ewes/ha
Gross margin ($/ha)
700
600
500
400
300
200
100
0
-100
April
May
June
July
Aug
Sept
Oct
Time of lambing


2nd X lambs (stores)
8 ewes/ha
Gross margin ($/ha)
700
600
500
400
300
200
100
0
-100
April
May
June
July
Aug
Sept
Oct
Time of lambing

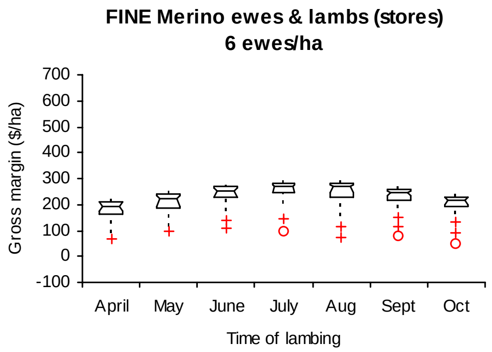

2nd X lambs (44 kg)
6 ewes/ha
Gross margin ($/ha)
700
600
500
400
300
200
100
0
-100
April
May
June
July
Aug
Sept
Oct
Time of lambing

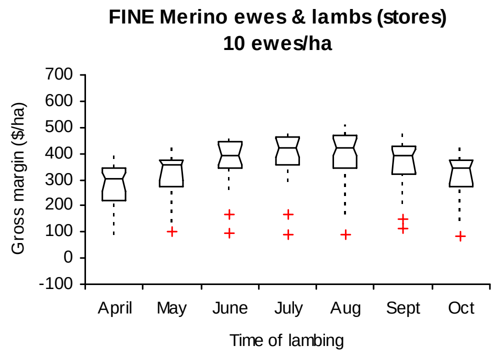

2nd X lambs (44 kg)
8 ewes/ha
Gross margin ($/ha)
700
600
500
400
300
200
100
0
-100
April
May
June
July
Aug
Sept
Oct
Time of lambing

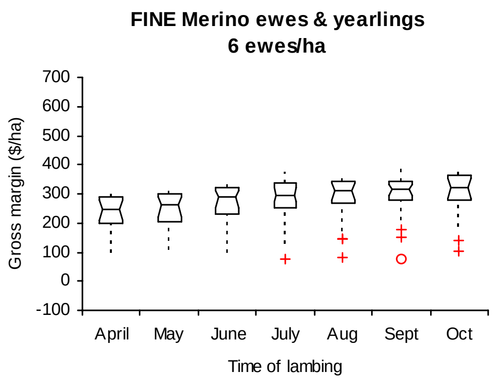

2nd X lambs (53 kg)
6 ewes/ha
Gross margin ($/ha)
700
600
500
400
300
200
100
0
-100
April
May
June
July
Aug
Sept
Oct
Time of lambing

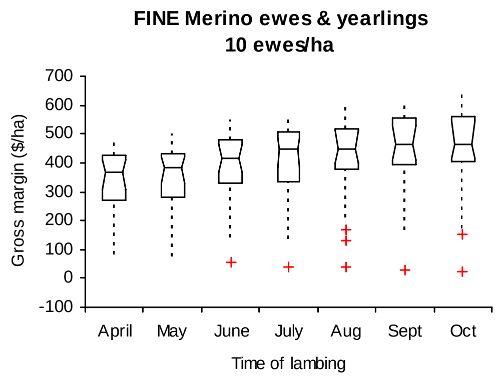

2nd x lambs (53 kg)
8 ewes/ha
Gross margin ($/ha)
700
600
500
400
300
200
100
0
-100
April
May
June
July
Aug
Sept
Oct
Time of lambing

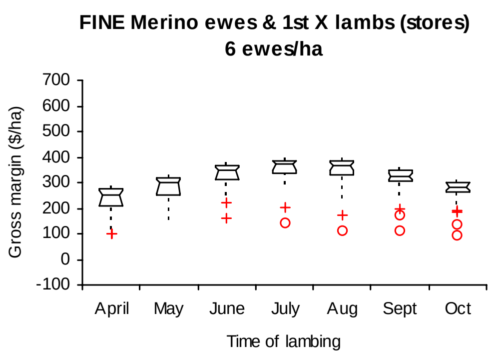
APPENDIX 1.4 - EFFECT OF TIME OF LAMBING ON VARIATION IN GROSS MARGIN (1966-2001) FOR 2 STOCKING RATES AND A RANGE OF SHEEP ENTEPRISES, AT COWRA

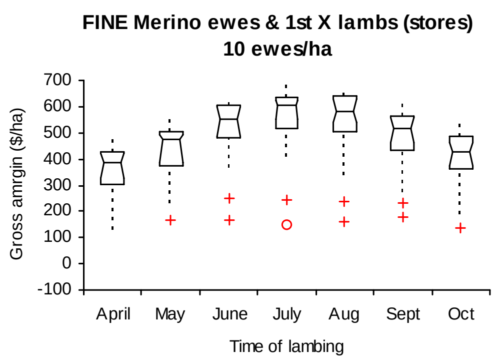


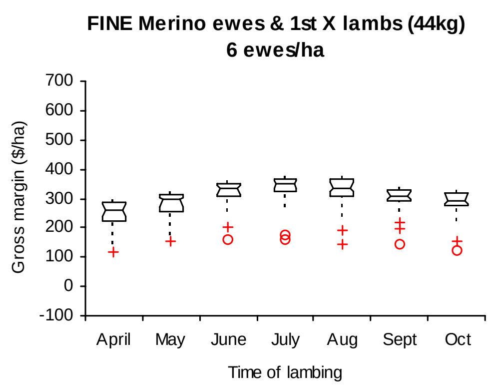


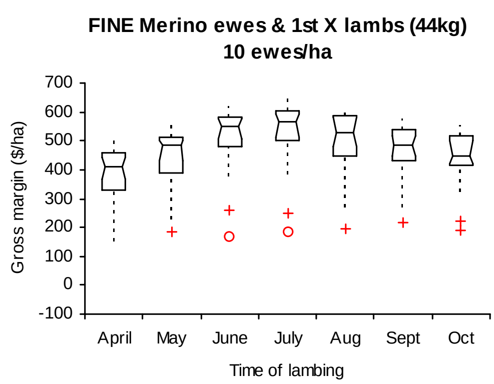


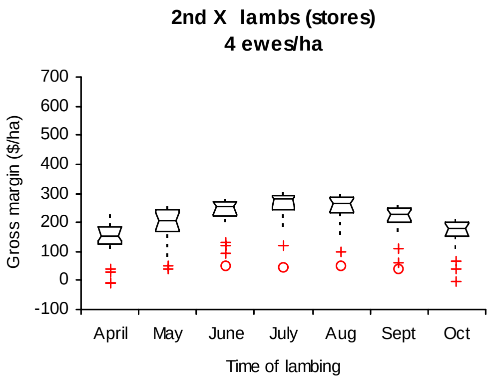


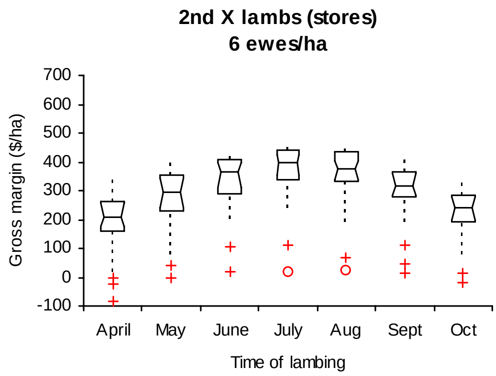


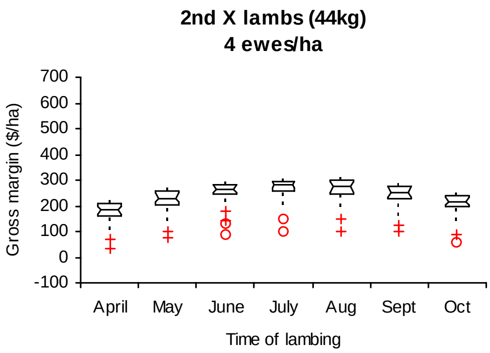


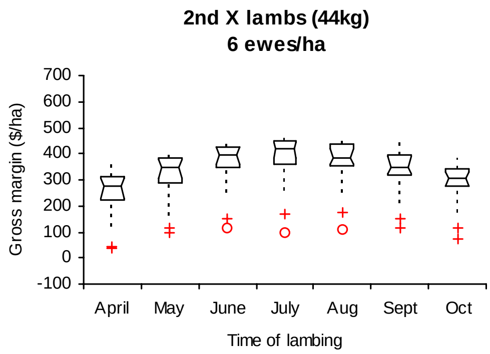


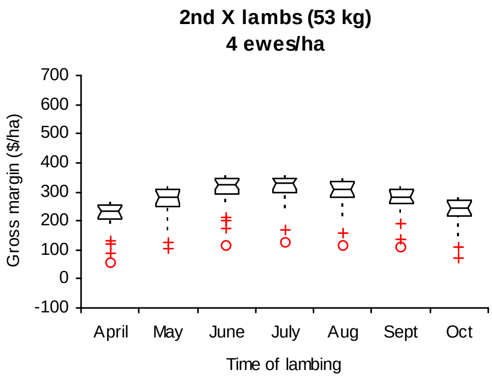


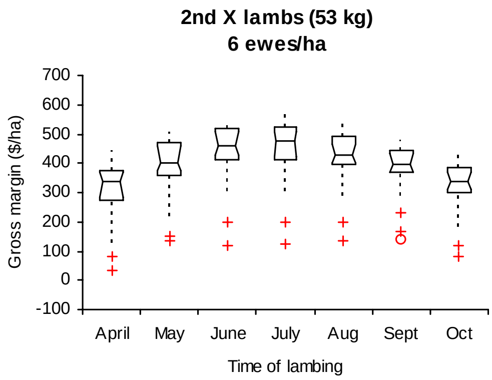

2nd X lambs (stores)
4 ewes/ha
Gross margin ($/ha)
700
600
500
400
300
200
100
0
-100
April
May
June
July
Aug
Sept
Oct
Time of lambing


2nd X lambs (stores)
6 ewes/ha
Gross margin ($/ha)
700
600
500
400
300
200
100
0
-100
April
May
June
July
Aug
Sept
Oct
Time of lambing


2nd X lambs (44kg)
4 ewes/ha
Gross margin ($/ha)
700
600
500
400
300
200
100
0
-100
April
May
June
July
Aug
Sept
Oct
Time of lambing


2nd X lambs (44kg)
6 ewes/ha
Gross margin ($/ha)
700
600
500
400
300
200
100
0
-100
April
May
June
July
Aug
Sept
Oct
Time of lambing


2nd X lambs (53 kg)
4 ewes/ha
Gross margin ($/ha)
700
600
500
400
300
200
100
0
-100
April
May
June
July
Aug
Sept
Oct
Time of lambing


2nd X lambs (53 kg)
6 ewes/ha
Gross margin ($/ha)
700
600
500
400
300
200
100
0
-100
April
May
June
July
Aug
Sept
Oct
Time of lambing

APPENDIX 2 : EFFECT OF STOCKING RATE AND TIME OF LAMBING ON MEAN GROSS MARGIN ($/HA) AND RISK (SUSTAINBLE STOCKING RATE CRITERIA), AT MORTLAKE. (AVERAGE 5YR PRICES: 1999-2003)

APPENDIX 2.1 MERINO EWES (FINE) / LAMBS (STORES)

Stocking rate (ewes/ha)	**Time of lambing**						
	April	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**
6	190	212	236	250	261	259	243
10	301	339	388	417	437	431	405
14	385	443	519	562	589	581	545
18	443	516	612	669	708	703	659
20	471	546	653	717	761	757	712

Ewe maintenance feeding criteria can't be met
Autumn pasture cover criteria can't be met
Both criteria can't be met

APPENDIX 2.2 - MERINO EWES (FINE)/ YEARLINGS

Stocking rate (ewes/ha)	**Time of lambing**						
	April	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**
6	279	281	293	298	305	311	316
10	416	426	452	456	467	485	502
14	516	538	568	569	584	611	647
15	540	564	597	596	616	643	680
16	565	588	619	619	638	668	708
17	586	608	640	638	661	690	734
18	604	627	658	658	678	710	754

APPENDIX 2.3 - MERINO EWES (FINE)/ 1ST X LAMBS (STORES)

Stocking rate (ewes/ha)	**Time of lambing**						
	April	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**
6	235	276	323	344	361	357	331
10	363	436	523	569	600	592	544
14	456	563	692	766	812	796	724
17	506	628	784	885	947	928	836
18	518	644	809	920	986	967	873
19	529	657	835	954	1025	1008	905
20	540	670	856	984	1062	1042	937

APPENDIX 2.4 - MERINO EWES(FINE)/ 1ST X LAMBS (FINISH 44KG)

Stocking rate (ewes/ha)	**Time of lambing**						
	April	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**
6	298	321	356	366	376	373	354
10	478	525	592	613	628	615	581
14	627	706	811	837	854	828	784
17	714	819	954	986	1006	972	925
18	740	855	1000	1029	1052	1016	969
20	795	915	1081	1116	1141	1102	1055

APPENDIX 2.5 - 1ST X EWES/ 2ND X LAMBS (STORES)

Stocking rate (ewes/ha)	Time of lambing						
	April	May	June	July	Aug	Sept	Oct
6	207	272	343	389	409	402	353
10	263	373	528	618	652	629	525
14	246	413	622	769	825	781	622
15	236	415	633	791	858	812	634
16	226	414	629	806	884	831	647
17	216	404	628	811	905	846	652
18	212	394	611	818	922	856	653

APPENDIX 2.6 - 1ST X EWES/ 2ND X LAMBS (FINISH 44KG)

Stocking rate (ewes/ha)	Time of lambing						
	April	May	June	July	Aug	Sept	Oct
6	270	312	366	399	412	405	366
10	385	461	587	642	664	634	552
14	430	601	756	822	850	796	683
15	442	627	785	857	890	825	713
16	449	651	811	886	921	853	742
17	465	664	831	903	944	874	763
18	480	660	834	931	966	897	782

APPENDIX 2.7 - 1ST X EWES/ 2ND X LAMBS (FINISH 53 KG)

Stocking rate (ewes/ha)	Time of lambing						
	April	May	June	July	Aug	Sept	Oct
6	330	383	450	485	493	465	411
10	467	560	722	775	774	711	623
12	503	632	829	893	887	807	705
14	530	694	910	981	974	894	781
16	560	724	968	1050	1042	962	844
18	592	698	974	1090	1092	1016	895

APPENDIX 3: EFFECT OF STOCKING RATE AND TIME OF LAMBING ON MEAN GROSS MARGIN ($/HA) AND RISK (SUSTAINBLE STOCKING RATE CRITERIA), AT RUTHERGLEN. (AVERAGE 5YR PRICES: 1999-2003)

APPENDIX 3.1 - MERINO EWES (FINE) /LAMBS (STORES)

Stocking rate (ewes/ha)	**Time of lambing**						
	April	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**
6	188	211	237	254	261	247	224
10	279	315	364	395	404	383	347
14	333	374	437	483	507	479	435
18	359	397	470	531	569	542	493

Ewe maintenance feeding criteria can't be met
Autumn pasture cover criteria can't be met
Both criteria can't be met

APPENDIX 3.2 - MERINO EWES (FINE)/ YEARLINGS

Stocking rate (ewes/ha)	**Time of lambing**						
	April	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**
6	250	257	273	281	288	299	306
8	304	317	336	346	355	367	381
10	353	367	389	400	409	422	439
14	416	436	462	467	469	479	491

APPENDIX 3.3 - MERINO EWES (FINE)/ 1ST X LAMBS (STORES)

Stocking rate (ewes/ha)	**Time of lambing**						
	April	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**
6	237	277	324	353	361	336	293
10	340	405	488	546	562	516	441
12	372	440	544	621	643	589	495
14	392	465	579	674	707	642	538

APPENDIX 3.4 - MERINO EWES(FINE)/ 1ST X LAMBS (FINISH 44KG)

Stocking rate (ewes/ha)	**Time of lambing**						
	April	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**
6	299	331	369	383	383	366	339
8	385	429	487	501	496	472	439
10	458	513	590	608	599	568	530
14	561	617	746	775	765	734	686

APPENDIX 3.5 - 1ST X EWES/ 2ND X LAMBS (STORES)

Stocking rate (ewes/ha)	Time of lambing						
	April	May	June	July	Aug	Sept	Oct
6	196	260	325	375	381	338	259
8	207	293	388	455	466	401	294
10	195	290	401	499	519	440	306
14	128	195	321	472	538	442	284

APPENDIX 3.6 - 1ST X EWES/ 2ND X LAMBS (FINISH 44KG)

Stocking rate (ewes/ha)	Time of lambing						
	April	May	June	July	Aug	Sept	Oct
6	260	317	364	393	389	359	309
8	303	388	457	487	480	434	373
10	328	437	509	549	542	491	426
14	311	435	526	582	597	570	492

APPENDIX 3.7 - 1ST X EWES/ 2ND X LAMBS (FINISH 53 KG)

Stocking rate (ewes/ha)	Time of lambing						
	April	May	June	July	Aug	Sept	Oct
6	309	383	439	460	443	404	348
8	356	468	544	562	540	493	420
10	385	527	605	631	609	563	475
14	370	546	634	676	689	660	538

APPENDIX 4: EFFECT OF STOCKING RATE AND TIME OF LAMBING ON MEAN GROSS MARGIN ($/HA) AND RISK (SUSTAINBLE STOCKING RATE CRITERIA), AT NARACOORTE. (AVERAGE 5YR PRICES: 1999-2003)

4.1 - MERINO EWES (FINE) /LAMBS (STORES)

Stocking rate (ewes/ha)	Time of lambing						
	April	May	June	July	Aug	Sept	Oct
6	178	201	230	249	261	249	227
8	224	257	297	324	341	324	294
10	254	305	358	394	416	393	356
14	319	367	437	495	523	495	446

Ewe maintenance feeding criteria can't be met
Autumn pasture cover criteria can't be met
Both criteria can't be met

APPENDIX 4.2 - MERINO EWES (FINE)/ YEARLINGS

Stocking rate (ewes/ha)	Time of lambing						
	April	May	June	July	Aug	Sept	Oct
6	242	251	264	273	283	297	305
8	302	314	333	342	358	377	390
10	341	353	376	384	401	424	445
14	412	426	453	464	476	495	517

APPENDIX 4.3 - MERINO EWES (FINE)/ 1ST X LAMBS (STORES)

Stocking rate (ewes/ha)	Time of lambing						
	April	May	June	July	Aug	Sept	Oct
6	221	264	315	346	365	343	300
8	274	334	406	453	478	445	388
10	320	395	488	550	579	538	459
14	381	460	582	692	740	673	561

APPENDIX 4.4 - MERINO EWES(FINE)/ 1ST X LAMBS (FINISH 44KG)

Stocking rate (ewes/ha)	Time of lambing						
	April	May	June	July	Aug	Sept	Oct
6	290	319	360	377	384	372	343
8	370	418	478	499	503	484	448
10	445	509	586	608	612	585	542
14	552	631	750	783	788	759	704

APPENDIX 4.5 - 1ST X EWES/ 2ND X LAMBS (STORES)

Stocking rate (ewes/ha)	Time of lambing						
	April	May	June	July	Aug	Sept	Oct
6	173	239	316	375	389	343	273
8	184	281	390	464	486	406	313
10	183	299	419	539	559	441	325
14	124	220	337	512	592	452	299

APPENDIX 4.6 - 1ST X EWES/ 2ND X LAMBS (FINISH 44KG)

Stocking rate (ewes/ha)	Time of lambing						
	April	May	June	July	Aug	Sept	Oct
6	245	294	357	391	396	360	317
8	291	379	460	497	494	434	383
10	320	442	522	575	563	495	434
14	313	438	544	603	623	576	502

APPENDIX 4.7 - 1ST X EWES/ 2ND X LAMBS (FINISH 53 KG)

Stocking rate (ewes/ha)	Time of lambing						
	April	May	June	July	Aug	Sept	Oct
6	291	362	438	464	454	408	358
8	339	452	559	580	559	498	434
10	374	511	612	652	632	571	486
14	383	498	622	697	722	673	547

APPENDIX 5: EFFECT OF STOCKING RATE AND TIME OF LAMBING ON MEAN GROSS MARGIN ($/HA) AND RISK (SUSTAINBLE STOCKING RATE CRITERIA), AT COWRA. (AVERAGE 5YR PRICES: 1999-2003)

APPENDIX 5.1: MERINO EWES (FINE) /LAMBS (STORES)

Stocking rate (ewes/ha)	**Time of lambing**						
	April	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**
6	182	209	240	254	251	231	205
8	234	272	313	334	327	301	266
10	280	326	378	402	396	362	318
14	347	403	477	515	503	457	400

Ewe maintenance feeding criteria can't be met
Autumn pasture cover criteria can't be met
Both criteria can't be met

APPENDIX 5.2 - MERINO EWES (FINE)/ YEARLINGS

Stocking rate (ewes/ha)	**Time of lambing**						
	April	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**
6	239	251	273	285	295	303	307
8	298	313	341	357	369	377	386
10	347	363	398	417	426	442	444
14	419	441	489	508	508	515	510

APPENDIX 5.3 - MERINO EWES (FINE)/ 1ST X LAMBS (STORES)

Stocking rate (ewes/ha)	**Time of lambing**						
	April	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**
6	235	279	330	353	348	312	269
8	303	361	432	462	452	404	343
10	359	432	521	561	549	483	404
14	436	522	654	720	701	606	489

APPENDIX 5.4 - MERINO EWES(FINE)/ 1ST X LAMBS (FINISH 44KG)

Stocking rate (ewes/ha)	**Time of lambing**						
	April	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**
6	250	280	321	334	326	302	288
8	325	369	424	436	423	392	372
10	391	450	519	532	507	471	445
14	492	570	669	683	654	609	570

APPENDIX 5.5 - 1ST X EWES/ 2ND X LAMBS (STORES)

Stocking rate (ewes/ha)	Time of lambing						
	April	May	June	July	Aug	Sept	Oct
4	146	195	236	259	249	214	166
6	198	274	338	373	355	299	224
8	234	334	417	464	437	358	256
10	243	356	460	527	492	393	271
14	196	281	420	550	525	406	257

APPENDIX 5.6 - 1ST X EWES/ 2ND X LAMBS (FINISH 44KG)

Stocking rate (ewes/ha)	Time of lambing						
	April	May	June	July	Aug	Sept	Oct
4	178	220	252	268	264	244	211
6	255	323	371	391	375	342	294
8	316	411	467	492	466	420	362
10	361	476	539	567	530	487	417

APPENDIX 5.7 - 1ST X EWES/ 2ND X LAMBS (FINISH 53 KG)

Stocking rate (ewes/ha)	Time of lambing						
	April	May	June	July	Aug	Sept	Oct
4	220	267	307	313	298	274	234
6	314	394	444	450	421	387	328
8	384	497	554	561	522	480	402
10	433	561	630	644	602	556	457

APPENDIX 6.1 COMPARISON OF ALL ENTERPRISES AT MORTLAKE WHEN RUN AT OPTIMUM[A] TIME OF LAMBING AND STOCKING RATE.

			Physical parameters								Financial parameters								Risk	
Mortlake Enterprise	**EWE Geno-type**	**Lamb time**	**Stock rate (ewes or wths /ha)**	**1 July DSE/ha**	**Avge annual DSE/ha**	**Pasture used %**	**Wool-clean kg/ha**	**Meat (LWT) kg/ha**	**Wean %**	**Sale wt. kg**	**GM $/ha**	**GM $/DSE**	**GM $/ha/ 100 mm**	**Income Wool $/ha**	**Income Meat $/ha**	**% from wool**	**Maint. supp fed $/ha**	**Prod. supp fed $/ha**	**Prob. < 800 kg DM/ha Jan-Apr**	**Prob. feed >30kg grain**
wethers	S FINE	-	22.0	29.5	27.0	51	68	271	-	65.9	**797**	**30**	120	1043	173	86	42	-	0.19	0.20
	FINE	-	20.0	28.8	27.1	52	70	274	-	73.6	**496**	**18**	75	709	175	80	41	-	0.19	0.20
Self-replacing Merino flock																				
Yearlings	S FINE	Oct	18.0	32.8	31.9	55	67	566	86	46.6	**1021**	**32**	154	1015	454	69	159	-	0.20	0.32
(12 mths)	FINE	Oct	16.5	33.0	32.1	56	70	574	86	51.4	**720**	**22**	109	692	456	60	159	-	0.20	0.36
	MED	Oct	15.0	32.8	31.8	55	69	576	86	56.4	**537**	**17**	81	484	453	52	150	-	0.20	0.35
Merino lambs	FINE	Sept	20.0	28.0	31.1	54	60	560	86	36.2	**759**	**24**	114	541	609	47	101	-	0.19	0.34
(18 wks)	MED	Sept	19.0	28.8	32.0	55	62	580	86	39.5	**669**	**21**	101	432	624	41	107	-	0.20	0.34
Dual purpose flock																				
1st X lambs	FINE	Sept	20.0	28.2	32.1	55	62	845	85	38.3	**1042**	**32**	157	593	1086	35	101	-	0.19	0.35
(18 wks)	MED	Sept	19.0	28.8	32.8	56	63	850	85	39.8	**893**	**27**	135	433	1081	29	108	-	0.20	0.34
1st X lambs (44 kg)	FINE	Aug	17.0	27.2	30.2	51	53	843	88	44.0	**1006**	**33**	152	490	1100	31	95	18	0.14	0.40
	MED	Aug	16.5	28.4	30.7	52	56	839	88	44.0	**886**	**29**	134	377	1082	26	100	15	0.15	0.38
Prime lamb flock																				
2nd X lambs (18 wks)		Aug	14.5	27.3	30.4	52	44	918	121	43.0	**844**	**28**	127	201	1259	14	89	-	0.14	0.38
2nd X lambs (44 kg)		Aug	14.5	27.3	31.3	53	44	955	120	44.0	**870**	**28**	131	200	1311	13	94	16	0.16	0.38
2nd X lambs (53 kg)		Aug	13.0	24.9	31.0	52	40	990	120	53.0	**931**	**30**	140	180	1367	12	82	47	0.14	0.38

[A] Optimum is where gross margins are optimised after consideration of economic risk and the supplementary feeding and pasture cover "rules". Stocking rate rounded off to nearest 0.5 wether or ewe/ha.

APPENDIX 6.2 COMPARISON OF ALL ENTERPRISES AT RUTHERGLEN WHEN RUN AT OPTIMUM [A] TIME OF LAMBING AND STOCKING RATE.

Rutherglen Enterprise	EWE Geno-type	Lamb time	Physical parameters: Stock rate (ewes or wths /ha)	1 July DSE/ha	Avge annual DSE/ha	Pasture used %	Wool-clean kg/ha	Meat (LWT) kg/ha	Wean %	Sale wt. kg	Financial parameters: GM $/ha	GM $/DSE	GM $/ha/ 100 mm	Income: Wool $/ha	Income: Meat $/ha	% from wool	Maint. supp fed $/ha	Prod. supp fed $/ha	Risk: Prob. < 800 kg DM/ha Jan-Apr	Prob. feed >30kg grain
wethers	S FINE	-	13.0	19.2	15.8	49	40	154	-	64.3	**459**	**29**	74	615	99	86	20	-	0.2	0.19
	FINE	-	12.0	19.5	16.2	50	42	158	-	71.3	**282**	**17**	46	422	101	81	21	-	0.2	0.20
Self-replacing Merino flock																				
Yearlings	S FINE	Oct	9.5	20.5	17.9	50	38	334	95	48.3	**569**	**32**	92	559	270	67	87	-	0.19	0.32
(12 mths)	FINE	Oct	8.5	20.4	17.7	50	38	333	95	53.4	**398**	**22**	64	372	266	58	81	-	0.19	0.32
	MED	Oct	8.0	20.9	18.1	51	39	344	95	58.4	**311**	**17**	50	275	273	50	84	-	0.19	0.38
Merino lambs	FINE	Aug	10.5	16.6	16.9	48	32	325	97	36.7	**422**	**25**	68	282	362	44	48	-	0.17	0.38
(18 wks)	MED	Aug	10.0	17.3	17.6	49	33	339	97	40.0	**373**	**21**	60	223	374	37	57	-	0.17	0.40
Dual purpose flock																				
1st X lambs	FINE	Aug	10.5	17.1	17.7	49	33	489	96	39.1	**584**	**33**	94	304	640	32	57	-	0.17	0.40
(18 wks)	MED	Aug	10.0	17.6	18.1	50	34	492	96	40.6	**514**	**28**	83	228	637	26	59	-	0.17	0.40
1st X lambs (44 kg)	FINE	July	9.5	18.0	17.4	47	30	503	97	44.0	**583**	**34**	94	271	666	29	60	13	0.18	0.40
	MED	July	9.0	18.5	17.4	47	31	487	97	44.0	**508**	**29**	82	205	638	24	58	9	0.18	0.40
Prime lamb flock																				
2nd X lambs (18 wks)		Aug	8.5	16.4	17.8	49	25.7	537	126	41.7	**481**	**27**	78	116	740	14	51	-	0.18	0.40
2nd X lambs (44 kg)		July	8.0	18.3	17.7	48	24.0	543	127	44.0	**487**	**28**	78	109	754	13	57	9	0.17	0.40
2nd X lambs (53 kg)		July	7.0	16.1	17.2	46	21.4	552	127	53.0	**515**	**30**	83	96	770	11	45	26	0.16	0.40

[A] Optimum is where gross margins are optimised after consideration of economic risk and the supplementary feeding and pasture cover "rules". Stocking rate rounded off to nearest 0.5 wether or ewe/ha.

APPENDIX 6.3 COMPARISON OF ALL ENTERPRISES AT NARACOORTE WHEN RUN AT OPTIMUM[A] TIME OF LAMBING AND STOCKING RATE.

			Physical parameters								**Financial parameters**								**Risk**	
														Income						
Naracoorte Enterprise	**EWE Geno-type**	**Lamb time**	**Stock rate (ewes or wths /ha)**	**1 July DSE/ha**	**Avge annual DSE/ha**	**Pasture used %**	**Wool-clean kg/ha**	**Meat (LWT) kg/ha**	**Wean %**	**Sale wt. kg**	**GM $/ha**	**GM $/DSE**	**GM $/ha/ 100 mm**	**Wool $/ha**	**Meat $/ha**	**% from wool**	**Maint. supp fed $/ha**	**Prod. supp fed $/ha**	**Prob. < 800 kg DM/ha Jan-Apr**	**Prob. feed >30kg grain**
wethers	S FINE	-	13.5	19.3	16.4	47	42	157	-	61.0	**488**	**30**	86	649	103	86	21	-	0.11	0.19
	FINE	-	12.0	18.7	16.2	47	43	161	-	72.4	**288**	**18**	51	425	103	80	20	-	0.11	0.19
Self-replacing Merino flock																				
Yearlings	S FINE	Sept	10.0	21.2	18.5	48	40	331	95	44.2	**582**	**31**	103	582	268	68	88	-	0.11	0.39
(12 mths)	FINE	Sept	9.0	21.1	18.4	48	40	332	95	49.0	**406**	**22**	72	390	266	59	85	-	0.11	0.39
	MED	Sept	7.5	20.0	17.1	46	38	313	96	54.9	**298**	**17**	53	255	248	51	61	-	0.08	0.36
Merino lambs	FINE	Aug	10.5	16.5	17.1	44	33	335	97	37.9	**433**	**25**	76	280	372	43	47	-	0.06	0.38
(18 wks)	MED	Aug	9.5	16.4	16.9	44	32	334	98	41.5	**378**	**22**	67	213	364	37	43	-	0.06	0.38
Dual purpose flock																				
1st X lambs	FINE	Aug	9.5	15.3	16.2	42	30	461	97	40.8	**555**	**34**	98	272	604	31	42	-	0.06	0.38
(18 wks)	MED	Aug	9.0	15.7	16.5	43	31	462	97	42.4	**496**	**30**	87	206	599	26	42	-	0.06	0.40
1st X lambs (44 kg)	FINE	Aug	9.5	15.4	17.5	44	30	503	95	44.0	**586**	**33**	103	276	662	29	47	23	0.06	0.38
	MED	Aug	8.5	14.7	16.5	43	29	463	96	44.0	**489**	**30**	86	194	602	24	43	13	0.06	0.40
Prime lamb flock																				
2nd X lambs (18 wks)		Aug	7.5	14.2	16.0	42	23	498	128	43.1	**446**	**28**	79	104	687	13	33	-	0.05	0.36
2nd X lambs (44 kg)		Aug	7.0	13.4	15.6	41	22	484	127	44.0	**449**	**29**	79	97	668	13	32	10	0.07	0.35
2nd X lambs (53 kg)		Aug	7.0	13.7	17.3	43	22	557	126	53.0	**510**	**29**	90	97	772	11	34	46	0.05	0.38

[A] Optimum is where gross margins are optimised after consideration of economic risk and the supplementary feeding and pasture cover "rules". Stocking rate rounded off to nearest 0.5 wether or ewe/ha.

APPENDIX 6.4 COMPARISON OF ALL ENTERPRISES AT COWRA WHEN RUN AT OPTIMUM [A] TIME OF LAMBING AND STOCKING RATE.

Cowra Enterprise	EWE Geno-type	Lamb time	Physical parameters: Stock rate (ewes or wths /ha)	1 July DSE/ha	Avge annual DSE/ha	Pasture used %	Wool-clean kg/ha	Meat (LWT) kg/ha	Wean %	Sale wt. kg	Financial parameters: GM $/ha	GM $/DSE	GM $/ha/ 100 mm	Income: Wool $/ha	Meat $/ha	% from wool	Maint. supp fed $/ha	Prod. supp fed $/ha	Risk: Prob. < 800 kg DM/ha Jan-Apr	Prob. feed >30kg grain
wethers	S FINE	-	10.5	16.7	13.0	38	33	126	-	65.1	**347**	**27**	55	476	81	85	14	-	0.16	0.13
	FINE	-	9.5	16.7	13.0	38	33	128	-	72.7	**214**	**16**	34	326	82	80	13	-	0.16	0.13
Self-replacing Merino flock																				
Yearlings	S FINE	Sept	8.0	19.8	16.0	42	34	304	103	47.6	**496**	**31**	79	476	267	64	66	-	0.19	0.35
(12 mths)	FINE	Sept	7.0	19.3	15.5	41	34	297	104	53.0	**345**	**22**	55	311	239	57	59	-	0.19	0.35
	MED	Sept	6.0	18.3	14.7	39	32	284	104	58.7	**266**	**18**	42	219	226	49	49	-	0.20	0.30
Merino lambs	FINE	July	10.0	18.2	16.4	43	31	327	103	36.4	**402**	**25**	64	263	367	42	54	-	0.19	0.35
(18 wks)	MED	July	9.0	18.0	16.2	42	31	326	104	40.0	**354**	**22**	56	204	362	36	50	-	0.19	0.35
Dual purpose flock																				
1st X lambs	FINE	July	10.0	18.9	17.0	44	31	483	102	38.1	**561**	**33**	89	283	636	31	58	-	0.19	0.35
(18 wks)	MED	July	9.0	18.5	16.5	43	31	458	102	38.7	**479**	**29**	76	208	597	26	52	-	0.20	0.35
1st X lambs (44 kg)	FINE	July	8.5	16.1	16.1	41	27	474	102	44.0	**462**	**29**	73	241	546	31	42	19	0.19	0.35
	MED	July	8.0	16.3	15.9	41	27	458	102	44.0	**402**	**25**	64	185	523	26	45	13	0.20	0.38
Prime lamb flock																				
2nd X lambs (18 wks)		July	8.0	18.4	17.0	44	24	522	131	41.7	**463**	**27**	73	108	721	13	51	-	0.19	0.38
2nd X lambs (44 kg)		July	7.0	16.2	15.9	41	21	494	131	44.0	**443**	**28**	70	95	684	12	42	13	0.20	0.40
2nd X lambs (53 kg)		July	7.0	16.2	17.6	43	21	569	130	53.0	**508**	**29**	81	94	791	11	44	46	0.19	0.40

[A] Optimum is where gross margins are optimised after consideration of economic risk and the supplementary feeding and pasture cover "rules". Stocking rate rounded off to nearest 0.5 wether or ewe/ha.

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SUPPORTING PARTIES

- Australian Wool Innovation Limited
- AWTA Wool Education Trust
- Bett Trust
- Department of Primary Industries, Victoria
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- Department of Agriculture, Western Australia
- Department of Primary Industries & Fisheries, Queensland
- NSW Agriculture
- The University of New England

ANALYSIS AND DISCUSSION OF YEARLING MERINO SHEEP PRODUCTION SYSTEMS

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Executive Summary

- A yearling merino sheep system will allow producers to capture the benefits of the current high sheep meat prices within their existing resource base. They can do this without having to change their genetics or substantially alter their pasture resource base to provide out of season feed. The system enables them to utilise two springs for weight gain purposes, whereas a weaner production system only has one.
- Based on the assumptions used in this analysis, over the long term and at the extreme ends of historical meat and wool prices the spring lambing, self replacing yearling merino wool production system is competitive with the profitability of all other flock structures and enterprise mixes.
- The extreme market circumstance where the yearling sheep flock structure is marginally outperformed by other flock structures or enterprises is when there are concurrent top quartile wool prices and bottom quartile sheep meat prices. Under this situation the wether dominant wool flocks came to the fore. Or alternatively where there are concurrent bottom quartile wool prices and top quartile sheep meat prices in which case the dual purpose flocks came to the fore.
- Current market prices would suggest that some incorporation of a dual purpose enterprise into the system is likely to lift farm profitability. To do this the manager would join a percentage of cull or older age group ewes to a terminal sire and sell all progeny.
- In making a change to either enterprise mix or flock structure the individual farm manager should be cognisant of the changed demands on their pasture resources, labour requirements, and their ability to control worms.
- It is recommended that further geographic area specific work needs to be done with regard to the ability for sheep liveweight specifications to be met across a range of seasons and with a varied pasture base to get a better understanding of the suitability of these enterprises to different locations. It is felt a large part of that work could be done using the CSIRO Plant Industries Grassgro model.

Section 1: The Gross Margin Model and Assumptions Used

Background

Holmes Sackett and Associates have been commissioned to compare a yearling Merino meat-wool production system with the profitability of other sheep enterprises. The aim of the study is to highlight key impacts that a yearling Merino production system is likely to have on the product mix and profitability of a wool enterprises and to develop a list of the qualitative 'management and resource' issues that will need consideration should a change to a yearling production system be implemented.Table 1 shows the proposed enterprise and management structures that were modelled using a sheep flock gross margin spreadsheet. The merino cross and prime lamb enterprises were included to provide perspective on whether the impacts of changing to a yearling sheep production system based on merinos are more or less significant than changing the genetics of the flock to specialise in sheep meat production.

A yearling system carries progeny past one year of age but they are sold before they reach 2 years of age. A weaner is sold before it reaches 1 year of age. The yearling system for prime lamb was included for the purposes of a theoretical comparison rather than as a suggested system for adoption.

Table 1: Enterprises analysed

Enterprises	**Self Replacing Merinos**	**Merino x Terminal Sire**	**Prime Lamb**
Variations	Sell Weaners	Sell Weaners	Sell Weaners
	Sell Yearlings	Sell Yearlings	Sell Yearlings
	Sell Wethers @ 3y.o.		
	Sell Wether @ 5y.o.		

A sophisticated gross margin model of a sheep flock was used for this analysis which determines the relative gross margins per DSE and per hectare based on interactions between the whole flock structure including age classes, the physiological state of each animal through winter and their relative intake requirements.

The model incorporates the impact of age effects on survival, reproductive performance, wool quality and wool quantity.

Assumptions

Flock Numbers

A fixed area with a predetermined maximum mid-winter DSE rating is used to determine the number of animals and the relative flock structure that can be run. The winter DSE limit is in place under the assumption that it is the time of the year where feed is most limiting. A constant flock structure is maintained from one year to the next. For the purposes of this study a stocking rate limit of 15 DSE's per hectare was chosen which is representative of a 600 to 700mm rainfall region in southern temperate Australia.

Expenses

The gross margin is derived by deducting the enterprise specific expenses from the gross income generated from the flock. Enterprise specific expenses include shearing, crutching, drenching, vaccinations, supplementary feed and selling costs.

The gross margin analysis does not include expenses such as labour, fertiliser, pasture costs or other general farm running expenses.

Genetics

The merino genetics used in the gross margin model have an adult wool fibre diameter of 20.5 micron and a clean fleece weight of 4kg. For the dual purpose flock the adult fibre diameter was increased to 21 micron with a clean fleece weight of 4kg. The prime lamb flock had an adult fibre diameter of 29 microns with a clean fleece weight of 4kg.

Lambing Time

Within any geographic region the lambing time chosen by producers may vary from March to October. The lambing times chosen for the modelling in this project are shown in Table 2. The chosen lambing dates were deemed to be reflective of a significant portion of the industry.

Because one of the most significant advantages of a yearling system might be increasing producer comfort with a spring lambing the yearling systems were replicated with a change in lambing time to spring to highlight the impact that a change in lambing time may have on profitability.

Table 2: Selected lambing times for individual enterprises

Self Replacing Merino Flock	Initial Lambing Date	Spring Lambing Date
Sell weaners	15th July	1st Sept
Sell yearlings	15th July	1st Sept
Sell 3 year old wethers	15th July	1st Sept
Sell 5 year old wethers	15th July	
Dual Purpose Flock		
Sell weaners	1st Jun	
Sell yearlings	1st Aug	1st Sept
Prime Lamb Flock		
Sell weaners	1st Jun	
Sell yearlings	1st Aug	1st Sept

The choice of lambing time is important to the model because it determines the DSE rating of the ewes through winter. This is then used to determine the number of animals that can be run per hectare and the required flock structure.

For the dual purpose and prime lamb enterprises the lambing date for turning off weaners was different to that chosen for the yearling production system. It is normal practice to lamb earlier in an attempt to achieve maximum weight gain in weaner lambs before the spring pasture growth finishes. This gives lambs a better chance of meeting suitable market weights and therefore a June lambing was chosen for this production system.

In the yearling system it was assumed that lambs would not need to reach maximum weights by the end of their first spring because they were to be run for another 12 months and sold at the end of their second spring. Therefore an August lambing was chosen so that more ewes could be run through winter as they would have less feed demand than ewes lambing earlier.

Sale Date and Live Weights

Because the gross margin model sets livestock numbers according to the target mid-winter DSE limit given (which for the purposes of this study was set at 15 DSE per hectare), an actual sale date was not necessary. If a sale date of less than one year old was chosen (as for weaners) it was assumed that lambs born in any year were not there the following winter. If a sale date of one year old was chosen then lambs born in any year were run for one winter after they were born, and so on up until the age that they are sold.

In all cases, ewes were kept until six years of age and non-replacement ewes bred on the property were sold as one year olds if they were not sold as weaners. Wether lambs were assumed to be sold at the end of the spring as either weaners, yearlings, three year olds or five year olds.

The sale live weights chosen for each system are shown in the Table 3 below. It is assumed that all sales occur at the end of spring off shears. Therefore for merino weaners to reach 30kg liveweight by mid December they must gain on average approximately 170g per day. The yearlings then must put on another 40g per day on average for the next 365 days.

The dual purpose weaners must grow at 190g per day to get to their target weight by the end of the first spring and in the yearling system they must average 60g per day from the end of their first spring to the end of the second spring assuming similar average growth rates until the end of the their first spring as occurs in the weaner system.

In the prime lamb system the weaners must gain 220g per day till the end of their first spring and in the yearling system they must average 75g per day from the end of their first spring to the end of the second spring to reach target weights assuming similar average growth rates until the end of the their first spring as occurs in the weaner system.

Table 3: Sheep live weight and age at sale (kg live weight).

	Weaners (<12 months)		Yearlings (14-18 months)		Wethers		CFA Ewes
	Ewes	Wethers	Ewes	Wethers	3YO	5YO	
Self Replacing Wool	28	30	42	46	60	60	55
Dual Purpose	41	43	54	57			55
Prime Lamb	46	49	65	65			65

Age at sale of retained progeny has a significant impact on flock structure Table 3. In this table the proportion of DSE’s that were represented by joined ewes, dry ewes, and wethers is shown. Note, the percentages do not add up to 100% because rams were left out of the table.

As the flock structure changes from selling weaners to yearlings then to 3 and 5 year old wethers the proportion of ewes in the flock during winter is reduced. Because each late pregnant or lactating ewe is worth greater than 1 DSE she can be replaced by more than 1 wether in the flock. Therefore there will be more sheep run per hectare for the same grazing pressure on the pastures.

Table 4: Mid-winter flock structure of the different enterprises modelled (% of total DSE’s)

	Joined Ewes	Replacement Ewes	Wethers
Self Replacing			
Weaners	84%	14%	0%
Yearlings	73%	13%	13%
3YO's	54%	9%	36%
5YO's	43%	7%	49%
Dual Purpose			
Weaners	99%	0%	0%
Yearlings	69%	15%	15%
Prime Lamb			
Weaners	99%	0%	0%
Yearlings	65%	17%	17%

Flock structure is expected to have a big impact on the quantity and quality of wool and meat produced and therefore a large impact on the findings of this report.

Weaning Percentages

The self replacing merino flock was assumed to have a weaning percentage of 80%, the dual purpose system was given a weaning percentage of 95% and the prime lamb systems were given weaning percentages of 120%. These are slightly higher than the Holmes Sackett and Associates benchmarking averages over 6 years (Table 5).

Table 5: Average weaning percentages from Holmes Sackett and Associates Benchmarking (1997-2003)

	Wool Flocks	Dual Purpose Flocks	Prime Lamb Flocks
Average	78%	86%	108%

Section 2: Impact of Flock Structure on Product Mix

Table 6: shows the relative product mix for each of the standard enterprises modelled.

Wool Quantity

As the flock structure changes from selling weaners to then yearlings to 3 and 5 year old wethers the amount of wool produced per hectare increases. This is because there are less breeding ewes which have higher feed demand, therefore more dry sheep can be run per hectare. The combination of more sheep per hectare and adult wethers cutting more kilograms of wool per head means the wool cut per hectare increases.

Wool Quality

There is also an impact of flock structure on the wool quality of the clip. In a self replacing wool flock the yearling system has the lowest average fibre diameter of any flock structure because there is a greater proportion of wool harvested from the young stock shorn each year. Both the weaner and 3 and 5 year old wether systems have a broader average clip fibre diameter due to a lower proportion of the clip coming from young sheep.

The impact of a finer clip will be greater as the flock average becomes finer because the premiums are larger. Half a micron difference in an 18 micron flock means more than half a micron difference in a 22 micron flock.

This does not apply for the dual purpose and prime lamb systems as the crossbred progeny have higher fibre diameter wool than the ewes and therefore shearing more young sheep results in an increase in the average fibre diameter and a lower fleece value.

Sheep Meat Quantity

The impact of flock structure on the amount of meat produced per hectare is determined by the age at which the sheep mature and liveweight gain begins to slow. Selling yearlings provides more kilograms of sheep meat per year than selling weaners because the lambs continue to grow rapidly past their first birthday. Retaining them in the flock past approximately 18 months of age decreases the amount of sheep meat produced per hectare because each individual gains very little weight.

Based on the assumptions of live weights and age at sale (Table 6:), keeping sheep in any system until they are between one and two years of age will increase the kilograms of sheep meat per hectare above that achieved by turning off weaners. However, beyond two years of age the sheep meat production per hectare begins to fall.

The increase in meat turn-off when comparing the weaner system to the yearling system for both the dual purpose and prime lamb flocks (Table 6:) is proportionally a lot higher than the corresponding systems in the wool flocks because there is also a shift in lambing time from June to August. This means that the ewes are no longer lactating through the middle of winter and therefore more sheep can be run per hectare.

Sheep Meat Quality

As flock structure changes from selling weaners to yearlings then to 3 and 5 year old wethers the quality and value of sheep meat produced is diminished. There is progressively less lamb and more of the older age categories sold. In the analysis of the impact of this on income, and therefore profitability it is assumed the yearling meat is of lower value than lamb but higher than mutton.

Table 6: Per hectare production for each enterprise and flock structure.

	Wool		Sheep meat (Kg Lwt/Ha)			
	F.D.	**Kg Clean /Ha**	**Total**	**Lamb**	**Yearling**	**Mutton**
Self Replacing						
Weaners	20.6	38	188	81	36	71
Yearlings	20.4	40	197	0	135	62
3YO's	20.5	44	166	0	24	143
5YO's	20.8	46	130	0	19	111
Dual Purpose						
Weaners	22.0	29	322	254	0	68
Yearlings	23.9	46	411	0	344	67
Prime Lamb						
Weaners	29.0	21	340	278	0	62
Yearlings	28.2	38	431	0	369	62

Key findings on product mix

In a self replacing merino flock the yearling system will:

- Have higher wool cut per hectare than a weaner system but lower wool cut per hectare than if wethers are retained past 2 years of age.
- Will lower fibre diameter of the clip to a greater percentage of wool produced coming from a younger age group. Whether this translates into increased value may be dependent on being able to maintain staple strength.
- Will provide maximum kilograms of meat produced per hectare
- Will have no lamb meat available for sale but will have a large volume of hogget meat for sale which is assumed to be at a premium to mutton.

Section 3: Impact of Flock Structure on Returns

A change in the product mix will have varied implications depending on the relative values of the different products at the time. To gain some appreciation of the impact of this we have used ten and one year average historical prices as well as top quartile and bottom quartile prices over the previous ten year period. The price assumptions used are shown in Table 7 and Table 8:

Table 7: Wool price assumptions used in the model

	1 year		10 year	
Micron	**Average**	**Bottom 25%**	**Average**	**Top 25%**
17	1242	1048	1830	2463
18	1047	1002	1371	1816
19	983	829	1070	1340
20	943	679	859	1084
21	925	545	763	986
22	911	489	709	971
23	891	465	660	966
24	866	455	642	955
25	807	442	617	914
26	753	428	588	859
27	661	420	557	769
28	569	410	531	690
29	527	391	508	656
30	485	371	483	601
31	459	364	469	577

Source: Information Commodity Services

Table 8: Mutton price assumptions used in the model

	1 year		10 year	
	Average	**Average**	**Bottom 25%**	**Top 25%**
Lambs (18-20kg c/kg Dwt)	388	136	221	343
Mutton Wethers (18-24kg c/kg Dwt)	219	69	108	182

Source: Information Commodity Services

A standard discount of 30% was given to the light merino weaner lambs based on the average discount they have incurred from 16-18kg lambs over the past seven years in the Wagga sale yards. In turn the yearling product was discounted 25% from the lamb product which is thought to be reflective of actual discounts received from abattoirs. This was an estimated discount and is not supported by price data. All sheep are assumed to be sold off shears and are therefore given a nominal skin value. The lamb skins were given $10, yearling skins were given $7, adult merino sheep were given $5 and crossbred adult sheep were given $3. This price structure reflects the current prices at the time of writing and was not varied under differing wool and sheep meat price scenarios.

The enterprise costs of the different systems are incorporated in the gross margin analysis that follows the analysis of income generating ability. The main variation in enterprise costs per hectare is caused by changes in the number of sheep run per hectare, however there are also changes associated with additional feeding costs for weaners and breeding ewes compared to dry sheep.

Impact of flock structure on income generated per hectare

10 year average prices

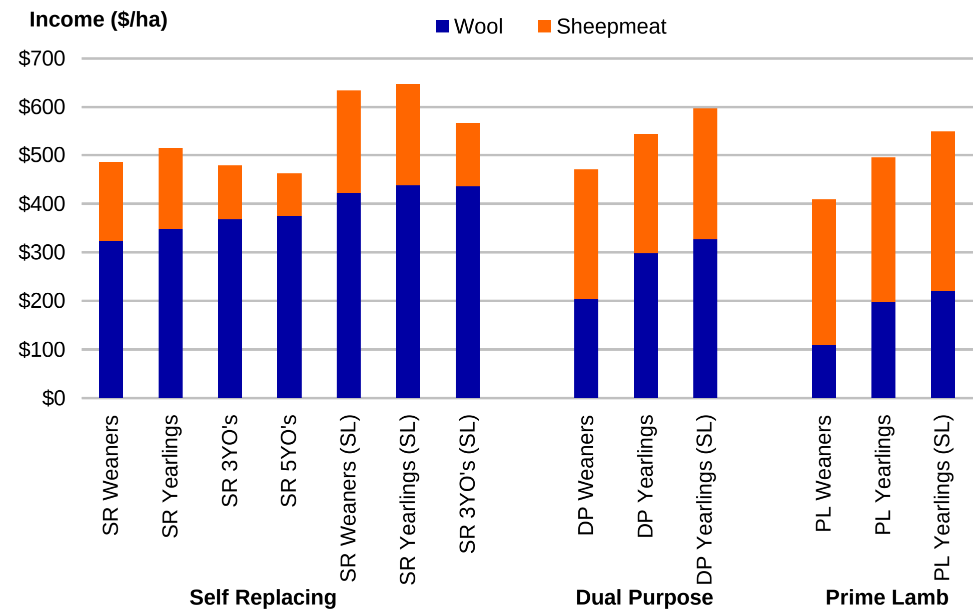
Under ten year average prices the yearling system has the potential to improve income per hectare over and above other flock structures and also other enterprise mixes should a change in lambing time be incorporated.

Graph 1 shows the relative income generated per hectare using ten year average wool, lamb and mutton prices.

The self replacing merino yearling sheep system, 'SR Yearling' produces $515 per hectare of income which is approximately $30-$55 per hectare more than the other winter lambing wool systems. This occurs because it has the optimum mix of sheep meat and wool income.

The large gains in sheep meat income over the wether systems are not offset by the reduction in wool income in the yearling system. In turn the yearling system has a higher wool and sheep meat income that the weaner system.

Graph 1: Income per hectare (10 Year Average Prices)



The labels *'SR Weaners (SL)'*, *'SR Yearlings (SL)'* and *'SR 3YO's (SL)'* represent the income earned per hectare if the lambing time was changed to spring (1st of September) from winter (15th July) for the more traditional flocks. In all cases there would be a significant increase in income generated per hectare due to more stock being run through winter.

The model has assumed no change in live weights of animals sold. Therefore in the weaner system the lambs would have to reach their target weights on feed produced outside the normal spring growing season. This would require specialty summer active pastures that are capable of providing high quality feed such as lucerne. The difficulty in achieving a saleable weight in summer with merino lambs, let alone the increased difficulty in managing them for survival through summer is a common reason for not moving to a Spring lambing.

The yearling and 3 year old wether systems require less emphasis on weight gain through the first summer as all lambs would have another spring at least on which to reach their specified sale weight.

There may however be a reduction in sale weight in a spring lambing system husbandry system, but such a large proportion of the income comes from wool that it would require virtually no income from the sale of sheep to reduce spring lambing income back to levels equivalent to those produced in an equivalent winter lambing system.

Note that the change to a spring lambing favoured the weaner system more than the 3YO wether system. This is because there are more ewes in the weaner system and therefore more additional space is created by lowering the feed requirements of the ewes through winter.

The dual purpose flocks have a much lower proportion of their income coming from wool as opposed to meat and using 10 year average prices the weaner system does not produce as much income as the self replacing wool flocks, however the yearling dual purpose system has a $29 per hectare higher income than the yearling wool flock.

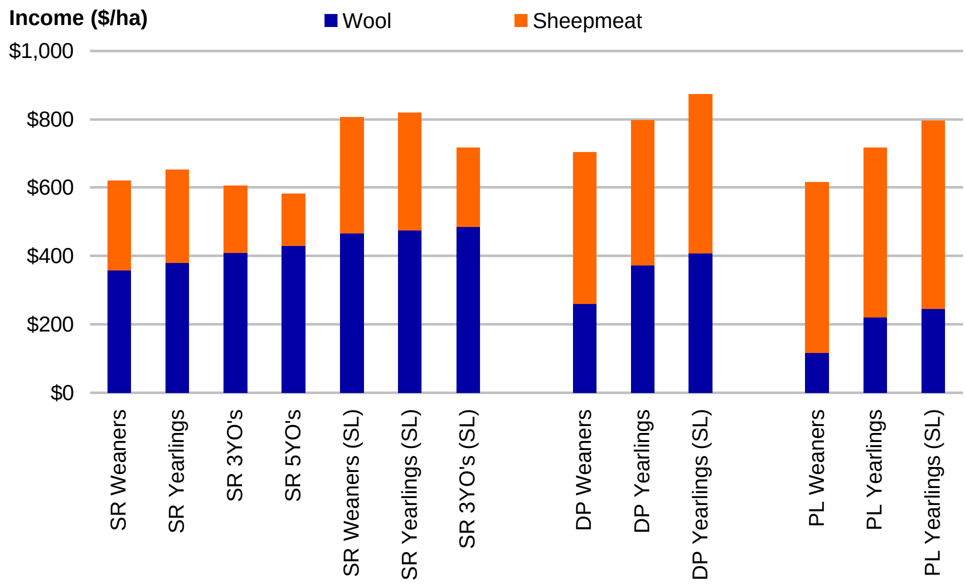
The change in lambing time from June to August in the yearling dual purpose flock will contribute a large proportion of the total increase in income generated per hectare. A further shift from the 1st of August to the 1st of September ('DP Yearlings SL') increases the income generated per hectare by $53 over the August lambing 'DP Yearling Flock'. This is purely a stocking rate benefit as weights at sale are held constant.

The traditional prime lamb weaner system underperforms the other enterprises using 10 year average prices with significantly lower wool income per hectare even though the meat income per hectare is substantially higher.

Current prices

Under current market prices a spring lambing yearling wool system will provide comparable income earning potential to any other enterprise analysed. Current prices were determined by averaging the past 12 month's wool and sheep meat prices. Graph 2 shows the impact of flock structure on income generated under the current prices.

Graph 2: Income per hectare (current prices)

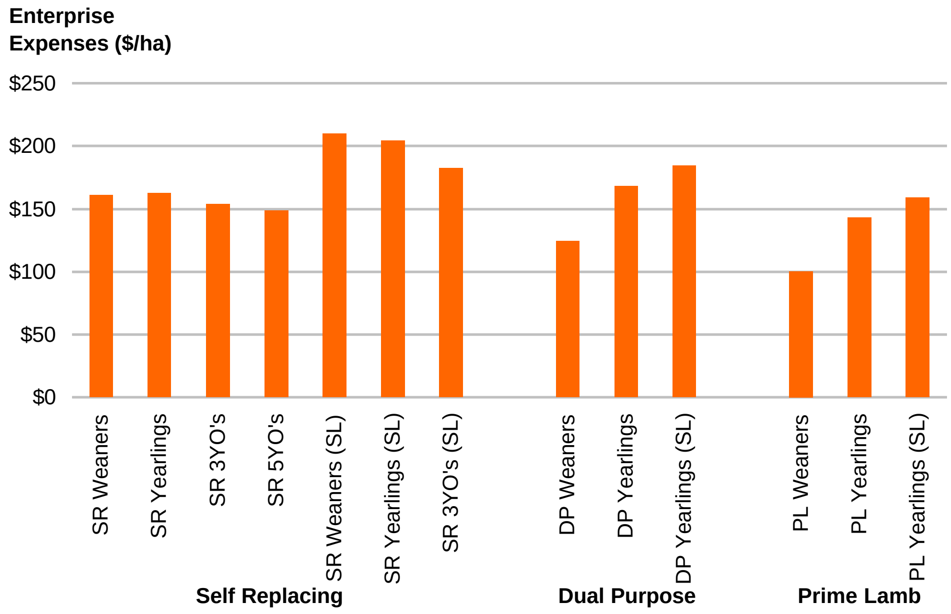


Again in the self replacing merino flocks the yearling sheep system has the highest income generating ability and this is further increased by a shift in lambing time to the spring. The main difference between the 10 year average prices and the current prices is that sheep meat is contributing to a larger percentage of the total income. This means that dual purpose enterprises have more income generating ability than any of the equivalent wool enterprises with the same lambing time. The prime lamb systems are competitive with the wool and dual purpose enterprises in their ability to generate income.

Impact of Flock Structure on Gross Margins

As mentioned previously changes in flock structure and the associated stocking rates bring about changes in enterprise expenses per hectare. Graph 3 shows the variation in enterprise expenses per hectare when 10 year average prices are used. Enterprise expenses vary with prices due to the inclusion of selling costs.

Graph 3: Enterprise expenses (10 year average prices)



10 year Average Prices

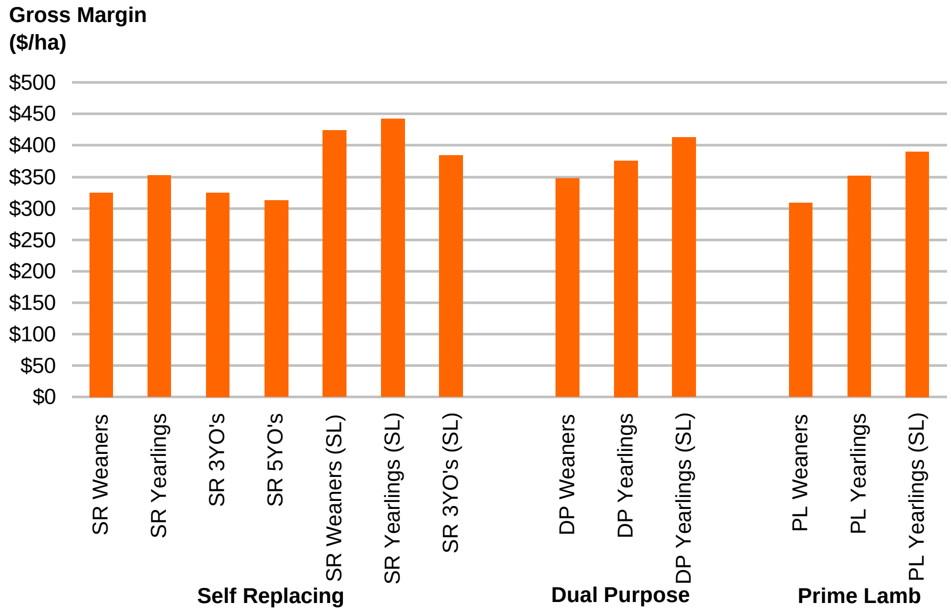
Accounting for enterprise expenses narrowed the differences in gross margins between enterprises and flock structures (Graph 4). For instance the difference between the income produced in the 3 year old wether flock structure and the yearling flock structure was $53 per hectare. However the difference in gross margins was $40 per hectare. Whilst these reductions occurred across the board there was no change in rankings as a result.

Using ten year average prices a spring lambing yearling wool system has the highest gross margins per hectare.

Of the self replacing merino wool enterprises, the yearling system produces the highest gross margin per hectare with a $27-$40 advantage over the other winter lambing flock structures, however these gross margins are $30-$40 behind the spring lambing systems.

Dual purpose gross margins are superior to the winter lambing wool systems, however the spring lambing yearling wool system is at least $30 per hectare above any other system

Graph 4: Gross margin (10 year average prices)



Current Prices

As was the case when using ten year average prices, the inclusion of enterprise expenses reduced the differences between enterprises and flock structures. Under current market prices the dual purpose enterprises have the highest gross margins and would therefore be useful in boosting farm profitability.

Graph 5 shows the yearling wool flock structure has a $33-$61 per hectare advantage over the other self replacing merino wool flock structures. The dual purpose gross margins out performed the winter lambing wool enterprises by upwards of $100 per hectare, however a switch to spring lambing would lift gross margins for the wool enterprises to within $70 per hectare of the dual purpose enterprises.

Prime lamb enterprises are competitive with the wool enterprises but lag behind the dual purpose enterprises. This is consistent with recent Holmes Sackett and Associates benchmarking data for non-drought affected properties (Table 9).

Graph 5: Gross Margin (current prices)

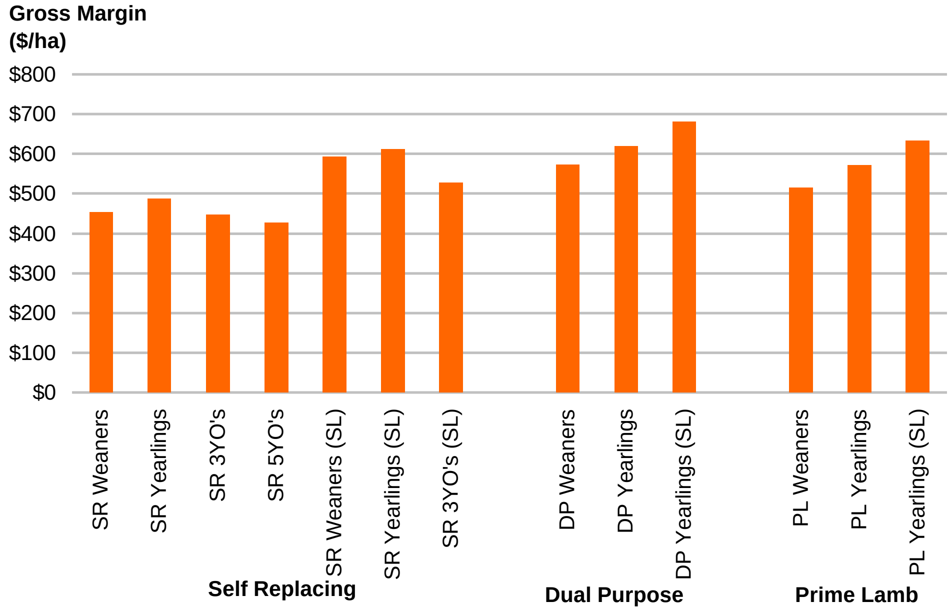


Table 9: Benchmarked enterprise gross margins.

	Wool Flocks	Dual Purpose Flocks	Prime Lamb Flocks
2001/02 Av. Gross Margin ($/DSE)	$23.36	$30.19	$25.04
2002/03 Av. Gross Margin ($/DSE)	$21.56	$24.54	$23.70

Source: Holmes Sackett and Associates

Impact of Flock Structure on Profits

Labour expenses were classified as overhead costs because whether they translate into an actual cost to the business is determined by whether the current labour resources are utilised fully. The methodology for accounting for labour costs is described below. Based on analysis of Holmes Sackett and Associates benchmarking direct labour related costs typically make up 45% of total overhead costs so the labour cost per hectare was divided by 45% to determine the total overhead costs for each enterprise. These were then deducted from the gross margins to determine the relative profitability of each enterprise.

Labour costs are assumed to vary according to which enterprise is being run. For the purposes of this model each animal was assigned a unit cost for labour and a multiple according to how intensively they are managed. These are shown in Table 10.

Table 10: Unit costs of labour

Cost Per Unit of Labour	$4
Stock Class	Multiple
Merino Weaners	2
Crossbred Weaner	1.5
1 Year Old	1.5
Breeding Ewe	1.5
Dry Ewe	1
Wether	1

In the 3 year old wether system which is thought to best represent the majority of the industry the labour cost per DSE was $5.50 which is similar to the five year Holmes Sackett and Associates benchmarking average for wool flocks of $5.43. The variation in labour costs per mid winter DSE is shown in Table 11.

Table 11: Variation in labour costs per mid winter DSE

	$/DSE
Self Replacing	
Weaners	$6.21
Yearlings	$6.28
3YO's	$5.49
5YO's	$5.04
Weaners (SL)	$8.09
Yearlings (SL)	$7.89
3YO's (SL)	$6.49
Dual Purpose	
Weaners	$4.77
Yearlings	$6.77
Yearlings (SL)	$7.43
Prime Lamb	
Weaners	$4.19
Yearlings	$6.17
Yearlings (SL)	$6.85

The labour costs decrease with increasing age at sale as there are less weaners and breeding ewes which have the higher labour inputs for the flock. They also increase with a change to spring lambing as there are more sheep run per mid winter DSE which requires more labour input.

10 year average prices

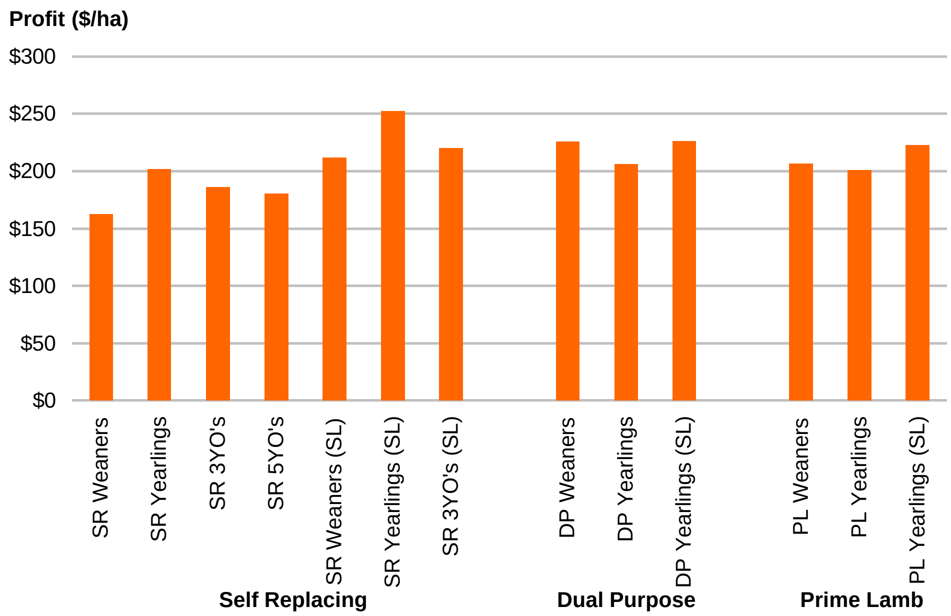
After labour costs are accounted for the winter lambing wool system generates the highest profit per hectare of the winter lambing flock structures. However, dual purpose enterprises are more profitable than winter lambing wool enterprises. The spring lambing wool system is the most profitable of all enterprises and flock structures.

Factoring in additional labour costs dramatically reduces the differences in profits between enterprises and different flock structures. As an example where the spring lambing yearling wool system had a $90 per hectare advantage in gross margin it has a $50 advantage in profit (Graph 6).

The winter lambing weaner wool flock structure, which had a higher gross margin than the wether flock structures, has a lower profit per hectare assuming the increased labour costs actually transpire. The increased labour costs come from the additional sheep being run per hectare which will require additional labour. If the current labour resources are fully utilised this will be an additional cost to the business. Therefore the availability of labour and the ability to cope with the increased labour demands will be an important consideration in any decision on a change in flock structure.

The winter lambing yearling wool production flock structure remains more profitable than the other winter lambing enterprises. Under these assumptions the spring lambing yearling system is more profitable than any other enterprise or flock structure by upwards of $25 per hectare.

Graph 6: Profit (10 Year Average Prices)



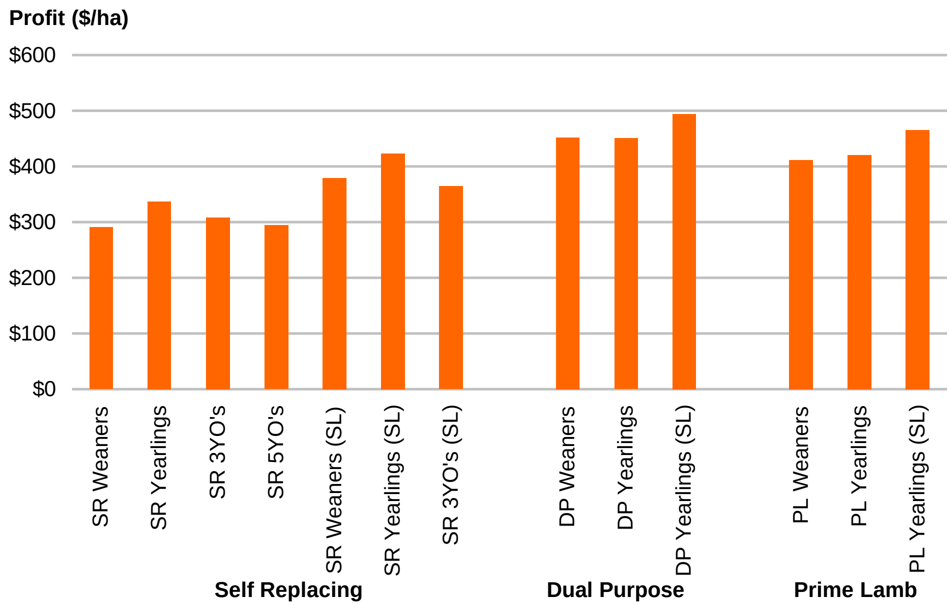
Current Prices

In the current market the dual purpose flocks, with their additional meat income are substantially more profitable than the wool enterprises.

At current market prices (

Graph 7) the dual purpose system is the most profitable system with a 25-55% advantage over the equivalent wool production systems. Within the self-replacing merino wool systems the yearling system remains the most profitable with the benefits from a change in lambing time still apparent.

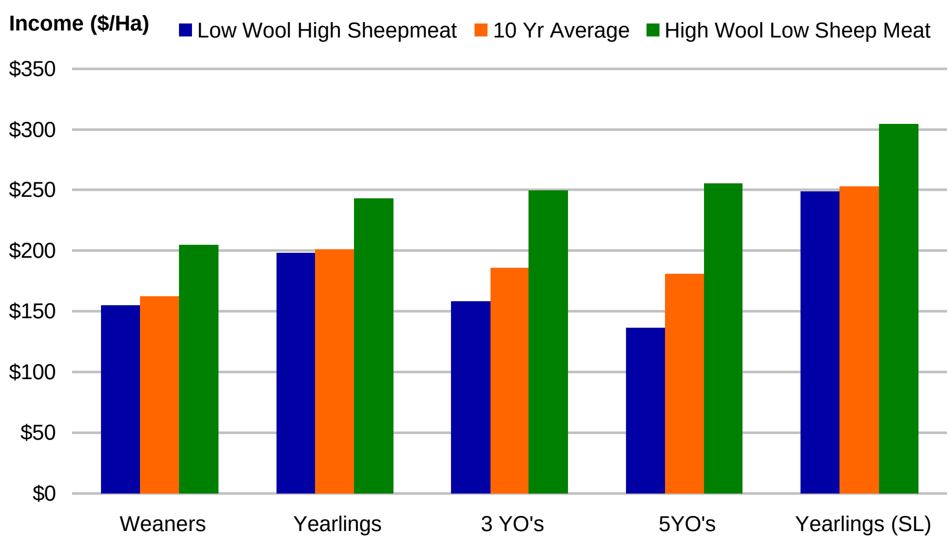
Graph 7: Profit (Current Prices)



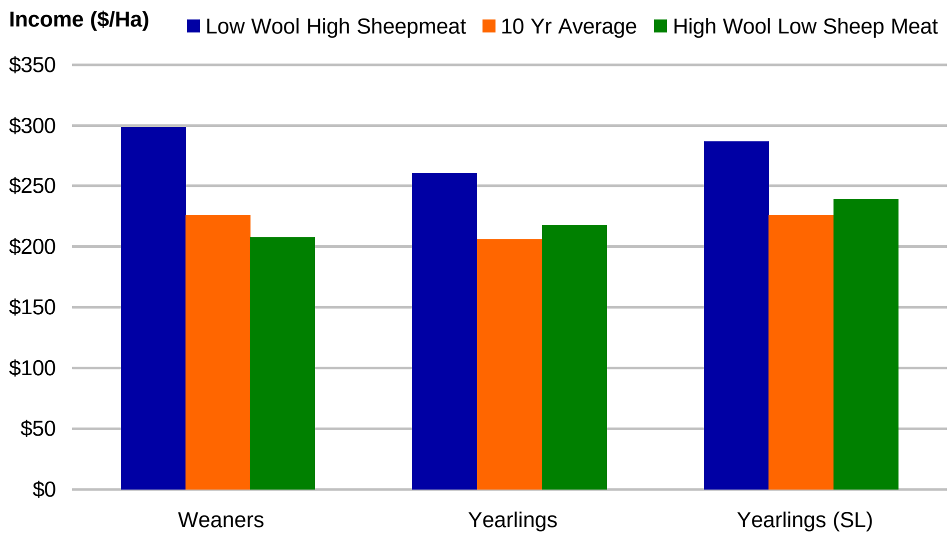
Sensitivity to Extreme Market Scenarios

The impact of extreme market scenarios on the profitability of the different flock structures within each enterprise is shown in Graph 8. The high price scenario is a top 25% wool or sheep meat price over the last ten years, while the low wool price scenario is bottom 25% wool or sheep meat price over the last ten years.

Graph 8: Self Replacing Merino Wool Flock Structures



Graph 9: Dual Purpose Flock Structures



High Wool Prices and Low Sheep meat Prices

The self replacing merino yearling sheep system and the dual purpose systems are the most resilient to extreme fluctuation in market prices due to their balance of sheep meat and wool products.

A high wool price, low sheep meat price scenario has a large impact on profitability of the wool enterprises (Graph 8). For all wool enterprises shown it improves the profitability by upwards of $50 per hectare. Most notably, however it increases the wether dominant flocks profitability over that of the ewe dominant flocks turning off weaners or yearlings. This is because a large portion of the income of these flocks comes from wool rather than meat therefore any increase in wool prices has a larger impact on the total flock income.

The spring lambing yearling sheep system profits rise to over $300 per hectare which is comparable to the best dual purpose profits modelled.

A high wool market with a low sheep meat market has only a minor impact on dual purpose flock profitability because the relative incomes from each are more evenly spread with between 35% and 55% of income coming from sheep meat using average market prices (Graph 9). Therefore, some of the gains from the improved wool income are offset by reduction in sheep meat incomes.

Low Wool Prices and High Sheep meat Prices

Low wool prices and high sheep meat prices reduce self replacing merino wool flock profits across the board (Graph 8). However, the weaner and yearling flock structures are more resilient than the wether flock structures as a greater portion of the income comes from sheep meat. While the wether flock structures lose $20 to $50 per hectare in profits, the yearling and weaner flock structures lose less than $10.

The dual purpose systems gain more than $50 per hectare in profits from the low wool market and high sheep meat market scenario, with the weaner system outperforming the yearling system due to a higher percentage of income coming from sheep meat.

Section 4: Discussion of qualitative issues

Gross margin models do capture the animal health impacts of changes to a production system or the increased demands on management resources. Results suggesting a move to a more ewe dominant flock should be viewed with some caution. Holmes Sackett and Associates benchmarking data over the previous two years whilst mutton and lamb prices have been high shows that those flocks that have less than 20% wethers have produced a lower profit than those with 20-60% wethers.

These benchmarking results would suggest that constraints to capturing the benefits of the increased sheep meat income from a ewe dominant flock exist in practice.

Table 12: The most profitable flock structure remains one with 20-60% wethers

	<20%	**20-60%**
Sheep Trading	$8.29	$5.49
Wool	$22.13	$28.50
Income/DSE	**$30.36**	**$33.92**
Enterprise Expenses/DSE	**$10.29**	**$10.19**
Gross Margin/DSE	**$20.08**	**$23.74**
Total Expenses/DSE	**$24.70**	**$24.19**
Net Profit/DSE	**$5.67**	**$9.73**
No of Flocks	**32**	**128**

Results are from 2001/02 and non drought flocks in 2002/03

The gross margin model that has been used in this case does attempt to account for the impact of changes in flock structure on the numbers of each class of animal that can be carried through winter by utilising the mid-winter stocking rate. However, it does not explicitly capture the impacts with regard to the following issues:

- Autumn stocking rates
- Pasture resources and weight gains
- Labour
- Parasite control.
- Differences between merino bloodlines.

Autumn stocking rates

It is normal in southern and eastern Australia for winter to be the bottleneck in terms of feed availability with which all stock units must pass through on a farm each year, and hence the focus on winter stocking rates. However, by changing the flock structure and lambing time to run more ewes through winter you place increasing pressure on autumn pastures and therefore you pull that bottleneck closer to the autumn. This happens because more sheep are run through summer which means that there is a faster utilisation of the available dry matter left from the previous spring.

This model does not account for this, and in fact assumes that a change to spring lambing and selling all progeny as weaners will have no impact on the farms ability to provide adequate nutrition to sheep through autumn. This may not necessarily be the case with greater amount of supplementary feeding required which begins to erode the perceived advantages calculated in the model. The impact of this is better tested with tool such as GrassGro in specific locations over a number of actual growing seasons.

Pasture resources and weight gains

Profitable wool production can occur on pastures that are considered below optimum for weight gain. In fact the lower the quality and quantity of feed given to the sheep, provided it meets the minimum survival requirements, the better the product may be at the end of the year as it will be finer. This will have an impact on price received which may outweigh any loss in cut per head in the finer fibre diameter bloodlines.

Production systems that require weight gain require not only good pasture availability but also good pasture quality with a significant legume component to maximise weight gains. In doing the gross margin modelling of changes to yearling sheep systems, or dual purpose and prime lamb systems where there is a greater dependence on achieving weight gain, the model assumes that the pasture resources are available.

In the gross margin models used for this project, an end of spring sale would go some way to ensuring that the nutritional requirements are met. However, not all farms and perhaps not all areas may be capable of achieving the desired weight gains to meet the modelled targets whilst still providing the ewe portion of the flock with its required nutrition.

In addition there is an issue of grass seeds in pastures and their impact on weaner productivity. Where grass seeds are a major constraint keeping lambs may not be an option.

Again Grassgro modelling may be useful in determining whether location and also pasture quality will have a role in the ability to adopt more profitable systems shown in this gross margin analysis.

Labour

As was mentioned earlier the labour inputs required for different classes of sheep differ. A spring born weaner has a much higher labour requirement than a four year old wether. Whether this translates to dollars for the individual farm will be dependent on whether the farm currently has full utilisation of labour or not. If the farm is fully utilising its labour then it will require cash to hire more. If there is excess labour available then the additional requirements may easily be soaked up with the current resources available by working harder.

In the modelling done for this project we have used a reasonably crude estimation of relative labour costs and it cannot be expected to represent the individual farm. We have included it as a variable overhead cost because it does need to be considered when contemplating a change in enterprise.

Parasites

As drench resistance is now common to all of the currently available active compounds, worm control on farms is an increasing problem. Part of the solution to that problem is to utilise the inherent differences in the ability of different classes of sheep to suppress worm burdens through their natural immunity. Grazing a pasture with an adult wether, which has a natural immune response to worm burdens, can reduce the worm eggs that are shed in faeces onto the pasture. This strategy reduces the contamination level on the pasture and therefore can be utilised to prepare a lower risk paddock for the more susceptible classes of sheep such as weaners and lactating ewes.

This is particularly pertinent to farms where the sheep enterprise dominates the enterprise mix on the farm. The higher the breeding ewe numbers the harder it is to maintain safe pastures for susceptible stock and therefore there is increased risk of production loss and/or increases in enterprise costs through additional drenching and labour requirements.

This difficulty in flock management is not modelled in the project but may provide a major constraint. The subject of worm control needs to be given careful consideration when contemplating a change in flock structure.

Bloodline Differences

The model contains substantial assumptions about the ability of lambs, yearlings and wethers to reach a weight at a given age. Whilst the bloodline may not matter for 3-5 year old wethers in terms of their ability to reach a given weight, it may matter for weaners and yearlings.
As they stand, the current assumptions allow for no difference in maturity pattern of the young sheep. When we consider the possible differences between say a Saxon bloodline versus a South Australian merino bloodline there may in fact be substantial differences in their ability to reach a given weight by a specified age.
In future, the availability of across flock EBV's may help determine whether the right genetics are present to achieve a particular system.

Shearing Time

Fitting an appropriate shearing time for lambs into the husbandry calendar is a major challenge for producers. Consideration needs to be given to the expected discounts for staple strength, staple length, or for selling adult sheep in wool. There will always be a number of options for the producer and each individual will have to weigh up their options according to the potential problems associated with timing. Shearing should be a secondary issue to choice of lambing time.

A farm-level economic assessment of a Merino prime lamb finishing system.

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Final Report for Project 1.2.6

EXECUTIVE SUMMARY

In Australia very favourable prices for lamb and mutton since 2001 has provided incentive for traditional Merino wool producers to increase production of sheep meat. While some producers choose to mate a proportion of their ewes to terminal sires to improve meat production, others, like the Western Australian grower group MerinotechWA, choose to improve meat production without bringing in alternative genetics.

This paper reports on the profitability of finishing Merino wether lambs as prime lamb, and identifies how profit is influenced by age of turnoff and the proportion of wether lambs finished. The paper also estimates the level of feed required to achieve the turn-off target weights for the lambs being finished, for a range of seasons experienced up until weaning.

The analysis uses a biophysical simulation model (GrassGro) and a whole-farm bio-economic model (MIDAS) representing the Great Southern region of Western Australia.

Results indicate:

- At standard prices, finishing a high proportion of wether lambs at 7 months of age is more profitable than selling wether lambs as stores, yearlings or shippers.
- The average amount of grain required to finish 90% of merino lambs is 76kg. Approximately 54kg is required to finish 10% of merino lambs.
- Seasonal conditions before and after weaning has a similar impact on the amount of supplement required to finish lambs. Producers need to retain up to 85kg/lamb in a poor season if they are aiming to finish 90% of their merino lambs.
- When grain prices are high or when sheep prices are low, it is more profitable to sell wether lambs as stores or yearlings than to finish Merino prime lambs.
- High quality paddock feed is better utilised feeding finished lambs than improving ewe reproductive rate.
- Very little difference in profit is generated from selecting lambs for finishing by weight compared with a random draft.

1. BACKGROUND

Wool production has been a long-standing feature of broadacre farming in Australia. However, in the 1990s many farmers began to question the financial wisdom of committing so many farm resources to wool production. Since the collapse of The Reserve Price Scheme in 1991, low wool prices have persisted. Competitive fibres (cotton and synthetics) expanded their value and share of wool end use markets; and more casual dressing in developed countries and increased use of wool blends rather than pure wool in developing countries restricted growth in demand for wool.

Also affecting wool production in the 1990s were large increases in grain prices during the mid-1990s. These heightened prices, combined with several favourable growing seasons, particularly in Western Australia, strongly shifted the profit relativity toward cropping and away from wool production. Also, a resurgence in sheepmeat prices in the early 2000s encouraged interest in meat production (Figure 1).

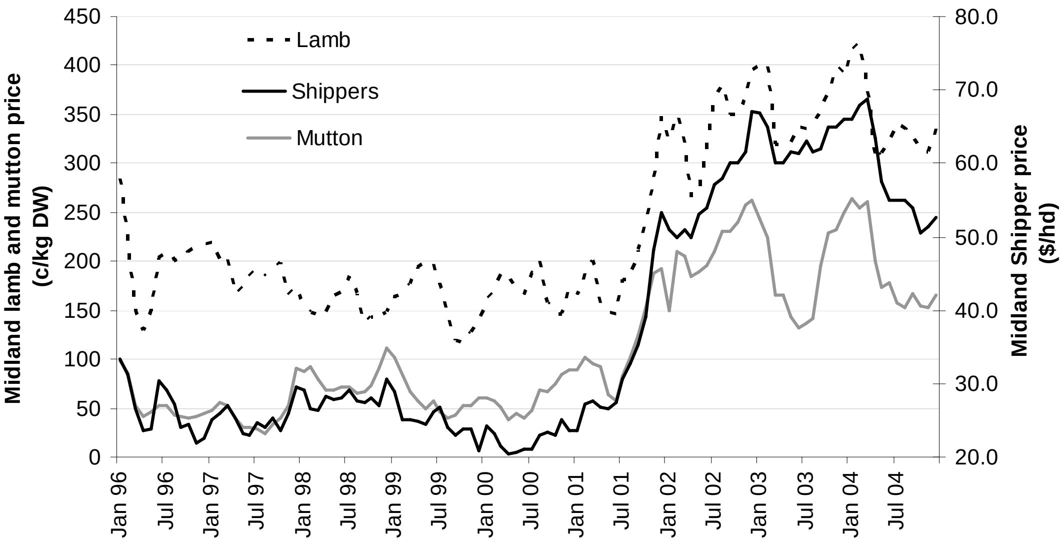


Figure 1: Lamb, mutton and shipper weekly sale prices.
Source: Elders Weekly, Midland Saleyards, medium – condition score 3 animals

It is against this backdrop of a prolonged period of diminished profitability of wool production, that many Australian wool producers began to consider how they might increase meat production without compromising their wool enterprise. Many farmers, including the producer group MerinotechWA, are curious about the merit of finishing merino wether lamb as prime lamb and wish to know how profitable this option is in their Western Australian broadacre farming systems.

Today some producers choose to mate a proportion of their ewes to terminal sires to improve meat production. However others, like MerinotechWA, choose to improve meat production within their merino genetic base without bringing in alternative breeds. They believe that finishing merino wethers as prime lambs can be profitable, and do not wish to spend time learning the new techniques necessary for introducing terminal sires to their production system.

MerinotechWA wish to better understand certain issues associated with finishing Merino lamb as prime lamb. They believe competition for the limited amount of high quality feed that is available on the farm in early summer could impact profit. It is during this period that lambs being finished require high quality feed. It is also at this time that breeding ewes require improved nutrition in order to achieve high lambing percentages. MerinotechWA are also curious about the level of feeding required to achieve the turn-off targets for the lambs being finished, and how the season experienced up until weaning and the season post weaning is likely to influence this.

Using a biophysical simulation model that draws on historical climate data from Kojonup in Southern Western Australia, the level of feed required to meet a range of turn-off specifications was examined for a range of seasonal conditions experienced up until weaning.

Using a whole farm model that typifies a mixed crop and livestock farming system in a region of southern Western Australia, the profitability of turning off different proportions of wether lambs at different ages was examined. The analysis also examines the profit trade off between feeding ewes to improve reproductive rate and feeding lambs to meet target weight. The profitability under varying commodity price scenarios is also examined to determine the robustness of the optimal turnoff scenarios.

2. METHOD

2.1 Supplementary feeding required to finish Merino prime lamb

Model background

The first part of this analysis was completed using the GrassGro™ model, version 2.4.3. GrassGro is biophysical simulation model which uses historical climate data to simulate pasture growth and the performance of livestock over a range of years. The user can select the locality, pasture type, soil type, enterprise, livestock genotype, management (time of lambing, stocking rate, time of sales etc) and costs/prices. The model generates information on a number of production variables, and generates gross margins for each year. A strength of GrassGro is its ability to calculate pasture and animal production in the paddock over a range of seasonal conditions.

Analysis description

Grassgro was used to generate pasture growth, pasture quality, stock intake, quantity of supplements and liveweight data-sets, for a range of scenarios from weaning (1st November) to the time of sale of lambs (28th February, 31st March or 30th April), which were then used in the MIDAS model. The scenarios investigated at weaning were as follows:

- Average feed on offer (4000 kg DM/ha)/average dry matter digestibility (68 DMD %)
- High feed on offer (5000 kg DM/ha)/High dry matter digestibility (75 DMD %)
- High feed on offer (5000 kg DM/ha)/low dry matter digestibility (60 DMD %)
- Low feed on offer (3000 kg DM/ha)/high dry matter digestibility (75 DMD %)
- Low feed on offer (3000 kg DM/ha)/low dry matter digestibility (60 DMD %)

In addition to varying the starting feed conditions for the GrassGro simulations, lamb weaning weight was also a variable, with a starting weight of 20,25,30 or 35 kg liveweight used.

Model assumptions

GrassGro simulations were run from 1966 to 2001, and the following assumptions were used:

- Annual grass/sub clover based pasture on a sandy loam soil with good fertility.
- Merino lambs were stocked at 15 lambs/ha from 1st November and sold at 49 kg liveweight or by the 28th February, 31st March or 30th April.
- Lambs were shorn 2 months before sale date.
- Lambs were from a 55 kg Merino ewe (when in average condition) cutting 5 kg/head greasy wool with a fibre diameter of 20.5 µm.
- Supplementary feed was lupins (13.3 MJ ME/kg DM, 32% protein), and was fed to achieve the target liveweight by the target sale date.

2.2 Profitability of merino prime lamb

Model Background

This second part of this analysis was performed using the Great Southern version of MIDAS (Model of an Integrated Dryland Agricultural System) (GS-MIDAS). MIDAS is a whole farm profit optimising model which calculates a set of profit maximising enterprise and rotational activities based on an average season. Optimal combinations of enterprises are found through using detailed biological, technical and financial information to compare the relative profitability of various enterprise combinations. Enterprise interdependencies are a feature of the model, for example the effects on cereal yields of previous leguminous pastures are depicted. An advantage of MIDAS is its ability to take into account the feed profiles of the different feeds available on the farm and the feed requirements of the different classes of stock throughout the year. For a full description of MIDAS see Kingwell and Pannell (1987).

The GS-MIDAS model is based on a typical mixed crop and livestock farming system although sheep production is the dominant enterprise. The results are applicable to regions with rainfall between 500mm and 600mm (medium rainfall zone) in the shires of Kojonup, Boyup Brook, Cranbrook, West Arthur and Williams. The GS-MIDAS model assumes a farm size of 1000 ha and is made up of 5 soil types. For further description of the Great Southern Model see Morrison and Young (1991) and Young (1995).

Changes made to GS-MIDAS

The ability for GS-MIDAS to select lucerne as part of its optimal solution was restricted, as most MerinotechWA producers do not grow lucerne.

Changes were made to the GS-MIDAS to better represent meat and wool production from finished and retained lambs, due to different levels of feeding. In previous versions, finished and retained lambs were represented with the same weaning weight, fleece weight and fibre diameter, regardless of the proportion of lambs finished as prime lamb. Matt Kelly (UNE) (*pers comm.*) calculated the changes in these production characteristics for the various proportions of lambs finished (Table 1).

Table 1: Changes made to weaning weight, fleece weight and fibre diameter in the GS-MIDAS model to better represent meat and wool production from finished and retained lambs for a range of % turnoff scenarios. Figures calculated by Matt Kelly (UNE) (*pers comm.*). Absolute values for weaning weight are in brackets.

% of lambs finished as MPL	Weaning weight Finished lambs (kg)	Weaning weight Retained lambs (kg)	Fleece weight Finished lambs (kg clean)	Fleece weight Retained lambs (kg clean)	Fibre diameter Finished lambs (micron)	Fibre diameter Retained lambs (micron)
0% Random draft	0 (25.6)	0 (25.6)	0	0	0	0
10%	+7.4 (33.0)	-0.8 (24.8)	+0.22	-0.02	+0.125	-0.01
40%	+4.1 (29.7)	-2.7 (23.0)	+0.12	-0.08	+0.07	-0.05
60%	+2.7 (28.3)	-4.1 (21.5)	+0.08	-0.12	+0.05	-0.07
90%	+0.8 (26.4)	-7.4 (18.2)	+0.01	-0.22	+0.01	-0.125

Model assumptions

Historically many farmers in the study region, including the MerinotechWA farmers, have maintained Merino flocks and therefore wish to know the Merino flock structure which is most likely to be profitable across a range of commodity price scenarios. Accordingly, this paper examines the likely profitability of finishing Merino wether lambs as prime lamb in contrast to alternative self-replacing Merino flocks.

The flock options examined, as listed in Table 2, include a production emphasis on: Merino wool and Merino prime lambs (option 1); Merino wool and store lambs (option 2); Merino wool and merino yearlings (option 3); and Merino shippers (option 4) where wethers are exported live to Middle East markets.

The lambs chosen to be sold as prime lamb are allocated to a lamb finishing system prior to being sold. Lambing is in July/August, and shearing is in January.

Table 2: Description of flock structures represented in this analysis.

Flock	Description
Wool and Merino prime lamb *(MPL)*	A self-replacing Merino flock. Emphasis is on wool production. A proportion of wether progeny are finished and sold as merino prime lamb. Any wether progeny not finished are sold as yearling.
Wool and store lambs *(Store)*	A self-replacing Merino flock. Emphasis is on wool production. Wethers are sold as store lambs to other graziers.
Wool and yearlings *(Yearling)*	A self-replacing Merino flock. Emphasis is on wool production. Wethers are sold as yearlings
Wool and shippers (S*hipper)*	A self-replacing Merino flock. All wethers are sold as older shippers or as cast-for-age mutton.

Note: All flocks lamb in late July /August and are shorn in January.

Analysis description

Sensitivity analysis was carried out to identify how key lamb management decisions were likely to influence farm profit[1] of the MPL flock. The following ranges of scenarios were examined:

- Proportion of wether lambs sold as Merino prime lamb (10%, 40%, 60% and 90%)
- Selling wether lambs at different ages (7 months, 8 months, 9 months)

This was done for four ewe liveweight patterns to different allocation of quality feed to the ewes pre and post joining:

- Standard: standard live weight pattern currently in MIDAS
- Pattern A: better quality feed pre-joining, same quality feed post joining (the ewes remain heavier for many months following joining)
- Pattern B: feeding of higher quality feed begins earlier than Pattern A then poorer quality feed post joining so ewes drop back to same liveweight as ‘standard’ ewe by the break of season.
- Pattern C: better quality feed pre-joining (as per Pattern A) and poorer quality feed post joining (as per Pattern B)

[1] Profit is calculated as monies left over from production receipts after deducting all operating costs, overhead costs, depreciation and opportunity costs associated with farm assets (exclusive of land).

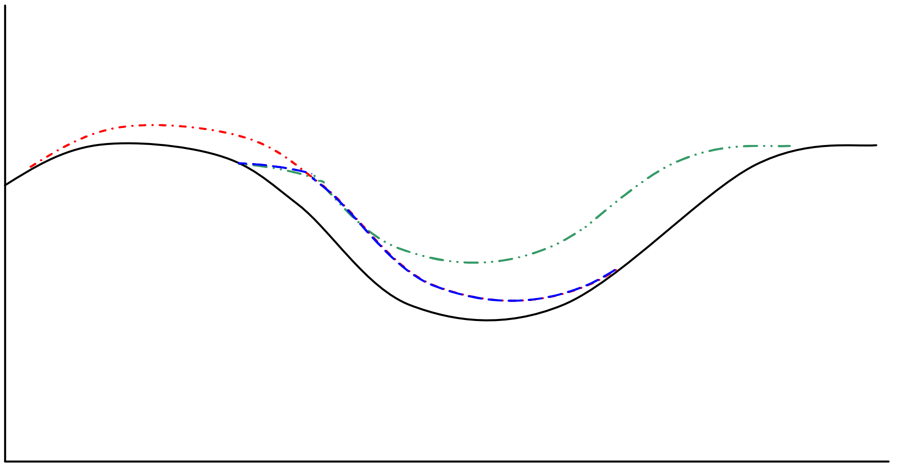


Figure 2: Stylised representation of changes in ewe liveweight pattern for a range of ewe feed supply conditions represented in this analysis.

To compare the profitability of selecting the lambs to be finished by random draft rather than on weight, the average weaning weight of all lambs was used to represent a random draft. The random draft was considered to have higher grain requirements for the finished lambs and a higher CFW and FD for the retained lambs (Table 1).

The base case or standard (Std) prices used in the analysis are outlined in Table 3. Standard prices are intended to represent medium term estimates and so do not directly correspond to current market prices.

Table 3: Scenarios for low (L), standard (S) and high (H) commodity prices.

	Wheat[1] $/t	Barley[2] $/t	Oats[3] $/t	Canola[4] $/t	Lupin[5] $/t		Wool[6] (c/kg)		Lamb[7] $/kg	Shipper[8] $/hd	Ewe[9] $/hd
L	156	160	112	300	160		610		1.50	30	25
S	**195**	**200**	**140**	**375**	**200**		**720**		**3.00**	**50**	**45**
H	234	240	168	450	240		865		4.50	70	65

1 Price for wheat APW 10% ($45/t freight, handling charges & levies to be removed).
2 Pool price for malt barley ($38/t freight, handling charges & levies to be removed).
3 Price of milling oats net at port ($17/t freight to be removed).
4 Price for canola with 42% oil ($44/t freight, handling charges & levies to be removed).
5 Price for lupin ($45/t freight, handling charges & levies to be removed).
6 Western Market Indicator (c/kg clean).
7 Sale yard price of prime lamb sold in January ($/kg dressed weight). Store lambs assumed to be $0.40/kg lower than prime lamb.
8 Price landed Perth (Commission and freight to be removed).
9 Saleyard price for 5½ yo ewes. 1½ yo ewes assumed to be $3/hd higher. 6½ yo ewes assumed to be $5/hd lower. Purchase price for ewe replacements is $2/hd higher (transport costs).

3. MODELLING RESULTS AND DISCUSSION

3.1 Supplementary feeding required for finishing Merino prime lamb

The approximate level of grain feeding required to achieve a Merino prime lamb turn-off target of 42kg at 7, 8 and 9 months of age, for a range of starting weaning weights (representing a range of seasons up till weaning), are shown in Figure 3 and Table 4 (see Appendix 4 for detailed data).

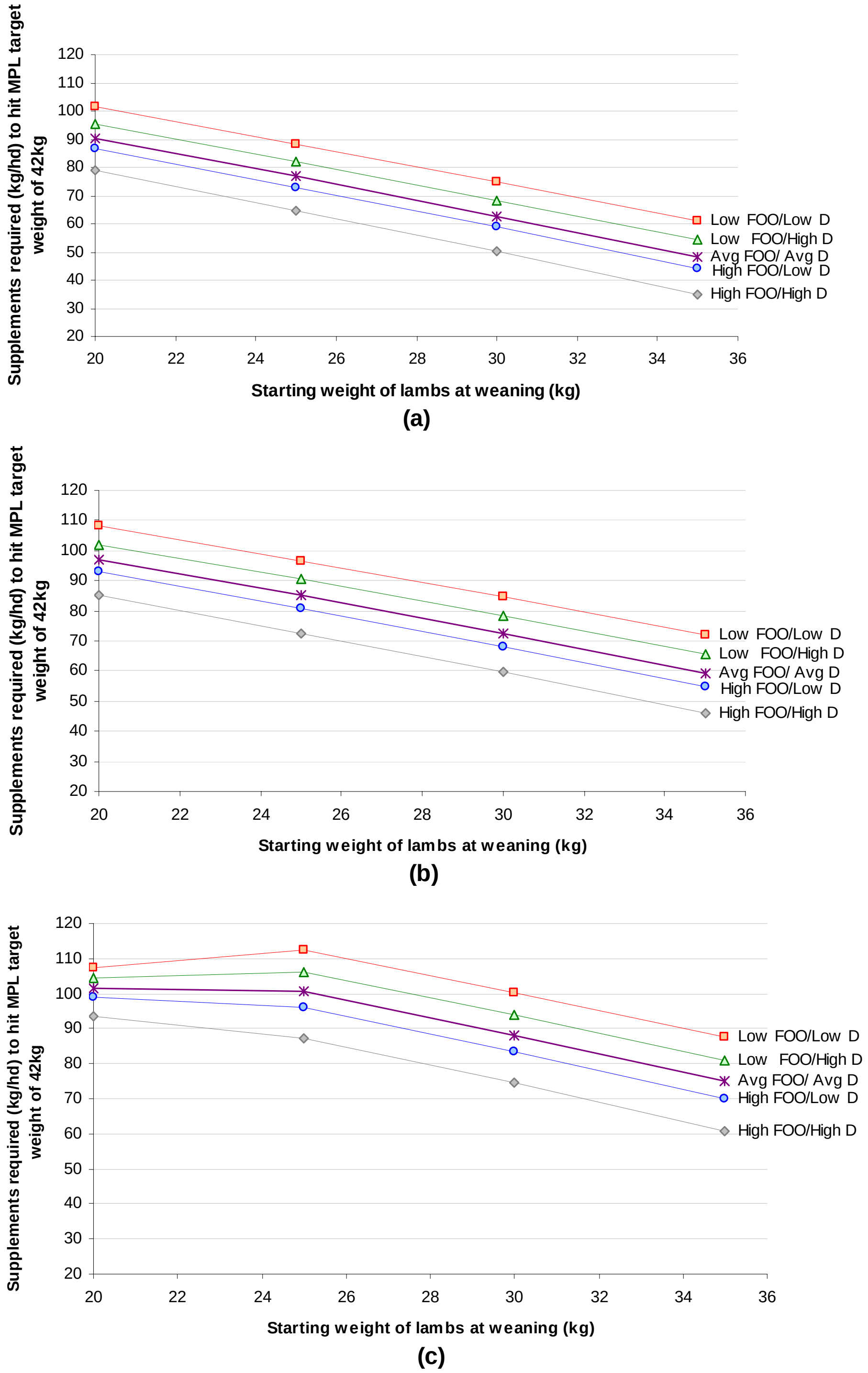


Figure 3: Supplements required (kg/hd) to hit MPL target weight of 42 kg for a range of season experienced up until weaning, and a range of weaning weights for prime lamb sold in a) Feb at 7 months of age; b) March at 8 months of age, c) April at 9 months of age.

Less grain is required to finish animals weaned at higher weights, the reduction is approximately 10kg/hd for every 5 kg of additional weight at weaning (Figure 3). The saving is slightly less for the later turnoff than earlier turnoff. Seasonal conditions up until weaning has a considerable impact on the amount of grain required to finish lambs to target weight. An additional 25kg/hd of grain is required in a bad season (low feed on offer, low digestibility) compared with a good season (high feed on offer, high digestibility) (Figure 3).

Table 4: Average grain required (kg/hd) to finish different proportions of merino lambs to the target specifications (42kg LW) by 7, 8 and 9 months of age. Includes the 10 & 90 percentiles for the range of season types experienced post weaning for turning off by 7 months of age.

Proportion of lambs finished	7 months			8 months	9 months
	90 percentile	Average	10 percentile	Average	Average
10%	65	54	40	65	80
40%	72	63	49	73	88
60%	78	68	55	78	93
90%	84	76	61	83	98

The season after weaning has a similar influence on the amount of grain required to achieve the turnoff targets (Table 4). For the range of seasonal conditions experienced after weaning during the period 1966 to 2001 the variation for the upper and lower 10 percentile is +/- 10-15kg/lamb. If producers want to retain sufficient grain to finish lambs in most seasons then up to 85kg/lamb will need to be retained if they are aiming to finish 90% of their merino lambs.

3.2 Profitability of Merino prime lamb flock relative to other Merino flocks

At standard prices, a self replacing flock finishing 90% of wether lambs as prime lamb at 7 months of age is the most profitable of the Merino flocks examined in this analysis (Table 5). This Merino prime lamb flock structure is more profitable than the store, yearling and shipper flocks by $7 400, $10 400, and $19 900 (standard prices). Other recent studies using GrassGro and a Sheep Flock model (Warn *et.al.* 2006) have also indicated that Merino flocks selling surplus lambs as stores or yearlings generated similar gross margins, and that profitability declined if wethers were kept to older ages.

The proportion of wether lambs finished as prime lamb, and the age which prime lamb are finished are integral to profitability of finishing Merino prime lambs. This is discussed further in section 4.3 and 4.4 of this paper.

Table 5: Profitability of Merino prime lamb (MPL) scenarios and alternative Merino flock options at standard prices.

Flock structure	**Profit $**
MPL (age of turnoff, % of wether lambs finished as MPL)	
7 months, 90%	**97 400**
8 months, 40%	88 600
9 months, 10%	86 700
Store	90 000
Yearling	87 000
Shipper	77 500

NOTE: Only the most profitable MPL proportions for each age of turnoff are shown.
Refer to Appendix 1 for results of all scenarios examined.

The requirement for supplementary feed is much greater for the MPL flock, in order to finish the prime lambs over the summer when feed quality and quantity diminishes with the onset of dry and hot conditions. The additional income generated from the sale of sheep for the MPL system was higher than the additional cost of supplementary feed, however, the return per extra dollar invested in grain is less than 15% (after covering the costs of seasonal finance). This level of return may be insufficient incentive for many producers to finish a high proportion of merino prime lambs.

Table 6: Optimal farm plans of Merino flock options based on standard prices of commodities. For more detail see Appendix 2.

	MPL	**Store**	**Yearling**	**Shipper**
Objective Function	$97 400	$90 000	$87 100	$77 500
Pasture %	100	100	100	100
Stocking rate (DSE/ha winter)	12.9	12.7	12.4	11.9
Total sheep numbers (winter DSE)	12 900	12 700	12 400	11 900
Supp feeding (kg/DSE)	47	23	23	21
(kg/pasture ha)	605	293	280	250
Wool production (kg greasy/WGha)	39.9	37.7	36.3	35.9
Avg fibre diameter (µm)	20.7	20.4	20.1	20.0
Value of wool sold ($/pasture ha)	274	264	264	267
Value of stock sold ($/pasture ha)	248	174	163	132

3.3 Factors influencing profitability of a Merino prime lamb flock

Effect of age of turnoff and proportion of turnoff on farm profit

At standard prices, the most profitable age to finish wether lambs as Merino prime lamb is 7 months of age (Figure 4 and Appendix 1). Figure 4 shows that prime lambs must be finished at 7 months of age for it to more profitable than turning off store merino lambs (however, this depends on the price premium achieved for finished lambs over store lambs). At standard prices, the profit from a flock finishing Merino prime lambs at 7 months is sensitive to the proportion of lambs turned off. Higher profits are achieved as the proportion of lambs finished increases. It is necessary to finish at least 40% of wether lambs as prime lamb for it to be more profitable finishing Merino wether lambs than selling store lambs.

Finishing merino lambs at 8 months of age achieves a similar profit to selling wethers as yearlings, however, much more grain is required. The profit from MPL sold at 8 months is relatively insensitive to changes in the proportion of lambs sold. This is because at the standard prices used in this analysis, the cost of feed required to finish additional lambs is about as much as the gain in profit from the sale of additional lambs. However a change in grain price would influence this sensitivity. A reduction in grain price would reduce the cost of feed required to finish additional lambs, ensuring that the profit generated from selling the lambs would increase. This would cause the slope of profit function for lambs sold at 8 months to increase. The opposite would occur if grain prices increased.

Finishing lambs at 9 months is less profitable than selling wethers as stores or yearlings, although finishing a small proportion (10%) is equally profitable to selling wethers as yearlings or merino prime lamb at 8 months of age. Selling wethers as shippers at 2½ years or older is the least profitable of the systems examined.

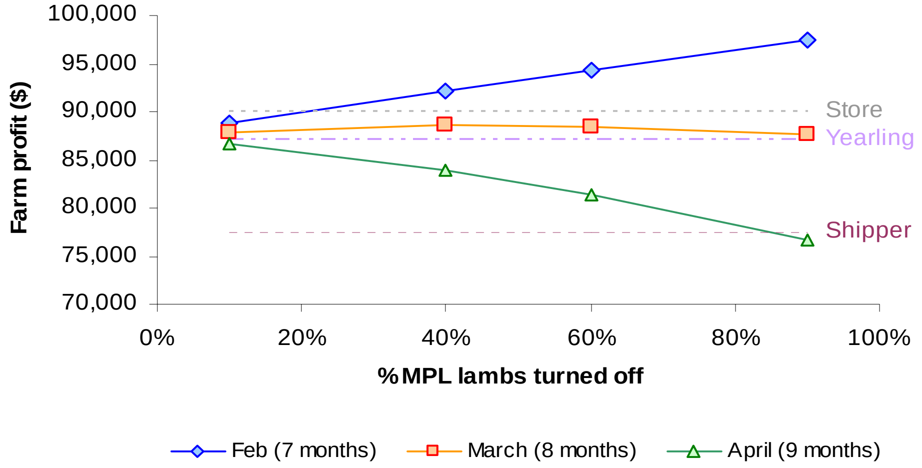


Figure 4: Profitability of selling wether prime lambs at 7, 8 and 9 months of age, for various proportions of lamb finished as prime lamb. **Note** Profitability of store flock, yearling flock and shipper flock are represented as dotted horizontal lines.

Effect of alternate ewe nutrition targets on farm profit

Results indicate there is no benefit in feeding ewes higher quality feed pre joining (Pattern A, B and C) even if feed quality feed post joining is reduced (Pattern B&C) (See Figure 5). This is because higher sheep and wool sales resulting from improved reproductive rate, does not offset the high supplementary feed costs associated with meeting the ewe energy requirement of these alternative live weight patterns.

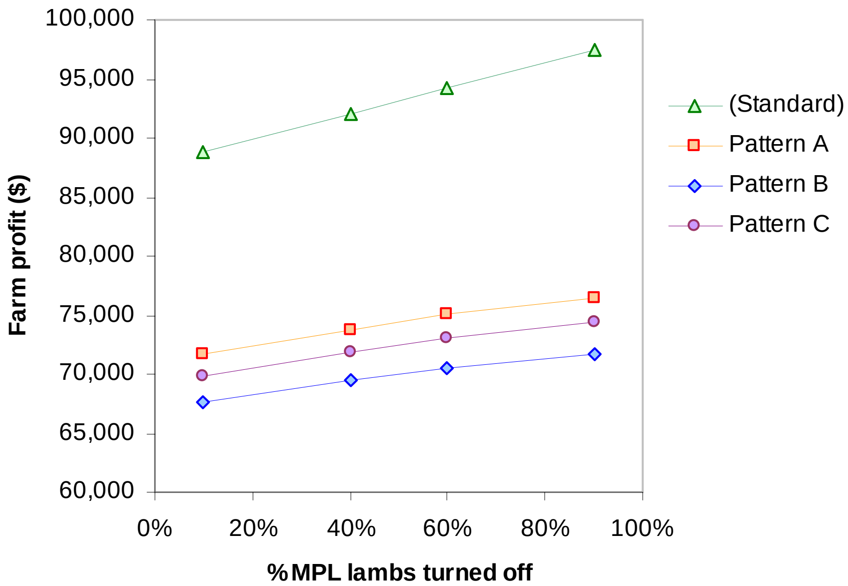


Figure 5: The impact of ewe live weight pattern on the profitability of a self replacing Merino flock finishing wether lambs (10% to 90%) as Merino prime lamb at 7 months (standard prices).

When feeding ewes a higher quality diet, there is a slight reduction in the extra profit that can be made by finishing a higher proportion of the wether progeny. This indicates that there is competition between ewes and finishing lambs for the high quality paddock feed. Therefore MerinotechWA producers are rightfully concerned about allocation of the high quality feed in early summer.

Selection of lambs for finishing: random draft versus selection by weight

The difference in farm profit generated from selecting lambs by weight versus a random draft is less than $1000 per year (Table 7). The benefit per lamb is greatest if a small proportion of lambs are finished. If the heaviest 10% are selected to be finished, the benefit is $3.15 per lamb finished compared with selecting 10% at random. This difference is driven by the 22kg/lamb saving in grain required to finish the heavier lambs compared with a random draft of lambs.

Table 7: Profitability of selecting lambs by weight versus by random draft, for various proportions of lambs finished as MPL. Lambs are sold at 7 months (standard prices, standard ewe live weight pattern)

Proportion of lambs finished	Farm Profit ($) Random Draft	Farm Profit ($) Selection by weight	Additional $/hd generated
10%	88 000	88 700	$3.15
40%	91 100	92 100	$1.10
60%	93 300	94 300	$0.65
90%	97 200	97 400	$0.10

The small difference in whole farm profit suggests that the decision about selecting on weight would be based on convenience rather than total amount of supplement required. GS-MIDAS does not consider the impact of producing an uneven line of lamb; a situation likely to occur when lambs are selected randomly. In this case, lambs would have to be turned off across a range of dates, requiring farmers to draft finished lambs on a number of occasions. Given that the labour differences are not represented in the modelling, it is likely in practice that it would be labour saving to select lambs by weight.

3.4 Sensitivity of farm profit to changes in commodity prices

Impact of changing sheep prices

Merino flock options

The profit of each Merino flock option is sensitive to movements in sheep price, as shown in Figure 6. A MPL flock is more sensitive to changes in sheep price than other flock options; when sheep prices are high it is the most profitable of all flock options examined and when sheep prices are low it is the least profitable flock option.

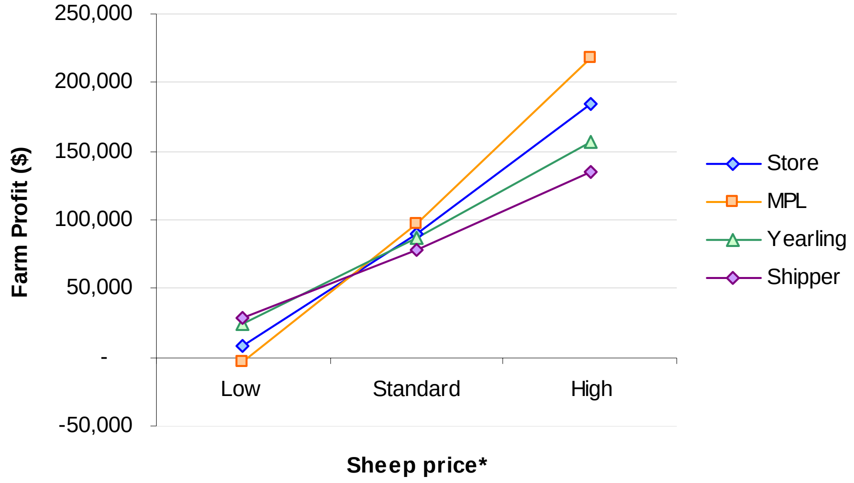


Figure 6: The impact of sheep price on the profitability of a self replacing Merino flock selling wethers as Merino prime lamb at 7 months of age (90%), store lambs, yearlings or shippers. * Price scenarios are outlined in Table 3.

The optimal farm plan for a MPL flock at low sheep prices, involves running fewer sheep at a lower stocking rate compared with other flock options (9 versus 10 DSE/ha). This is to ensure enough feed is available to finish off the Merino prime lambs over the summer when paddock feed quality and quantity diminish. Lower receipts from wool and sheep sales explain a majority of the difference in profit between the MPL flock and other pure Merino flocks when sheep prices are low.

As expected, the profit of each Merino flock option increases as sheep price increases (Figure 6). However, the flock options which are less able to respond to high sheep prices by turning off more animals benefit the least from high prices (ie yearling flock and shipper flock).

For yearlings to be as profitable as Merino prime lambs at high sheep prices, the price per yearling needs to be considerably higher than the price received for prime lambs. At standard prices (Merino lamb $3/kg), the yearling price must be over $61/hd ($2.70/kg) for a yearling flock to be more profitable than a MPL flock (Figure 7). If the price of yearling is above this price, it is more profitable to run a yearling flock (all other prices standard). Figure 7 shows how the breakeven yearling price changes as lamb price changes.

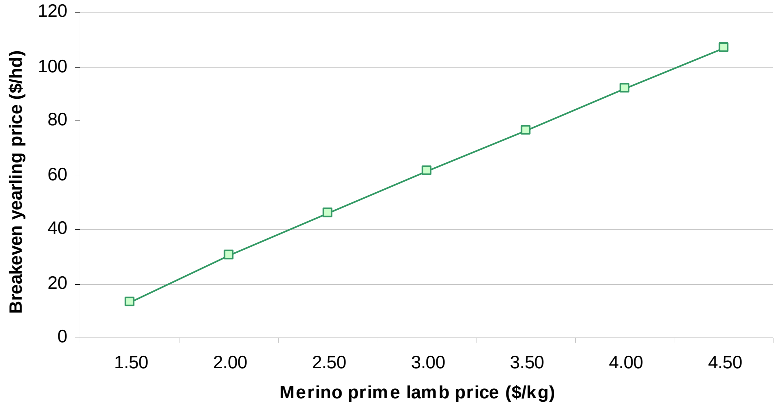


Figure 7: Breakeven prices for yearlings at different Merino prime lamb prices. Note: The breakeven yearling price is the price of yearlings that will cause a yearling flock to be as profitable as a self replacing Merino flock finishing 90% of wether lambs as Merino prime lamb at 7months of age.

For shippers to be as profitable the price per shipper needs to be over $62.50/hd to breakeven with a Merino wool and prime lamb flock.

Impact of changing wool prices

Merino flock options

The profit of each Merino flock is sensitive to movements in wool price, as shown in Figure 8. As expected, increasing wool price from 610 c/kg to 865 c/kg (WMI) causes the profit of each flock option to increase. In all cases the Merino prime lamb flock remains the most profitable and the shipper flock the least profitable. The difference in profit between each flock diverges slightly as wool price increases. The profit difference between a store flock and Merino prime lamb flock is $5 000 at 610c/kg and $9 500 at 865c/kg. The profit difference between a yearling flock and Merino prime lamb flock is $7 500 at 610c/kg and $12 500 at 865c/kg. With an increase in wool price, a MPL flock increase wool production by the greatest amount, and therefore benefits most from high wool prices.

Farm profit is more sensitive to changes in wool price than sheep price for all flock types analysed. An 18% increase in wool price from low to standard (see Table 3) causes the profit of a MPL flock to increase by $40 500, whereas a 20% increase in sheep price increases profit of a MPL flock by around $18 500.

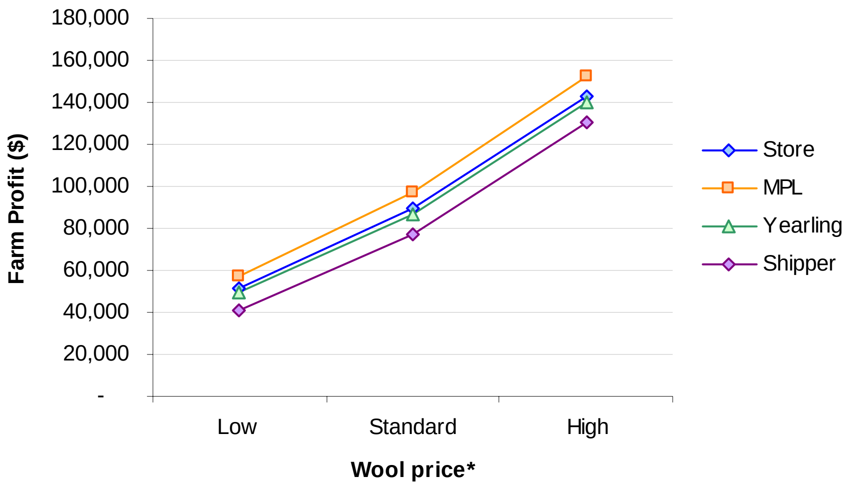


Figure 8: The impact of wool price on the profitability of a self replacing Merino flock selling wethers as a) Merino prime lamb at 7 months of age (90%), b) store lambs, c) yearlings, and d) shippers
* Price scenarios are outlined in Table 3.

Merino prime lamb flock options

As shown in Figure 9, irrespective of wool price, it is more profitable to finish a high proportion of wether lambs as Merino prime lamb at 7 months of age.

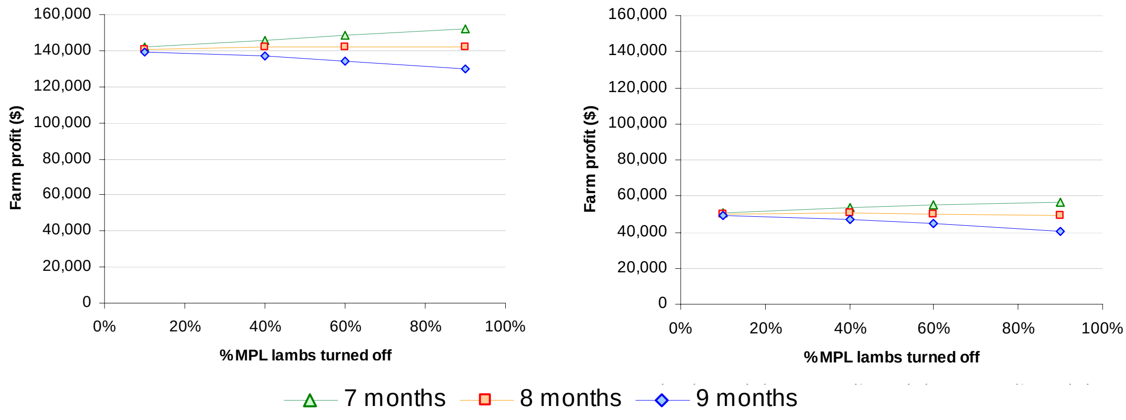


Figure 9: The impact of wool price on the profitability of a self replacing Merino flock finishing wether lambs as Merino prime lamb (10% to 90%) at 7, 8 and 9 months of age. (a) high wool price and (b) low wool price.

Impact of changing grain prices

Merino flock options

Figure 10 shows that the profit of each Merino flock is sensitive to movements in grain price. As expected, an increase in grain price from low to standard (See table 3) causes the profit of each flock option to decrease. The reduction in profit of a MPL flock in line with this price change is almost twice that of the other flock structures: $24 500 compared with $12 000 for store, $11 500 for yearling and

$10 000 for shipper (Figure 10). This is because the supplementary feed requirement of a MPL flock is around twice that of other flock options (Table 7).

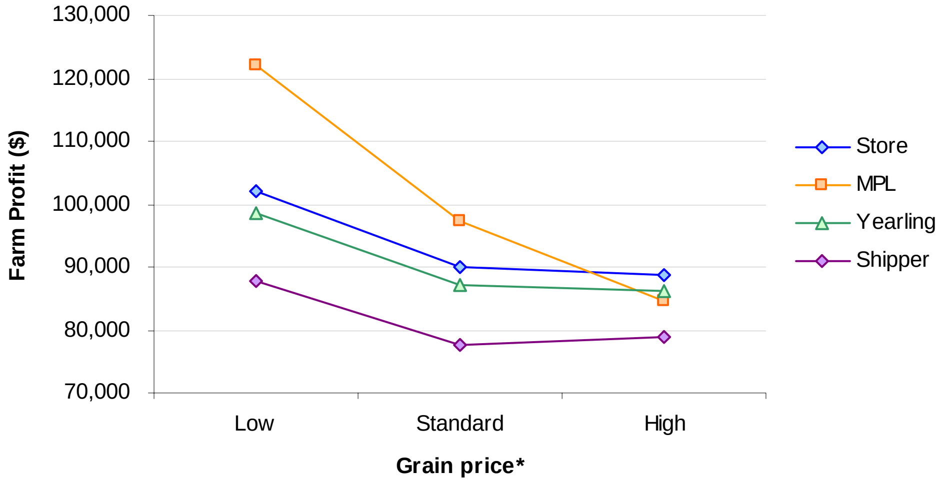


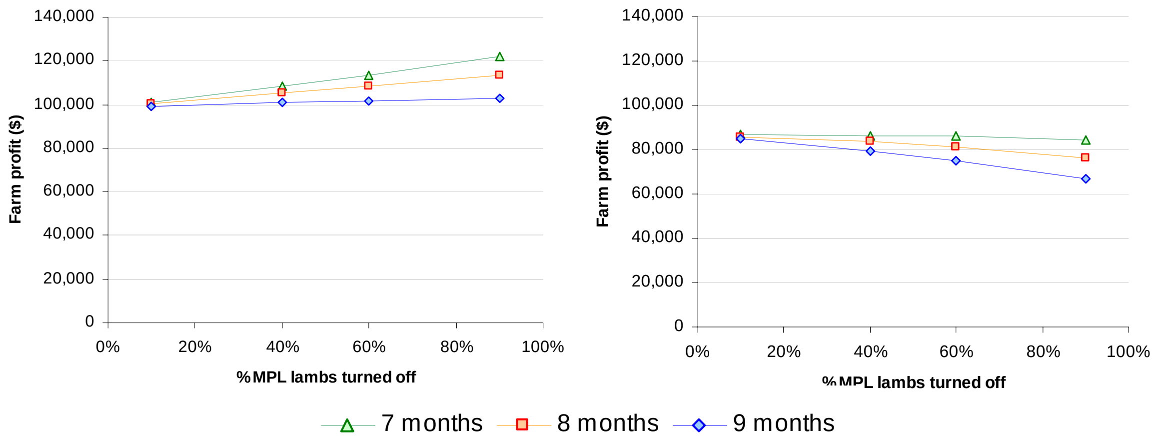
Figure 10: The impact of grain price on the profitability of a self replacing Merino flock selling wethers as a) Merino prime lamb at 7 months of age (90%), b) store lambs, c) yearlings, and d) shippers
* Price scenarios are outlined in Table 3.

When grain prices are at low or standard levels, the optimal farm plan includes 100% land in pasture for all flock options. However, when grain prices are high, the optimal area of land allocated to pasture is 80% for all flocks. As grain prices increase and the optimal area of land allocated to pastures declines, the optimal number of sheep also declines reducing revenue from sheep and wool sales.

Merino prime lamb flock options

As shown in Figure 11, it is more profitable to finish wether lambs as Merino prime lamb at 7 months of age, irrespective of grain price. However, when grain price is high it is more profitable to finish a lower proportion of lambs.

Farm profit is more sensitive to changes in wool price than grain price for all flock types analysed. As mentioned previously, an 18% increase in wool price from low to standard (see Table 3) causes the profit of a MPL flock to increase by $40 500, whereas a 20% increase in grain price increases profit of a MPL flock by around $24 500.



(a) Low grain price (b) High grain price

Figure 11: The impact of grain price on the profitability of a self replacing Merino flock finishing wether lambs as Merino prime lamb (10% to 90%) at 7, 8 and 9 months of age. (a) Low grain price and (b) High grain price.

Impact of changing grain type

In this analysis lupins have been used as the supplement fed to Merino lambs. Other supplements could be used, however to finish lambs a supplement containing at least 12% protein and 10 MJ ME/kg DM is required. If other supplements are available, the focus should be on formulating a least cost-ration which supplies the desired levels of energy and protein. However, the high protein content of lupins relative to cereal grains, can mean that dead pasture can sometimes be utilised more effectively, that is, if feeding cereal grains there will be more substitution of grain for pasture. Data in Table 8 illustrates the potential impact of changing from lupins to wheat, on supplement intake, lamb growth rate, and cost of ration. GrassGro was used to do this additional analysis. The assumptions were: average feed on offer/average digestibility, lamb weaning weight 25 kg, lamb turn-off date 28th February, lupins at $200/t (13.3 ME MJ/kg DM, 32% protein) and wheat (13.3 ME MJ/kg DM, 13% protein) at $195/t (standard prices).

Table 8. Effect of supplement type fed to lambs on supplement intake, lamb growth rate, and cost of ration for one scenario.

Supplement	***Total supplement intake per lamb (kg/head)***	***Lamb weight at turn-off date (kg)***	***Total cost of supplement ($/ha)***
Lupins	***76.6***	***49***	***$262***
Wheat	***80.6***	***49***	***$265***

3.5 Other factors influencing the profitability of Merino prime lambs

Lucerne in the optimal farm plan

Growing lucerne to at least partly fill the 'summer feed gap' in Mediterranean (winter rainfall dominant) farming systems contributes significantly to the profit of all Merino flock options analysed in this paper (Table 9, Figure 12, Appendix 3). The MPL flock benefits most from the inclusion of lucerne in the farming system, as this flock can utilise the additional feed to finish the prime lambs over the summer and reduce the requirement for expensive grain feeding.

Table 9: Profitability of Merino prime lamb flock and alternative Merino flock options at standard prices with and without lucerne in farming system.

Flock	Farm Profit ($) Without Lucerne	Farm Profit ($) With Lucerne	Difference in farm profit ($)
MPL	97 400	145 200	**47 800**
Store	90 000	118 200	**28 200**
Yearling	87 000	111 700	**24 700**
Shipper	77 500	102 600	**25 100**

As shown in Figure 12, with lucerne in the farming system, turning off more than 40% of MPL at 8 months of age is more profitable than running a store, yearling or shipper flock. The practical implications of this is the added flexibility a producer has in choosing the age to turn off Merino prime lambs. Without lucerne, turning off lambs at 7 months was the only profitable system.

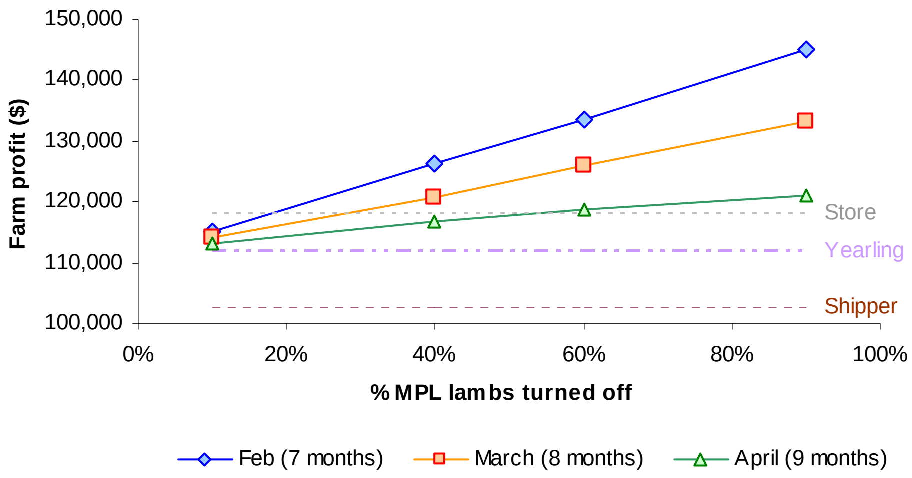


Figure 12: Profitability of selling wether prime lambs at 7, 8 and 9 months of age, for various proportions of lamb finished as prime lamb with Lucerne. **Note** Profitability of store flock, yearling flock and shipper flock are represented as dotted horizontal lines.

4. CONCLUSIONS

In Australia very favourable prices for lamb and mutton since 2001 has provided incentive for traditional Merino wool producers to increase production of sheep meat. A biophysical simulation model was used to estimate the level of feed required to achieve the turn-off target weights for the merino lambs being finished, for a range of seasons experienced up until weaning and a range of seasonal conditions post weaning. A whole-farm bio-economic model was used to identify the profitability of finishing Merino wether lambs as prime lamb, for the Great Southern region of Western Australia. Sensitivity analysis was undertaken to identify how profit is influenced by age of turnoff and the proportion of wether lambs finished as Merino prime lamb. Sensitivity analysis was also undertaken to identify how robust each flock option is to changes in commodity price

Results from GrassGro modelling found that less supplementary feeding is required to finish animals weaned at higher weights (around 10kg/hd) less for every 5 kg of additional weight at weaning). Results also showed that an additional 25kg/hd of supplementary feed is required in a bad season (low feed on offer, low digestibility) compared with a good season (High feed on offer, high digestibility). The average level of grain feeding required to finish 90% of lambs is 76kg/lamb, to finish 10% requires 54kg/lamb on average. If producers want to retain sufficient grain to ensure they don't have to buy grain in poor seasons then an extra 10 to 15kg/lamb is required.

Results from the GS-MIDAS modelling indicate that age of turnoff and the proportion of wether lambs finished are important to the profitability of finishing Merino prime lamb. Profit is maximised if a high proportion of wether lambs are finished at 7 months of age. At standard model prices, this flock option is more profitable than selling wether lambs as stores, yearlings or shippers. Only when grain prices are high or sheep prices are low, is it less profitable to finish Merino prime lamb.

Although it is more profitable to finish a high proportion of merino lambs the return per dollar invested is less than 15% because of the high requirement for grain. If the proportion of lambs finished is reduced, the return per dollar invested (in grain) is increased up to 34%.

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APPENDIX 1

Farm profit and supplementary feed requirements for all lamb turnoff scenarios examined in the MIDAS modelling (standard live weight pattern)

Age of sale	% turnoff	Profit $	Supp feed (t) (Lambs)	Supp feed (t) (Ewes)	Supp feed (t) (Wethers)
7 months MPL	10%	88 700	149	156	0
	40%	92 100	233	166	0
	60%	94 300	300	174	0
	90%	**97 400**	418	187	0
8 months MPL	10%	87 800	153	155	0
	40%	**88 600**	243	165	0
	60%	88 500	316	173	0
	90%	87 700	444	185	0
9 months MPL	**10%**	**86 700**	155	155	0
	40%	84 000	252	164	0
	60%	81 400	329	170	0
	90%	76 600	461	181	0
Store		**90 000**	104	189	0
Yearling		**87 000**	128	152	0
Shipper		**77 500**	104	125	21

APPENDIX 2

Farm plan (without lucerne) at standard prices, for a self replacing Merino flock selling wethers as a) Merino prime lamb at 7 months of age (90%), b) store lambs, c) yearlings, and d) shippers.

	MPL (90% 7 months)	Store	Yearling	Shipper
Farm Profit ($/yr)	$97,400	$90,000	$87,100	$77,500
Landuse				
- Lucerne (%)	0	0	0	0
- Pasture (%)	100	100	100	100
- Crop (%)	0	0	0	0
Stocking rate (DSE/ha)	12.9	12.8	12.4	11.9
Total sheep numbers (winter DSE)	12884	12752	12367	11925
Flock Structure				
- Ewes (hd)	7109	7180	5782	4729
- Ewe hoggets (hd)	2075	2096	1688	1380
- Ewe lambs (hd)	3016	3046	2453	0
- ewe lamb sold as stores (hd)	0	0	0	0
- ewe lamb sold as prime lamb (hd)	0	0	0	0
- wether lamb sold as stores (hd)	0	3046	0	0
- wether lamb sold prime (hd)	2714	0	0	0
- wether lamb sold yearling (hd)	286	0	2330	0
- wethers sold as shippers (hd)	0	0	0	1773
Supp feeding (kg/DSE)	47	23	23	21
(kg/pasture ha)	605	293	280	250
Wool production (kg greasy/WGha)	39.9	37.7	36.3	35.9
Avg fibre diameter (u)	20.7	20.4	20.1	20.0
Value of wool sold ($/pasture ha)	274	264	264	267
Value of stock sold ($/pasture ha)	248	174	163	132

APPENDIX 3

Farm plan (with lucerne) at standard prices, for a self replacing Merino flock selling wethers as a) Merino prime lamb at 7 months of age (90%), b) store lambs, c) yearlings, and d) shippers.

	MPL (90% 7 months)	**Store**	**Yearling**	**Shipper**
Farm Profit ($/yr)	$145,200	$118,200	$111,700	$102,600
Landuse (rounded)				
- Lucerne (%)	17	15	14	14
- Pasture (%)	66	69	71	71
- Crop (%)	17	15	14	14
Stocking rate (DSE/ha)	10.9	11.5	11.3	10.9
Total sheep numbers (winter DSE)	10957	11530	11305	10911
Flock Structure				
- Ewes (hd)	5913	6417	5183	4220
- Ewe hoggets (hd)	1692	1832	1483	1207
- Ewe lambs (hd)	2649	2875	2323	1891
- ewe lamb sold as stores (hd)	0	0	0	0
- ewe lamb sold as prime lamb (hd)	0	0	0	0
- ewe lamb sold as yearling (hd)	825	900	724	0
- wether lamb sold as stores (hd)	2259	2875	0	0
- wether lamb sold prime (hd)	825	0	0	0
- wether lamb sold yearling (hd)	371	0	2206	0
- wethers sold as shippers (hd)	0	0	0	1685
Supp feeding (kg/DSE)	30	19	20	19
(kg/pasture ha)	403	261	260	243
Wool production (kg greasy/WGha)	41.6	41.1	39.4	39.2
Avg fibre diameter (u)	20.7	20.4	20.1	20.1
Value of wool sold ($/pasture ha)	286	287	286	294
Value of stock sold ($/pasture ha)	265	199	185	150

APPENDIX 4:

Supplements required (kg/hd) to hit MPL target weight of 42 kg for a range of season experienced up until weaning, and a range of weaning weights.

Season up until weaning	**weaning weight**	**Turnoff Feb (7 months)**	**Turnoff March (8 months)**	**Turnoff April (9 months)**
High FOO/ High digestibility	20	79	85	94
	25	65	73	87
	30	50	60	74
	35	35	46	61
High FOO/ Low digestibility	20	87	93	99
	25	73	81	96
	30	59	68	83
	35	44	55	70
Low FOO/ High digestibility	20	95	102	104
	25	82	90	106
	30	68	78	94
	35	54	66	81
Low FOO/ Low digestibility	20	101	108	107
	25	88	97	112
	30	75	85	100
	35	61	72	88
Avg FOO/ Avg digestibility	20	90	97	102
	25	77	85	100
	30	63	73	88
	35	48	59	75

Australian Sheep CRC

Benchmarking Sub-Project

Final Report

Efficiency and Productivity Analysis of Wool Production on Benchmarked Farms

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Draft only

Not to Be Quoted

Executive Summary

Aims of the analyses

The analyses undertaken during this benchmarking sub-project of the Australian Sheep Cooperative Research Centre were directed towards providing knowledge in two main areas:

1. The extent of technical efficiency, and rates of technological change and change in productivity, in sheep production activities in Australia
2. The potential to extend to benchmarkers capability to use advanced methods of efficiency and productivity analysis as part of their toolkit for benchmarking activities that would enable them to improve their advice to clients.

Measures of efficiency and productivity

The main technical performance measures used in the analyses are: *technical efficiency* – using all the inputs available to the farmer to produce the maximum possible output for a given production technology and scale of operation; *technological change* – a change in production methods that shifts the production frontier; *total factor productivity* – output produced from all inputs available to the farmer, including the differential effects of production technology and scale of operation; and *scope economies* – a measure of synergies between different farm enterprises. A variety of estimates are provided for each of these measures over a period of five to 12 years, using data supplied by four benchmarking groups.

Technical inefficiency

Technical inefficiency was found to be a common occurrence among benchmarked farmer groups. It is likely to be even greater in the general sheep farm population given that the samples of benchmarked farmers are likely to be biased towards consistently better-performing farmers. The correlation between technical efficiency scores of farms and their gross margins varied considerably. For the most homogeneous group of farms, the correlation coefficient was remarkably high. Drought conditions in many areas most likely contributed to low correlation coefficients in the benchmarking group with the most diverse set of farms.

Stocking rate and technical efficiency

Among the inputs in wool production, stocking rate proved to have easily the greatest influence on productivity, as expected. But its relations with technical efficiency appear counterintuitive at first glance, with a higher stocking rate associated with significantly greater technical inefficiency. An inquiry into the effect of increasing stocking rate to raise output on best-practice and average (inefficient) farms provided an insight into why this might be so. As stocking rate increases, the rate of increase in output declines much more rapidly on average farms than on best-practice farms indicating that the latter have greater capability to manage stocking rates at high levels.

Estimates of productivity change in the wool enterprise

Mean annual rates of productivity change varied between around 2 per cent and 5 per cent among benchmarked groups of wool enterprises. The highest rate was recorded for a homogeneous group of farms in South-West Western Australia where a reliable climate, good pasture conditions for sheep production, sound technical advice and an increase in mean farm size over time encouraged the use of improved production methods. For the two benchmarking groups where consultancy advice is regularly received, best-practice farms were experiencing more rapid rates of productivity growth than average farms over the study period.

Measuring productivity growth proved difficult because of the variability in climatic conditions over time. Various measures were attempted to account for the effects of rainfall on productivity from year to year but none was wholly satisfactory. The subjective judgments of benchmarkers about the nature of the season proved as good as any measure.

Estimates of productivity change in the lamb enterprise and aggregate sheep enterprise

Models were separately estimated for prime lamb producers in two benchmarking groups, but only one result – for Holmes Sackett and Associates – is considered reliable as the sample changed markedly over the study period in the other group. The production frontier for lamb producers in the Holmes Sackett and Associates group was estimated to be virtually static, but mean technical efficiency increased significantly leading to a productivity growth rate similar to that achieved for wool production on farms in the Eastern States benchmarking groups. An estimated model for the aggregated sheep enterprises (wool, dual-purpose and lamb) for producers in this group provided a similar result, with a slightly lower productivity growth rate. A whole-farm estimate of technological change and productivity growth among producers in the Holmes Sackett and Associates group, which included beef and cropping enterprises, was similar to that obtained for the wool enterprise alone.

Accounting for quality changes in wool and lamb production

An attempt was made to take into account the quality improvements made in wool and lamb production when measuring productivity growth. The concern is that analysts have previously underestimated productivity growth rates in wool production by failing to account for the higher quality production implicit in the move to finer wool. The same situation is likely to have prevailed in estimates of lamb production with a move to lamb products more highly desired by producers and therefore fetching higher prices. It was estimated that the productivity growth rates in the wool enterprise reported above were underestimated by as much as 0.5 per cent per annum depending on the region.

Analysis of data across benchmarking groups and regions

Pooling data from a number of benchmarking groups to obtain one set of technical efficiency indices might be preferred to individual estimation procedures for each group for a number of reasons relating to data availability. A pooled model was estimated for two benchmarking groups in order to test the proposition that farmers in different benchmarking groups can be satisfactorily combined as if they are one group. This estimation procedure was successfully completed although little advantage was gained over separate estimates. It is important for combined benchmarking groups to use similar methods for classifying and aggregating inputs.

Analysis of data across regions

Pooling across regions can yield similar benefits to pooling across benchmarking groups within regions but it can be difficult to capture the substantial environmental variations between benchmarking groups due to differences in rainfall, sunshine, humidity, soils, topography, pests, diseases and infrastructure support. These environmental differences can nullify any advantage of pooling data. We explored the extent to which regional variations in technical performance in wool-producing regions of Eastern Australia are due to environment-technology gaps rather than simply differences in technical efficiency.

The evidence on technology gaps is not conclusive in that, while significant technology gaps exist and they differ between regions, these differences are not likely to be any greater than technology gaps within regions and over time as climate imposes constraints on production possibilities, Nevertheless, using a panel data set pooled across different benchmarking groups and regions should be avoided providing sufficient data are available for analysis within each benchmarking group.

Estimates of scope economies

Two types of scope economies were estimated: between wool and lamb output, and between sheep output, grain output and beef output. Estimated scope economies were derived from models based on stochastic input distance functions for the farms in two benchmarking groups.

Significant scope economies were detected between livestock activities. Medium to strong synergies were found to exist between wool and lamb production and weaker synergies were identified between wool and beef production, and between lamb and beef production. Strong synergies were found to exist between sheep and crop enterprises and between beef and crop enterprises, while significant but weaker synergies were detected between sheep and beef enterprises.

Extension of productivity and efficiency analytical methods to benchmarkers

Two sets of exercises were undertaken to gauge the ease of extending the analytical methods for operation by benchmarking groups themselves: collaboration with benchmarking staff in performing data manipulation according to a simple set of instructions; and training sessions in running models and interpreting results. Results of the first exercise showed that the extraction of data for conducting productivity and efficiency analyses was exceedingly quick and easy, provided data were appropriately recorded in spreadsheets and a staff member in the benchmarker's office is competent in the use of spreadsheets.

Training in the two methods took the form of a one-day training session and a distance training session. The sessions were very successful in enabling the benchmarking staff to run the models. A Powerpoint presentation was prepared to guide people through the various steps needed to run models using two software packages – FRONTIER 4.1c and DEAP2.1 – and to interpret basic results. The latter package proved handy for estimating single-year technical efficiency scores but tended to be less discriminating in identifying technical inefficiency. Dissemination of the analytical methods to other benchmarkers in the sheep industry is a potentially valuable outcome of the sub-project. Experiences gained from data collection and the ease with which data sets were assembled and models run by staff members of benchmarking groups suggests it should be possible for other benchmarking groups to estimate technical efficiency and productivity change. The establishment of a bureau to process data and provide results on efficiency and productivity measures is not considered desirable as in-house estimation should be comfortably handled if a benchmarker wishes to obtain such measures.

Analysis of factors influencing technical efficiency and gross margins

An important part of the sub-project was to analyse factors influencing technical efficiency and profitability in sheep production. From a technical viewpoint, the work involved was to ascertain why one farm has a higher level of technical efficiency or productivity than another farm. This analysis was initially carried out for three benchmarking groups using principal components analysis, with only limited success.

An alternative approach was considered: to decompose technical efficiency into its component influences and use regression analyses to discern causal relations in each of the components making up technical efficiency. This approach was adopted in the sub-project, except that gross margins were used instead of technical efficiency scores so that financial as well as technical influences on performance could be taken into account. The same approach could be adopted for decomposing technical efficiency scores into their component parts and determining their causal relationships. A separate report was prepared on the factors influencing production performance in the sheep industry that focuses on results from the decomposition analysis of gross margins.

1. Background to the Study

1.1 Benchmarking sub-project of the Australian Sheep Cooperative Research Centre (Sheep CRC)

This report covers a benchmarking sub-project of the Sheep CRC. Four benchmarking groups participated in the provision of data on sheep production by their members. One benchmarking group, Holmes Sackett and Associates (HSA), provided data for nine years, 1997-1998 to 2005-2006, for farms across four states: New South Wales, Victoria, Queensland and Tasmania. Farms in this group encounter a wider range of environmental conditions than do farms in the other groups. Another group, Darkan in south-west Western Australia, is operated by JRL Hall and Co. This group provided data for twelve years, 1994-1995 to 2005-2006. A third group, Farm Monitor Project (FMP) in south-west Victoria, provided data for 12 years, 1994-1995 to 2005-2006. Farms within each of the latter two groups face similar environmental conditions. A limited amount of data was obtained from the fourth group, the Mackinnon Project benchmarking group at the University of Melbourne in Victoria, for a shorter period of five years from 1999-2000 to 2003-2004. Numbers of farms were small in the final two years of the period.

1.2 Current approach to benchmarking

The practice of benchmarking has long been established as a farm management tool for detecting areas where individual producers could increase net operating profit by adopting the methods of their peers who were able to achieve better results. But use of the term, benchmarking, is a relatively recent occurrence. The early form of benchmarking was called comparative analysis.

Outputs and costs are usually calculated for comparative analysis on a per hectare basis, or sometimes on the basis of some other factor of production such as animal or labour. Calculations incorporate adjustments for opening and closing values, and the addition of non-cash items of receipts and payments. Net output figures are used to account for internal transfers between activities, such as feed produced from crops that is used in livestock production (Barnard and Nix 1979, p. 527).

Woolmark (1999) provides a good guide on existing benchmarking methods used in the wool industry in Australia. These sorts of benchmarking methods are currently being applied by benchmarkers participating in this study. The aim is to determine whether benchmarkers could use more quantitatively advanced methods to provide information on farm performance to complement the information that the existing methods currently provide.

1.3 Research goals and plan of the study

Five research goals were set for the study, setting the scene for the empirical analysis that forms the basis of the work undertaken:

1. Provide a set of estimates of wool production models for farmers in each benchmarking group from which farm-level technical efficiency indices and productivity trends are estimated.
2. Demonstrate the types of outputs that can be produced by analysing productivity and technical efficiency.
3. Ascertain the problems in establishing an appropriate and consistent data set that allows farm-level data from a number of benchmarking groups to be pooled for efficiency and productivity analysis.
4. Identify gaps in the information on farm performance in the sheep industry that could be filled by expanding the 'toolkit' for analysing efficiency and productivity.
5. Identify the main factors influencing technical efficiency in wool production at the farm level.

Each of these goals was achieved to varying degrees of success, as outlined in the following sections. Methods used to measure efficiency and productivity are outlined in section 2. The material in sections 3 and 4 focuses on the analyses of technical efficiency and productivity, respectively. Results from the estimation of frontier production models pooled across different benchmarking groups and regions are presented in section 5. Section 6 contains an analysis of factors influencing technical efficiency and gross margins. During the sub-project, it was found that useful information could be elicited from the analyses on scope economies, which is presented in section 7. The potential for developing training sessions for benchmarkers in productivity and efficiency analyses is assessed in section 8, and is followed by a conclusion.

2. Methods to Measure Efficiency and Productivity

A beneficial feature of the technical efficiency, scale efficiency, technological change and productivity measures reported in this study is that they identify the best-practice producers, and measure the performance of other producers in relation to these best-practice producers. Appendix 1 contains details on the framework and methods for obtaining these measures using simply understood indices. A best-practice producer is one who is located on the production frontier.

Definitions of key concepts are to be found in the glossary in Appendix 2. Technical efficiency is using all the inputs available to the farmer to produce the maximum possible output. A farm is technically inefficient if it produces less than this maximum possible output. Scale efficiency refers to the ability of a farm to achieve a level of scale of operations that allows it to produce at the highest productivity (lowest cost per unit of output). Productivity is measured as total factor productivity (TFP – hereafter referred to simply as productivity), which is the ratio of outputs produced to all inputs used in the production of that output. For an individual farm, its technical efficiency index multiplied by the maximum output achievable from using all available inputs equals its productivity index.

Two estimation methods were used for the analyses undertaken during the sub-project. Stochastic frontier production analysis (SFPA) is an econometric method suited to situations where there are many years of data available. Data envelopment analysis (DEA) is a linear-programming approach that requires a balanced data set for analysing changes over time but can be used for single-year estimation of technical and scale efficiency. The application of these methods is outlined in Appendix 1, along with a description of the output and input variables used in the estimated models. A crucial part of the analyses entailed the specification of a suitable variable to account for variations in rainfall between years. After testing a number of options, we settled on a set of dummy variables for seasons from excellent to very bad.

Appendix 1 also contains a description of the approach adopted to assess the correspondence between technical efficiency estimates and gross margins for benchmarked farms for each year.

3. Analyses of technical efficiency in sheep production

3.1 Estimates of technical efficiency

Many estimates of technical efficiency were made for four sets of benchmarked farmers using two different models: SFPA and DEA. They covered a range of activities within each benchmarking group. Separate estimates were made solely for specialist wool producers, dual-purpose producers and lamb producers, for sheep production as a whole, and for the whole farm.

Technical inefficiency was found to be present among the sample of each benchmarking group for wool specialists, dual-purpose producers and lamb specialists during the various study periods. There is therefore scope for extension activities to be undertaken to improve the technical performance of the bulk of sheep producers.

In studies over a number of years, an interesting divergence was found to exist between the studies. In the Darkan and HSA results, specialist wool producers tended to become less technically efficient (that is, were located further from the production frontier) over time. That is, the technical performance of the average producers (in terms of their ability to turn inputs into output) fell further behind best-practice producers. Note that this finding does *not* mean that the technical performance of average farmers declined; their performance only declined *relative to that of best-practice producers*. The productivity gains for average producers are a better guide as to their technical performance over time – see section 4. In contrast, inefficient specialist wool producers in the FMP benchmarking group moved closer to the production frontier over time, in contrast to trends in the other two benchmarking groups, but the production frontier did not expand over the study period. Little trend in technical efficiency was found for FMP sheep producers as a whole.

3.2 Comparison of technical efficiency and gross margin estimates

For Darkan farms, high positive correlations were found between technical efficiency/productivity and gross margin estimates per DSE and per hectare grazed to sheep for wool production. For wool production on FMP farms, moderately high positive correlations were found to exist between technical efficiency/productivity and gross margin estimates per DSE and hectare grazed to sheep. The high correlations for Darkan farms suggest that farmers are following similar resource allocation strategies and are facing similar production conditions. In situations such as this, a benchmarker would gain a good idea of productivity change by comparing gross margins over time.

In contrast to the Darkan and FMP correlations, low correlations were found between technical efficiency and gross margin estimates for wool production on farms in the HSA group. The presence of many negative gross margins over the study period, frequently associated with prevailing drought conditions, might explain these unexpectedly low coefficients.

3.3 Stocking rate and technical efficiency

The SFPA models can be used to establish relationships between stocking rates and marginal products (additional output) across a sample of farms, taking into account changes in other inputs used when the stocking rate changes. Currently, stocking rate varies widely across sheep-producing units in benchmarking groups. In the Mackinnon group, for example, stocking rates varied from 6 DSEs per hectare to 26 DSEs per hectare with an average stocking rate was 13.7 DSEs per hectare. Stocking rate was included as an efficiency variable as well as an input in the production function model to assess whether the stocking rate is associated with either higher or lower technical efficiency. The coefficient was strongly significant and of a sign that indicates that the stocking rate is associated with greater technical inefficiency. A plausible explanation for this result derives from the risky nature of wool production. Producers who push their stocking rate to the limit suffer disproportionately when unfavourable climatic conditions prevail given the downside risk that is typical of agricultural production, where the gains in good seasons are outweighed by losses in bad seasons. Recent widespread drought conditions in the study area may well have accentuated this outcome. This result suggests a need for more careful research on the obviously complex effects of stocking rate on output.

At one level, increasing the stocking rate is crucial to achieving maximum output for a given set of inputs, and it is probable that all benchmarked farmers have been successful in achieving most of these gains. Figure 1 shows the additional output achieved in percentage terms for adding another DSE to stocking rate for best-practice and average producers. The fifth DSE adds 5.5 per cent more output for the best-practice producer and 7.2 per cent more output for the average producer. But by the time the average stocking rate for the sample is reached, the increment has fallen to around 4 per cent. The additional output per DSE falls more quickly for the average producer. As a result, maximum output is achieved at 26.5 DSEs for the average producer and at 31.5 DSEs for the best-practice producers, respectively.

Of course, with diminishing returns to inputs, producers can be expected to maximise technical efficiency by choosing a stocking rate well below the rate that maximises output. (Indeed, the average stocking rate is around one-half these levels.) This is because increasing amounts of inputs other than DSEs are required as stocking rate increases. In other words, there is a point beyond which increasing the stocking rate pushes producers below the production frontier.

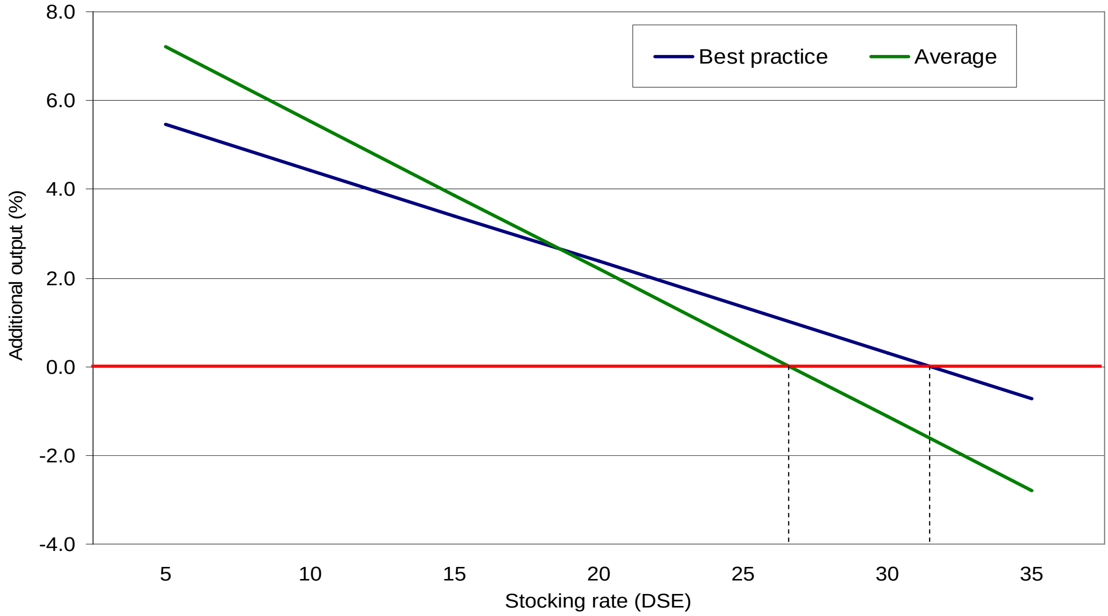

Figure 1 Relationship between the marginal product and stocking rate, Mackinnon, 1999/2000 to 2003/2004

4. Main Findings on Productivity Change

4.1 Estimates of productivity change

Details on estimation procedures used to measure productivity change have been described in detail by Fleming et al. (2005, 2006) and detailed results are available in the technical papers listed in Appendix 3. Estimates of productivity change were made for three of the four benchmarking groups. A lack of observations in the latter years of the Mackinnon benchmarking group meant that any estimates of productivity change were unreliable.

Individual farm estimates of productivity can change over time because a farmer becomes more or less technically efficient and/or because they take advantage of improved technologies. Both of these changes were evident during the study periods in the benchmarking groups, as spelt out below.

Satisfactory estimates were made of the stochastic frontier production functions of farmers in each benchmarking group that enabled calculation of individual technical efficiency indices for each farm in each year. In the Darkan analysis, a separate (and significantly higher) production frontier was estimated for a handful of stud farms in the sample. In the HSA analysis, farms were assigned to eight regions: North-West New South Wales; North-East New South Wales; South-West New South Wales; Central New South Wales; South-East New South Wales and North-East Victoria; South-West Victoria; King Island, Tasmania; and Queensland. A pooled data set was used in order to take into account the different environmental conditions in each region.

Estimates of technical change and productivity change were made for the sheep enterprise as a whole, combining data for different enterprises. First, data were combined on wool and lamb production to estimate multi-input multi-output stochastic production functions. These functions were satisfactorily estimated for FMP and HSA farms.

Second, whole-farm estimates of technical change and productivity change could be made for each farm where mixed farming is important. Such an analysis was successfully undertaken with HSA data, including the crops and beef enterprises. A similar exercise was attempted with FMP farms, aggregating the data on different enterprises. The presence of a large number of zeros for outputs where farms did not undertake a particular enterprise made this exercise less than satisfactory. While it was not attempted, aggregating farm outputs and inputs across all enterprises in a whole-farm analysis is a simple extension for benchmarkers to make when estimating technological change and productivity change.

4.2 Results for benchmarking groups

Best-practice wool producers in the Darkan group experienced a substantial increase in productivity over the study period of 4.9 per cent per year while the productivity of the average producer increased by 3.5 per cent per annum. Although they had a significantly higher productivity level, stud farms achieved a productivity growth rate lower than that of ordinary producers.

Best-practice wool producers in the HSA group also experienced a substantial increase in productivity over the study period of 3.3 per cent per year. The productivity of the average producer in this group, however, increased by around one-half that rate, at 1.7

per cent per year. The lower growth rate for the average farmer may be due in part to the different effects of drought across regions. A rainfall variable was successfully included in the estimated model but it is likely that the adverse consequences of severe drought were felt in following years for many farms, possibly depressing the average productivity growth rate.

The productivity levels of some producers fell well behind those of best-practice producers over the study period. In fact, a handful of producers in 2004/2005 were at an absolute level of productivity that was still lower than that achieved by the most efficient producers in 1997/1998. This trend is reflected by the less compact distributions in later years of the period. Two possible reasons are the effects of drought on the performance of some producers and the entry of some less efficient producers into the benchmarking process in later years. A farmer sample that constantly changes over time is a major concern for the accurate measurement of productivity change.

Different productivity levels were found to exist between most regions in the HSA group. These differences were in line with expectations about variations in land and climatic conditions from one region to the next. This finding is explored in section 5.

Estimates of productivity change were made for individual farms in the FMP benchmarking group for the period from 1994/1995 to 2004/2005. They were derived for two sets of farmers. One set comprised only those farmers who specialise in wool production. The other set also included farmers who have a lamb enterprise. The inclusion of this second set in the analysis was based on the observation that many farmers changed from being specialist wool producers to producing lambs as well as wool over the study period, which is likely to have influenced the efficiency and productivity estimates. The data sets of prime lamb production among sampled wool producers show that the number has increased dramatically over the study period.

While the positive trend in productivity for specialist wool producers is similar to that achieved in the Darkan group, its composition is different. The average annual rate of productivity growth was around 2 per cent was generated primarily by improved technical efficiency. Technical change was strongly positive until 1997-1998 after which the index declined until 2002-2003 before slightly increasing in the final two years of the study period.

The composition of changes for all FMP wool producers is more in line with that on Darkan farms although the magnitude is considerably lower. The mean annual rate of productivity growth was marginally less than 1.5 per cent, slightly below that for average HSA producers. Technical change was strongly positive to 1997-1998 after which it experienced a gradual decline.

The shift to joint production of wool and prime lamb production is a possible explanation of the trends outlined above. The overall lower rate of productivity growth compared reasonably closely to the rate achieved by average producers in the Darkan and HSA benchmarking groups. Previously less efficient specialist wool producers would now have been left on the contracting frontier whereas in earlier years they would have been below it. Their improvement in performance is consistent with the level of productivity growth achieved by average farms in the Darkan and HSA benchmarking groups.

Another possible explanation for the downward trend in productivity for specialist wool producers in the latter half of the 1990s and early 2000s is the decline in fine wool (19 micron and less) prices relative to medium wool (19-23 micron) prices that occurred in the period between 1995 and 2001. The average micron declined steadily throughout the study period, and it would be expected that better wool producers would have been more prominent in this shift towards finer wool production.

Models were separately estimated for prime lamb producers in the FMP and HSA benchmarking groups. In the FMP group, there was an unexpected and startlingly high productivity decline among both best-practice and average producers. This surprising result may be due to the substantial changes in the sample during the study period, but nevertheless needs further investigation. In the HSA estimates, the frontier was estimated to be virtually static. But mean technical efficiency increased significantly, leading to a productivity growth rate similar to that achieved for wool production. An estimated model for the aggregated sheep enterprises (wool, dual-purpose and lamb) for HSA producers provided a similar result, with a slightly lower productivity growth rate.

Two examples follow in Figures 2 and 3 for benchmarked HSA producers. They show how the distribution of scores of annual technical efficiency and productivity change of the producers over a number of years can be visually presented.

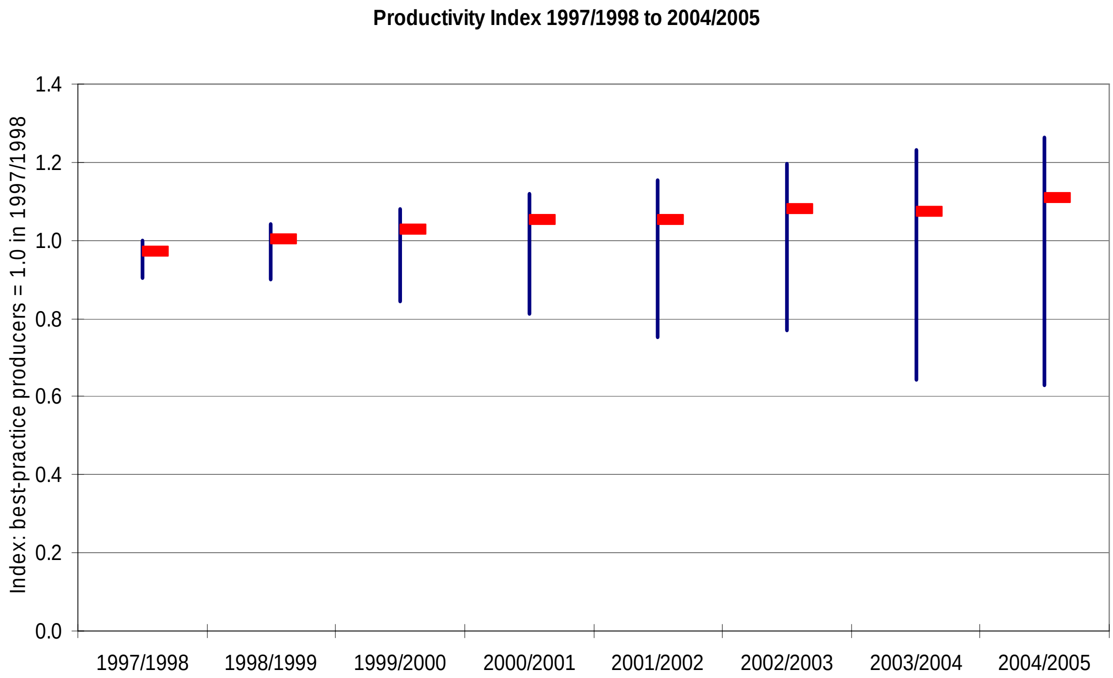

Figure 2 Productivity trends by year, HSA: 1997-1998 to 2004-2005.

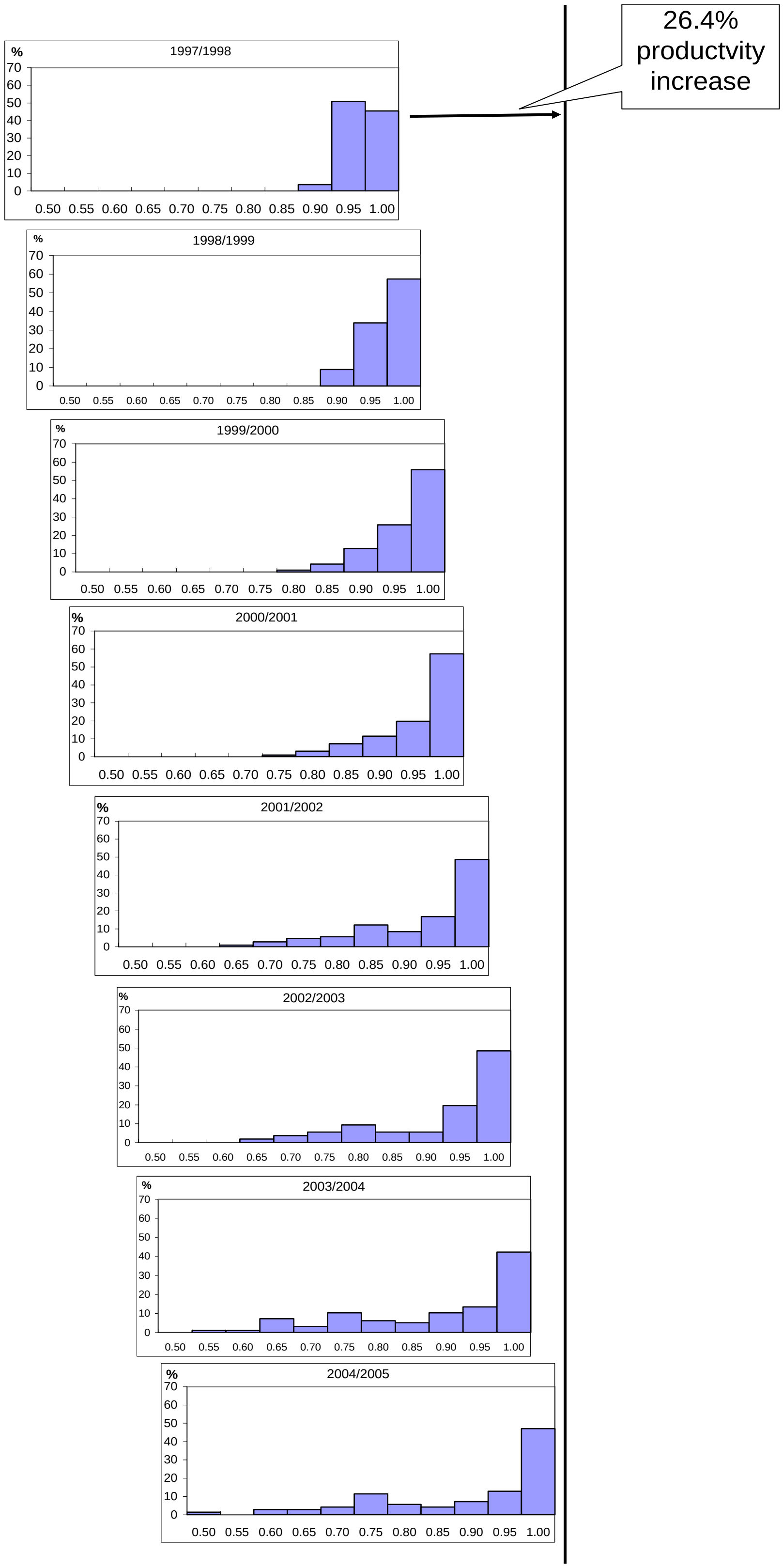

Figure 3 Distribution of technical efficiency estimates by year, HSA: 1997-1998 to 2004-2005.

4.3 Accounting for quality changes in wool and lamb production

An attempt was made to take into account the quality improvements made in wool and lamb production when measuring productivity growth on farms over the study periods of the different benchmarking groups. In the case of wool production, the concern is that analysts have previously underestimated productivity growth rates because they failed to account for the higher quality production implicit in the move to finer wool. The finer wools fetch higher prices, and so the wool price index used to deflate wool revenue to implicit outputs overstates the extent to which prices are higher due to exogenous market factors. The same situation is likely to have prevailed in estimates of lamb production with a move to lamb products more highly desired by producers and therefore fetching higher prices.

In the case of wool, the appropriate price deflator should be based on the original weights for wool types included in the regimens of the regional indicators at the start of the study period. These regimens were regularly rebased over the period. The divergence between price series over recent years can be gauged from AWEX (2006). The average annual increase in the Eastern Price Indicator from mid-2003 to mid-2006 was around 1 per cent, while the average annual increase in the regional indicator for Western Australia was around 1.3 per cent. Assuming this rate applied over the whole decade when the productivity estimates were made for benchmarking groups, it was estimated that the productivity growth rates reported above were underestimated by as much as 0.5 per cent per annum depending on the region.

5. Analysis of data across benchmarking groups and regions

There are three reasons why pooling data from a number of benchmarking groups to obtain one set of technical efficiency indices might be preferred to individual estimation procedures for each group. First, there might not be sufficient annual observations on farm inputs and outputs in a particular group to obtain reliable technical efficiency estimates. Second, if benchmarkers within a group are acting upon the same advice, there might be only a small difference in their production practices, making it difficult to discern factors explaining why one wool producer in the group is more technically efficient than another. Third, comparisons can be made of the levels of productivity and technical efficiency across a wider group of farms. A pooled model was estimated for Victorian farms in the FMP and HSA groups in order to test the proposition that farmers in different benchmarking groups can be satisfactorily combined as if they are one group.

This estimation procedure was successfully completed. A surprisingly strong contrast in results is observed in the two benchmarking groups in terms of the estimates of both technical change and productivity change. While these estimates are not vastly different from estimates obtained in the individual analyses, the rates of growth on HSA farms are improbably high. The reason for this exaggeration is most likely a result of the fairly crude way of differentiating between production relations on the two groups of farms.

An alternative approach is to use a larger set of benchmark dummy variables to allow for differences in production response to each input between benchmarking groups. Following this approach can help overcome the exaggerated differences in growth rates between groups, but it defeats the purpose of the first reason for pooling data across benchmarking groups, namely a shortage of observations. Nevertheless, it might still provide benefits in discerning variations in technical efficiency between farms where production practices differ between the groups.

Unless there is a problem of a small number of observations for an individual benchmarking group, the gains from pooling data across groups in different regions are likely to be slight while the potential for inaccurate estimates of technical efficiency becomes much greater when pooling is undertaken. The pooling of data among groups in the same geographical region is more likely to yield benefits, as indicated by the analysis of farms from two benchmarking groups in Victoria.

The strongest argument generally articulated against pooling data across regions is the difficulty in capturing the substantial environmental variations between benchmarking groups in estimating the stochastic frontier production function. These environmental variations exist in many dimensions, such as rainfall, sunshine, humidity, soils, topography, pests, diseases and infrastructure support. It is argued that if they are not captured fully in model estimation, any knowledge gleaned from model estimates that production frontiers or technical efficiency levels are higher in one region than another is of little use. This nullifies one of the main advantages of pooling data. In some instances, the environmental differences are technologically based but in most cases they are a function of spatial and temporal variations in the environmental conditions in which farms operate.

We explored the extent to which regional variations in technical performance in wool production are due to environment-technology gaps in wool-producing regions of Australia rather than simply differences in technical efficiency. Our aim was to assess the extent to which pooling across regions results in incorrectly attributing inferior performance to technical efficiency when it is a gap in performance that could not have been bridged under any circumstances given environmental factors. While environmental differences in wool production are a function of spatial and temporal variations in the conditions in which producers operate, they are also technologically based in that producers adjust their production technologies to suit the environment in which they operate. Even so, the ability of producers to adjust their production technology to the environment is unlikely to bridge the productivity gap between a producer operating in a favourable environment and one operating in a difficult environment, with poorer resources and greater production uncertainty brought about by climatic variability.

The evidence on technology gaps is not conclusive in that, while technology gaps differ between regions, these differences are likely not any greater than technology gaps within regions and over time as climate imposes constraints on production possibilities, Nevertheless, using a panel data set pooled across different benchmarking groups and regions should be avoided providing sufficient data are available for analysis within each benchmarking group. It is possible to pool data for more than one benchmarking group if farmers are from the same geographical region and benchmarkers are using consistent data sets. Otherwise, the gains from pooling are likely to be slight while the potential for inaccurate estimates of technical efficiency becomes much greater.

6. Estimates of Scope Economies

Scope economies are a measure of synergies between different farm enterprises. They exist between two farm enterprises when, for a given level of resource use, more can be produced by combining the production of the enterprises than by operating the enterprises as separate systems. Two types of scope economies were estimated: between wool and lamb output, and between sheep output, grain output and beef output. Estimated scope economies were derived from models based on stochastic input distance functions for the farms in the FMP and HSA benchmarking groups.

Significant scope economies were detected between livestock activities on FMP benchmarked farms. Strong synergies were found to exist between wool and lamb production and weaker synergies were identified between wool and beef production, and between lamb and beef production.

For HSA benchmarked farms, evidence was found of significant scope economies between wool and lamb production, similar to the finding for FMP farms, but they were in the moderate rather than strong range. Strong synergies were found to exist between sheep and crop enterprises and between beef and crop enterprises, while significant but weaker synergies were detected between sheep and beef enterprises.

7. Training Sessions for Benchmarkers in Productivity and Efficiency Analyses

The analyses undertaken to date have required benchmarkers to provide data to staff in the School of Economics at the University of New England, who have then manipulated the data and analysed it. This was a necessary first step but is cumbersome and costly in time, so a more expedient method of analysis was explored.

Two sets of exercises were undertaken to gauge the ease of extending the analytical methods for operation by benchmarking groups themselves:

1. Collaboration with benchmarking staff in performing data manipulation according to a simple set of instructions.

2. Two training sessions in running models and interpreting results.

The aim of the first exercise was to assess the ease with which data manipulation could be undertaken by the benchmarker, based on existing *Excel* files kept for the purpose of providing farm accounts and calculating other benchmarking indicators. Results showed that the extraction of data for conducting productivity and efficiency analyses was exceedingly quick and easy, provided two relatively straightforward conditions hold. First, the data need to be recorded in *Excel* spreadsheets in a manner similar to the procedure followed by HSA. Second, there must be a staff member in the benchmarker's office who is competent in the use of spreadsheet techniques, especially pivot tables.

Once data were in a format ready for analysis, the next step to undertake the analysis was more challenging and called for a staff member in the benchmarker's office being competent in the operation of the SFPA software (FRONTIER 4.1c) and DEA software DEAP 2.0), as used in the analyses discussed in this report. Training in the two methods took two forms. First, a one-day training session was run in Perth with staff from two of the benchmarking groups. Second, a distance training session was attempted with a staff member of a third benchmarking group applying the same two techniques. The first session was very successful in enabling the benchmarking staff to run the models. Much of the day was spent interpreting results and comparing subjective judgments held by one of the benchmarking staff from JRL Hall and Co. with the technical efficiency scores calculated for farmers in the group. After this training was completed, a Powerpoint presentation was prepared to guide people through the various steps needed to run FRONTIER and DEAP models and interpret basic results.

The dissemination of the analytical methods to other benchmarkers in the sheep industry is a potentially valuable outcome of the sub-project. The experiences gained from data collection and the ease with which data sets were assembled and models run by staff members of benchmarking groups should help streamline the processes for other benchmarking groups to estimate technical efficiency and productivity change.

An alternative approach would be for a benchmarker to provide the data in an appropriate spreadsheet form and send it for analysis to an organisation such as the School of

Economics at the University of New England. It is estimated that this analysis, together with a summary of results and report, could be completed in three working days providing no follow-up work is required to get the data set into a format ready for analysis.

Finally, the establishment of a bureau to process data and provide results on efficiency and productivity measures is not considered a desirable strategy. In-house estimation should be comfortably handled if a benchmarker wishes to obtain such measures.

8. Analysis of Factors Influencing Technical Efficiency and Gross Margins

An important part of the sub-project was to analyse factors influencing technical efficiency and profitability in sheep production (see Figure 5). From a technical viewpoint, the work involved was to ascertain why one farm has a higher level of technical efficiency or productivity than another farm. This analysis was initially carried out for three benchmarking groups using principal components analysis, with only limited success.

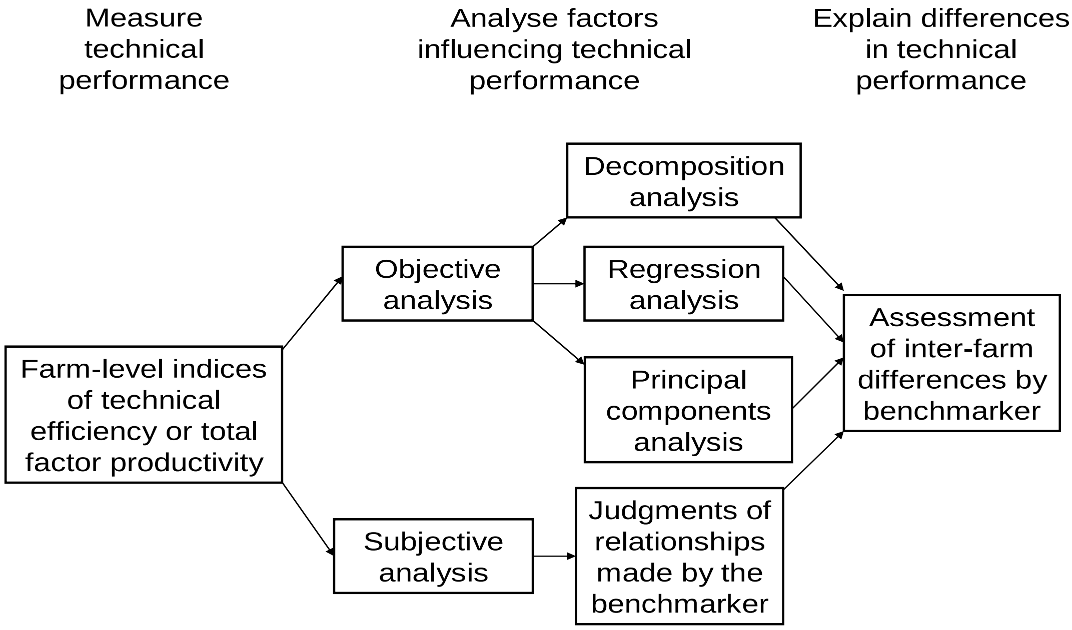

Figure 5 Alternative ways to explain differences in technical performance by wool producers.

Five factors limited this analysis:

1. Probably the most important limitation has been that there is no ‘magic bullet’ solution to improve the technical aspects of wool production in Australia. As Scott (2004) observed, livestock farmers need to be on top of a multitude of aspects of the farming system, which means that differences in technical performance among farms boils down to a large number of ‘1 per cent’ gains that can be made rather than a single action that leads to a quantum leap in technical efficiency.
2. The nature of the farms in the benchmarking groups is such that most of the wool producers have been receiving the same advice from the benchmarker for many years and have been acting on this advice. All the major gains in technical performance that could be made have already been achieved, and benchmarkers face a situation of heavily diminishing returns to their advice on further improvements. Therefore, little variation occurs in production practices that would cause differences in technical efficiency or productivity.
3. Some of those factors that might lead to variations in efficiency and productivity are not readily quantifiable, and do not appear in the list of variables included in the set used in the principal components analysis. Examples are attitudes to work, knowledge of sheep production systems, work practices, attention to detail in planning and scheduling farming tasks, effort put into physical work on the farm and motivation.
4. It is difficult to purge the so-called ‘key performance indicators’ used as variables influencing technical efficiency and productivity of elements already incorporated in the estimation of the production functions from which the technical efficiency and productivity indices have been derived. Many if not most of these indicators contain at least some elements of input-output relationships that have already been captured in the estimated production functions.
5. Estimating technical efficiency indices for an individual farm requires the prediction of trends over time. This prediction process results in indices that are approximations, given that variations between years are not estimated precisely,

and could restrict the efficiency of the estimations made in the principal components analysis. But the substitution of gross margins for technical efficiency indices did not improve the ability to draw inferences from the results.

Regression analysis is an alternative approach that can be conducted simultaneously with the estimation of the stochastic frontier production function (Figure 5). However, it has the disadvantage of assuming independence among variables explaining differences in technical efficiency between farms and suffers from some of the shortcomings of principal components analysis, outlined above.

Third, there is always the option of relying on the judgment of the benchmarker who is likely to understand intimately why one farmer is performing better than another. Knowledge of best-practice farmers can assist benchmarkers in selecting peers against which to compare inefficient farmers. This knowledge should also help a benchmarker select demonstration farms for sessions from which other farmers can learn how to improve performance. This approach should continue to be followed in all analyses as a means of comparing quantitative estimates with the performance level that the benchmarker subjectively believes each producer is achieving.

The final, and potentially most effective, approach is to decompose technical efficiency into its component influences and use regression analyses for understanding causal relations in each of the components making up technical efficiency. This was the approach adopted in the sub-project, except that gross margins were used instead of technical efficiency so that financial as well as technical influences on performance could be taken into account. The same approach could be adopted for decomposing technical efficiency scores into their component parts and determining their causal relationships. Rutley (2007) has published a separate report on the factors influencing production performance in the sheep industry. The report focuses on results from a decomposition analysis of gross margin.

9. Conclusion

This benchmarking sub-project has amassed a rich set of data that provides a valuable reference source for conducting efficiency and productivity analysis in Australian wool and sheepmeat production. The results reported above have provided some findings that should prove useful to benchmarkers in generating indicators of farm performance, enhancing the advice and information they provide to farmers. They also provide a valuable basis for assessing future initiatives to improve the flow of information on performance by wool producers.

Estimates of technical efficiency and scale efficiency, technological change and productivity were successfully calculated for each farm in each year of the respective study periods for four benchmarking groups individually and as a group. These estimates accord reasonably closely to results obtained from earlier work in Australia. The most challenging task arising from the results is to explain why different trends in productivity and technical efficiency occurred between benchmarking groups over time. We suspect two factors are at play. First, our attempts to capture both spatial and regional variations in climate have not been fully successful; nor are they likely ever to be perfect. Second, the most recent years of the study period have not been kind to either the farmers or the analysis. Attempts to estimate realistic technical efficiency indices in the midst of a drought, the severity and timing of which vary between regions, is a challenge that is extremely difficult to meet.

Scope economies were also successfully estimated. These estimates were made between wool and sheepmeat production within the sheep industry and between sheep output, beef output and grain output.

The future direction of efficiency and productivity analysis in wool production would appear to offer most benefits by focusing on individual regions or benchmarking groups rather than attempting to pool data across farms that experience a wide range of environmental conditions. In particular, much valuable work remains to be done for these individual groups by following a whole-farm approach to efficiency measurement by modelling all activities on the farm instead of simply wool production. There is also considerable scope for exploring in more depth the factors that influence technical efficiency. It is this information that is likely to be most valuable in enabling inefficient producers to improve their technical and financial performance through a better understanding of production methods.

The extension of analytical methods to more benchmarkers offers some potential gains to the industry. It was shown that staff members in benchmarking firms are quite capable of running the necessary models and interpreting results. On the whole, most farm efficiency and productivity scores appear to be in line with the expectations of benchmarkers, but a few are not. More work is needed, however, in reconciling why some individual scores do not correspond to the expectations of benchmarkers before these methods are recommended for implementation in the field.

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Appendix 1
Summary of Methods to Measure Efficiency and Productivity

A1 Measuring technical efficiency, scale efficiency, technological change and productivity

A beneficial feature of the technical efficiency and productivity measures reported in this study is that they identify the best-practice producers, and measure the performance of other producers in relation to these best-practice producers.

In order to calculate measures of technical efficiency, scale efficiency, technological change and productivity, a production frontier needs to be established. This frontier can be considered as an envelope around the relations between all inputs and outputs in sheep production, as shown in Figure A1 for the simple case of a production process with a single output and a single input. The production function for the average producer, who is technically inefficient, lies beneath the production frontier.

The technical efficiency measure is simple in that the best possible performance is given an index measure of 100 per cent (or 1.0) and producers who are not at the best-practice level obtain an index less than 100 per cent. The distance they are below 100 per cent measures the extent to which these producers are capable of improving farm performance if they were able to reach the standard of the best-practice producers in a technical sense. For example, a producer with an output orientation who has a technical efficiency index of 0.7, or 70 per cent, should be able to increase output of the farm activity being benchmarked by 30 per cent (1.0 minus 0.7), using the same amount of inputs, by reaching best-practice standard. An alternative way of looking at the index is with an input orientation. That is, by achieving best practice the producer could reduce the amounts of all inputs used by 30 per cent and still maintain the same level of output.

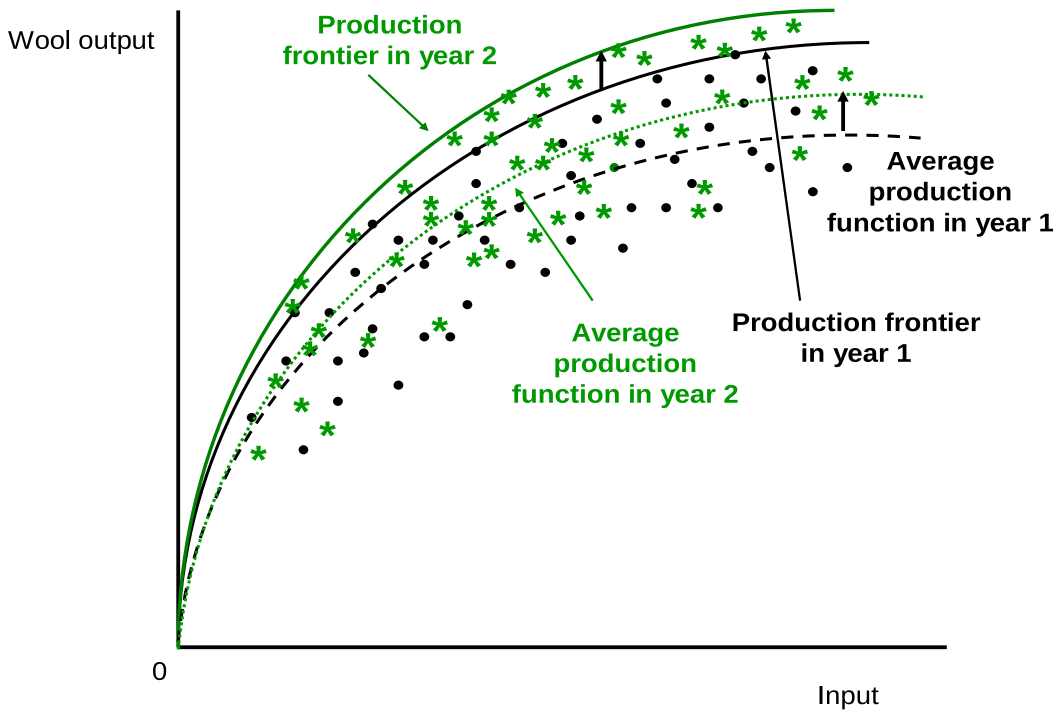

Figure A1 Production frontier for a single output before and after technological change.

Scale efficiency effects can be separated from technical efficiency, depending on the analytical method used. A scale-efficient farm is one that is closest to the point of optimal scale – where the long-run cost per unit of output is at its lowest level (or productivity is highest). As for technical efficiency, scale efficiency can be simply measured where the most scale-efficient farm is given an index measure of 1.0. Producers who are not at this level (have higher average costs) obtain an index less than 1.0. The distance of their scores below 1.0 measures the extent to which they are capable of improving farm performance if they can change the size of their farming operations to the perfectly scale-efficient level.

Productivity is the most relevant indicator to use when looking at changes over a number of years. The frontier shifts outwards as research output leads to new production technologies becoming available to farmers over time,. That is, more can be produced for the same amounts of inputs used. Productivity can change from one year to the next as a result of technological change as well as any change in mean technical efficiency (inefficient producers on average moving closer to or further away from the production frontier).

Technological change is represented by a shift of the production frontier between years. This is illustrated in Figure A1 where the black dots represent farms in year 1 and green asterisks the positions of farms in year 2. Best-practice farms have increased output per unit of input over the year, lifting the production frontier.

The average production function has also gone up by an amount roughly equivalent to the shift of the production frontier, suggesting that mean technical efficiency has probably not changed significantly in this case. Some farms might have remained at about the same level of productivity but, because the frontier has shifted, their technical efficiency index would have fallen.

A2 Estimation methods

Two estimation methods were used for the analyses:

- Stochastic frontier production analysis (SFPA) is an econometric method suited to situations where there are many years of data. This method allows unbalanced data sets to be analysed, an important advantage when changes over time are being measured and not all farmers have provided benchmarking data for all years in the study period. Technical efficiency indices are calculated by estimating what is called a stochastic frontier production function to allow for random events. This method does not easily allow scale efficiency to be measured separate from technical efficiency, which means that productivity and technical efficiency in any given year can be regarded as the same on the grounds that farmers have access to the same set of production technologies.

- Data envelopment analysis (DEA) is a linear-programming approach. It requires a balanced data set for analysing changes over time but can be used for single-year estimation of technical and scale efficiency so long as there are at least 30 observations given the number of input and output categories used in the analyses.

A detailed description of these techniques is not presented here because its widespread use means there are numerous descriptions already available in the efficiency and productivity literature. Coelli, Rao and Battese (2005) is a good reference for those interested in finding out more about the theoretical properties and modelling methods used in this approach. The SFPA models were estimated using the program, FRONTIER Version 4.1c and the DEA models were estimated by DEAP Version 2.1.

While a number of flexible functional forms can be used to portray the production function, we settled for a simple power function, familiarly termed the Cobb-Douglas function. Despite the fact that it entails some restrictive assumptions, the Cobb-Douglas production function was specified for two main reasons. First, it is easy to estimate, being linear in logarithms. Because it is intended that benchmarkers are able to do their own calculations of technical efficiency indices, ease of use is vital. Second, the Cobb-Douglas has proved to be very robust in estimation, especially when compared with flexible functional forms. This is an admirable attribute for use in benchmarking because it means the people estimating the frontier production function are not faced with a set of results that make little sense and require a good deal of re-estimation until a satisfactory function is estimated.

A3 Output and input variables

For wool enterprises, output is defined as either two variables – the implicit quantity of wool produced per annum and the annual net profit on the mature sheep trading account – or an aggregate of these two variables. The implicit quantity of wool was calculated as the value of wool output deflated by a wool price index from the Commodity Statistics published by the Australian Bureau of Agricultural and Resource Economics (ABARE). The advantage of using an implicit wool quantity rather than actual quantity in kilograms of wool is that it takes into account variations in wool quality while eliminating the effects of inter-year wool price variations by using the price deflator. For dual-purpose and lamb enterprises, an additional output variable – profit on the lamb trading account – was also included.

Inputs in all forms of production were aggregated into the following categories (data on which varied to a minor degree between groups): effective grazed pasture area, grazed stubble area, health inputs, pasture inputs, feed inputs, agistment, selling inputs, shearing inputs, labour and overheads. Outputs and inputs were expressed in dry sheep equivalents

(DSEs) in FMP analyses, and both DSEs and per farm in analyses for other benchmarking groups. All variables expressed in costs were deflated by the ABARE farm input price index to enable them to be expressed in implicit inputs. Imputed values were made by the benchmarkers for operator and family labour in the FMP and HSA groups, and total labour costs were allocated to the wool enterprise on the basis of the proportion of total grazed area used for each enterprise. Labour was measured as the number of full-time adult-equivalent workers in the Darkan group.

A3 Accounting for environmental factors influencing production

Rainfall and trend over time were two other variables that needed to be included in models where data spanned many years. We included a trend variable to account for any productivity trend. The most dominant trend effect is likely to be changes in production technology over the decade. Another possible factor is scale economies due to larger farm sizes that enable producers to take better advantage of existing production technologies. The likely productivity gains by producers over the period suggest a positive coefficient on the trend variable. A trend dummy variable for stud producers was also included in the Darkan analysis to determine whether the rate of productivity change on these properties was significantly different from that for ordinary producers.

Considerable effort was put into the calculation of a suitable rainfall variable. After testing a number of options, we settled on a set of dummy variables for seasons from excellent to very bad. In the Darkan analysis, these variables representing the type of season experienced by farmers were successfully included in the estimated model as JRL Hall and Co. was able to identify accurately the impact of seasonal conditions on output. The seasons were defined as very bad, bad, average, good, very good or excellent. It was expected that the worse the season the higher the negative impact on production.

In the FMP and HSA models, an attempt was made to account for variations in rainfall by specifying a set of dummy variables for different seasonal conditions that were measured according deviations from the long-run historical average for the four months of the main growing season, which varied according to region. These seasonal dummy variables were defined using the same terminology as for Darkan farms.

The resulting set of dummy variables was successfully included in the estimated model for HSA farmers. A similar approach was followed for the Mackinnon model but in this case annual rainfall had to be used rather than the four months of the main growing season. In the FMP analyses, use of rainfall deviations for the main growing season was unsuccessful in capturing the effects of seasonal variations on wool output. In the absence of subjective estimates of the type of season, statistical methods were used to define seasons using the same seasonal dummy variables as for the other benchmarking groups.

A4 Relating technical efficiency to gross margin

An assessment can be made of the correspondence between technical efficiency estimates and gross margins for benchmarked farms in each year by examining the correlation coefficient and the rank correlation coefficient. Correlation coefficients can be estimated between technical efficiency and various gross margin estimates. The two most common estimates in the sheep industry are gross margin per DSE and gross margin per hectare grazed to sheep for wool production.

Correlations should not be perfect, for two major reasons. First, technical efficiency indices represent only one of the two components of economic efficiency, for which gross margin is proxy, namely the technical aspects of production. They exclude allocative efficiency, or how a farmer selects a mix of inputs to produce a given quantity of output at minimum cost given prevailing input prices, pertinent to an input orientation, and output prices, pertinent to an output orientation (Coelli, Rao and Battese 1998, p. 5). Second, the two gross margins are partial measures only, in that each is expressed per unit of one factor of production, whereas technical efficiency indices take into account all inputs used in production.

Appendix 2
Glossary

A **production technology** is the set of methods used on the farm to produce wool and other sheep outputs.

A **production function** is the numerical relationship between an output, wool (or set of sheep outputs), produced on the farm and the set of inputs used to produce that output or set of outputs. It expresses farm output as a function of the inputs used to produce output.

The **production frontier** measures the output that can be produced by farmers who are technically efficient (use 'best-practice' farming methods). The production frontier function used in this study can be considered as an envelope around the relations between all inputs and outputs in wool production after allowing for random events. The allowance for random events leads to use of the term, **stochastic production frontier.**

Inputs refer to the farm resources (grazed pasture land, stubble land and labour) and purchased goods and services (agistment, feed inputs, pasture inputs, health inputs, shearing inputs, selling inputs and overheads) used in production of wool or set of sheep outputs.

Scale efficiency refers to the ability of a farm to achieve a level of scale of operations that allows it to produce at the highest productivity (lowest cost per unit of output). A scale-inefficient farm produces output at a unit cost less than maximum productivity.

Scope economies are a measure of synergies between different farm enterprises.

Technical efficiency is using all the inputs available to the farmer to produce the maximum possible output for a given production technology and scale of operations. A farm is **technically inefficient** if it produces less than this maximum possible output.

Technological change is a change in production methods that shifts the production frontier.

Total factor productivity (referred to simply as productivity) also measures the output produced from all inputs available to the farmer. But it takes into account the fact that not all farmers have access to the same production technology. For an individual farm, it is its technical efficiency index multiplied by the maximum output achievable from using all available inputs.

Appendix 3
Articles and Technical Papers

Articles

Fleming, E., Villano, R., Farrell, T. and Fleming, P. 2005, *Efficiency and Productivity Analysis, Report on Benchmarking Sub-Project*, Australian Sheep Industry CRC, Armidale.

Fleming, E., Villano, R. Farrell, T. and Fleming, P. 2006, ‘Is benchmarking the new acceptable face of comparative analysis?’, *Australasian Agribusiness Review* 14, Paper 12.

Geenty, K.G., Fleming, E.M., Rutley, D.L. and Kemp, D.R. 2006, ‘Farm benchmarking: the next level’, in P. Cronjé and D. Maxwell (eds), *Wool Meets Meat: Tools for a Modern Sheep Enterprise, Proceedings of the 2006 Australian Sheep Industry CRC Conference*, Orange, August, pp. 72-77.

Rutley, D.L., Geenty, K.G., Fleming, E.M. and Villano, R.A. 2006, Defining the future sheep enterprise: the role of benchmarking, Poster paper presented at Horizons in Livestock Sciences: Research for the Farm of the Future, Gold Coast, 8-11 October.

Department of Primary Industries 2007, ‘Feature article: efficiency and productivity: evidence from the Farm Monitor Project in South West Victoria’, in *South West Monitor Project: Summary of Results 2005/2006*, Victoria Department of Primary Industries, Melbourne, pp. 26-31.

Villano, R., Fleming, E., Farrell, T. and Fleming, P. 2006, Productivity change in the Australian sheep industry revisited, Contributed paper accepted for presentation at the 26th International Conference of International Association of Agricultural Economists, Brisbane, August.

Villano, R., Fleming, E., Farrell, T. and Fleming, P. 2006, Productivity change in the Australian sheep industry revisited, Contributed paper to the 50th Conference of the Australian Agricultural and Resource Economics Society, Sydney, February.

Villano, R., Fleming, E. and Fleming, P. 2007, Accounting for environmental differences in efficiency measurements in the Australian wool industry, Contributed paper to the 10th European Workshop on Efficiency and Productivity Analysis, Lille, June.

Technical Papers

1. Technical efficiency and productivity estimates for wool production on farms in the JRL Hall benchmarking group, Darkan
2. Technical efficiency and productivity estimates for wool production on farms in the Holmes Sackett and Associates benchmarking group
3. Technical efficiency and productivity estimates for the wool enterprise on farms in the Farm Monitor Project benchmarking group, South-West Victoria
4. Technical efficiency and productivity estimates for the wool enterprise on farms in the Mackinnon benchmarking group, Victoria
5. Estimates of technical efficiency and productivity change in wool production on farms pooled across two benchmarking groups
6. Estimates of technical efficiency and technology gaps in wool production on farms pooled across regions
7. Technical efficiency and productivity estimates for dual-purpose and lamb production on farms in the Holmes Sackett and Associates benchmarking group
8. Technical efficiency and productivity estimates for joint wool and lamb production on farms in the Farm Monitor Project benchmarking group in south-west Victoria
9. Estimates of scope economies in sheep production
10. A procedure for estimating relations between stocking rate, technical efficiency and additions to output in wool production

11. Accounting for quality changes in wool and lamb production when estimating productivity change
12. Powerpoint training file for estimating efficiency and productivity in sheep production

Australian Sheep CRC

Benchmarking Sub-Project

Final Report

Efficiency and Productivity Analysis of Wool Production on Benchmarked Farms

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School of Economics

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Draft only

Not to Be Quoted

Executive Summary

Aims of the analyses

The analyses undertaken during this benchmarking sub-project of the Australian Sheep Cooperative Research Centre were directed towards providing knowledge in two main areas:

1. The extent of technical efficiency, and rates of technological change and change in productivity, in sheep production activities in Australia
2. The potential to extend to benchmarkers capability to use advanced methods of efficiency and productivity analysis as part of their toolkit for benchmarking activities that would enable them to improve their advice to clients.

Measures of efficiency and productivity

The main technical performance measures used in the analyses are: *technical efficiency* – using all the inputs available to the farmer to produce the maximum possible output for a given production technology and scale of operation; *technological change* – a change in production methods that shifts the production frontier; *total factor productivity* – output produced from all inputs available to the farmer, including the differential effects of production technology and scale of operation; and *scope economies* – a measure of synergies between different farm enterprises. A variety of estimates are provided for each of these measures over a period of five to 12 years, using data supplied by four benchmarking groups.

Technical inefficiency

Technical inefficiency was found to be a common occurrence among benchmarked farmer groups. It is likely to be even greater in the general sheep farm population given that the samples of benchmarked farmers are likely to be biased towards consistently better-performing farmers. The correlation between technical efficiency scores of farms and their gross margins varied considerably. For the most homogeneous group of farms, the correlation coefficient was remarkably high. Drought conditions in many areas most likely contributed to low correlation coefficients in the benchmarking group with the most diverse set of farms.

Stocking rate and technical efficiency

Among the inputs in wool production, stocking rate proved to have easily the greatest influence on productivity, as expected. But its relations with technical efficiency appear counterintuitive at first glance, with a higher stocking rate associated with significantly greater technical inefficiency. An inquiry into the effect of increasing stocking rate to raise output on best-practice and average (inefficient) farms provided an insight into why this might be so. As stocking rate increases, the rate of increase in output declines much more rapidly on average farms than on best-practice farms indicating that the latter have greater capability to manage stocking rates at high levels.

Estimates of productivity change in the wool enterprise

Mean annual rates of productivity change varied between around 2 per cent and 5 per cent among benchmarked groups of wool enterprises. The highest rate was recorded for a homogeneous group of farms in South-West Western Australia where a reliable climate, good pasture conditions for sheep production, sound technical advice and an increase in mean farm size over time encouraged the use of improved production methods. For the two benchmarking groups where consultancy advice is regularly received, best-practice farms were experiencing more rapid rates of productivity growth than average farms over the study period.

Measuring productivity growth proved difficult because of the variability in climatic conditions over time. Various measures were attempted to account for the effects of rainfall on productivity from year to year but none was wholly satisfactory. The subjective judgments of benchmarkers about the nature of the season proved as good as any measure.

Estimates of productivity change in the lamb enterprise and aggregate sheep enterprise

Models were separately estimated for prime lamb producers in two benchmarking groups, but only one result – for Holmes Sackett and Associates – is considered reliable as the sample changed markedly over the study period in the other group. The production frontier for lamb producers in the Holmes Sackett and Associates group was estimated to be virtually static, but mean technical efficiency increased significantly leading to a productivity growth rate similar to that achieved for wool production on farms in the Eastern States benchmarking groups. An estimated model for the aggregated sheep enterprises (wool, dual-purpose and lamb) for producers in this group provided a similar result, with a slightly lower productivity growth rate. A whole-farm estimate of technological change and productivity growth among producers in the Holmes Sackett and Associates group, which included beef and cropping enterprises, was similar to that obtained for the wool enterprise alone.

Accounting for quality changes in wool and lamb production

An attempt was made to take into account the quality improvements made in wool and lamb production when measuring productivity growth. The concern is that analysts have previously underestimated productivity growth rates in wool production by failing to account for the higher quality production implicit in the move to finer wool. The same situation is likely to have prevailed in estimates of lamb production with a move to lamb products more highly desired by producers and therefore fetching higher prices. It was estimated that the productivity growth rates in the wool enterprise reported above were underestimated by as much as 0.5 per cent per annum depending on the region.

Analysis of data across benchmarking groups and regions

Pooling data from a number of benchmarking groups to obtain one set of technical efficiency indices might be preferred to individual estimation procedures for each group for a number of reasons relating to data availability. A pooled model was estimated for two benchmarking groups in order to test the proposition that farmers in different benchmarking groups can be satisfactorily combined as if they are one group. This estimation procedure was successfully completed although little advantage was gained over separate estimates. It is important for combined benchmarking groups to use similar methods for classifying and aggregating inputs.

Analysis of data across regions

Pooling across regions can yield similar benefits to pooling across benchmarking groups within regions but it can be difficult to capture the substantial environmental variations between benchmarking groups due to differences in rainfall, sunshine, humidity, soils, topography, pests, diseases and infrastructure support. These environmental differences can nullify any advantage of pooling data. We explored the extent to which regional variations in technical performance in wool-producing regions of Eastern Australia are due to environment-technology gaps rather than simply differences in technical efficiency.

The evidence on technology gaps is not conclusive in that, while significant technology gaps exist and they differ between regions, these differences are not likely to be any greater than technology gaps within regions and over time as climate imposes constraints on production possibilities, Nevertheless, using a panel data set pooled across different benchmarking groups and regions should be avoided providing sufficient data are available for analysis within each benchmarking group.

Estimates of scope economies

Two types of scope economies were estimated: between wool and lamb output, and between sheep output, grain output and beef output. Estimated scope economies were derived from models based on stochastic input distance functions for the farms in two benchmarking groups.

Significant scope economies were detected between livestock activities. Medium to strong synergies were found to exist between wool and lamb production and weaker synergies were identified between wool and beef production, and between lamb and beef production. Strong synergies were found to exist between sheep and crop enterprises and between beef and crop enterprises, while significant but weaker synergies were detected between sheep and beef enterprises.

Extension of productivity and efficiency analytical methods to benchmarkers

Two sets of exercises were undertaken to gauge the ease of extending the analytical methods for operation by benchmarking groups themselves: collaboration with benchmarking staff in performing data manipulation according to a simple set of instructions; and training sessions in running models and interpreting results. Results of the first exercise showed that the extraction of data for conducting productivity and efficiency analyses was exceedingly quick and easy, provided data were appropriately recorded in spreadsheets and a staff member in the benchmarker's office is competent in the use of spreadsheets.

Training in the two methods took the form of a one-day training session and a distance training session. The sessions were very successful in enabling the benchmarking staff to run the models. A Powerpoint presentation was prepared to guide people through the various steps needed to run models using two software packages – FRONTIER 4.1c and DEAP2.1 – and to interpret basic results. The latter package proved handy for estimating single-year technical efficiency scores but tended to be less discriminating in identifying technical inefficiency. Dissemination of the analytical methods to other benchmarkers in the sheep industry is a potentially valuable outcome of the sub-project. Experiences gained from data collection and the ease with which data sets were assembled and models run by staff members of benchmarking groups suggests it should be possible for other benchmarking groups to estimate technical efficiency and productivity change. The establishment of a bureau to process data and provide results on efficiency and productivity measures is not considered desirable as in-house estimation should be comfortably handled if a benchmarker wishes to obtain such measures.

Analysis of factors influencing technical efficiency and gross margins

An important part of the sub-project was to analyse factors influencing technical efficiency and profitability in sheep production. From a technical viewpoint, the work involved was to ascertain why one farm has a higher level of technical efficiency or productivity than another farm. This analysis was initially carried out for three benchmarking groups using principal components analysis, with only limited success.

An alternative approach was considered: to decompose technical efficiency into its component influences and use regression analyses to discern causal relations in each of the components making up technical efficiency. This approach was adopted in the sub-project, except that gross margins were used instead of technical efficiency scores so that financial as well as technical influences on performance could be taken into account. The same approach could be adopted for decomposing technical efficiency scores into their component parts and determining their causal relationships. A separate report was prepared on the factors influencing production performance in the sheep industry that focuses on results from the decomposition analysis of gross margins.

1. Background to the Study

1.1 Benchmarking sub-project of the Australian Sheep Cooperative Research Centre (Sheep CRC)

This report covers a benchmarking sub-project of the Sheep CRC. Four benchmarking groups participated in the provision of data on sheep production by their members. One benchmarking group, Holmes Sackett and Associates (HSA), provided data for nine years, 1997-1998 to 2005-2006, for farms across four states: New South Wales, Victoria, Queensland and Tasmania. Farms in this group encounter a wider range of environmental conditions than do farms in the other groups. Another group, Darkan in south-west Western Australia, is operated by JRL Hall and Co. This group provided data for twelve years, 1994-1995 to 2005-2006. A third group, Farm Monitor Project (FMP) in south-west Victoria, provided data for 12 years, 1994-1995 to 2005-2006. Farms within each of the latter two groups face similar environmental conditions. A limited amount of data was obtained from the fourth group, the Mackinnon Project benchmarking group at the University of Melbourne in Victoria, for a shorter period of five years from 1999-2000 to 2003-2004. Numbers of farms were small in the final two years of the period.

1.2 Current approach to benchmarking

The practice of benchmarking has long been established as a farm management tool for detecting areas where individual producers could increase net operating profit by adopting the methods of their peers who were able to achieve better results. But use of the term, benchmarking, is a relatively recent occurrence. The early form of benchmarking was called comparative analysis.

Outputs and costs are usually calculated for comparative analysis on a per hectare basis, or sometimes on the basis of some other factor of production such as animal or labour. Calculations incorporate adjustments for opening and closing values, and the addition of non-cash items of receipts and payments. Net output figures are used to account for internal transfers between activities, such as feed produced from crops that is used in livestock production (Barnard and Nix 1979, p. 527).

Woolmark (1999) provides a good guide on existing benchmarking methods used in the wool industry in Australia. These sorts of benchmarking methods are currently being applied by benchmarkers participating in this study. The aim is to determine whether benchmarkers could use more quantitatively advanced methods to provide information on farm performance to complement the information that the existing methods currently provide.

1.3 Research goals and plan of the study

Five research goals were set for the study, setting the scene for the empirical analysis that forms the basis of the work undertaken:

1. Provide a set of estimates of wool production models for farmers in each benchmarking group from which farm-level technical efficiency indices and productivity trends are estimated.
2. Demonstrate the types of outputs that can be produced by analysing productivity and technical efficiency.
3. Ascertain the problems in establishing an appropriate and consistent data set that allows farm-level data from a number of benchmarking groups to be pooled for efficiency and productivity analysis.
4. Identify gaps in the information on farm performance in the sheep industry that could be filled by expanding the ‘toolkit’ for analysing efficiency and productivity.
5. Identify the main factors influencing technical efficiency in wool production at the farm level.

Each of these goals was achieved to varying degrees of success, as outlined in the following sections. Methods used to measure efficiency and productivity are outlined in section 2. The material in sections 3 and 4 focuses on the analyses of technical efficiency and productivity, respectively. Results from the estimation of frontier production models pooled across different benchmarking groups and regions are presented in section 5. Section 6 contains an analysis of factors influencing technical efficiency and gross margins. During the sub-project, it was found that useful information could be elicited from the analyses on scope economies, which is presented in section 7. The potential for developing training sessions for benchmarkers in productivity and efficiency analyses is assessed in section 8, and is followed by a conclusion.

2. Methods to Measure Efficiency and Productivity

A beneficial feature of the technical efficiency, scale efficiency, technological change and productivity measures reported in this study is that they identify the best-practice producers, and measure the performance of other producers in relation to these best-practice producers. Appendix 1 contains details on the framework and methods for obtaining these measures using simply understood indices. A best-practice producer is one who is located on the production frontier.

Definitions of key concepts are to be found in the glossary in Appendix 2. Technical efficiency is using all the inputs available to the farmer to produce the maximum possible output. A farm is technically inefficient if it produces less than this maximum possible output. Scale efficiency refers to the ability of a farm to achieve a level of scale of operations that allows it to produce at the highest productivity (lowest cost per unit of output). Productivity is measured as total factor productivity (TFP – hereafter referred to simply as productivity), which is the ratio of outputs produced to all inputs used in the production of that output. For an individual farm, its technical efficiency index multiplied by the maximum output achievable from using all available inputs equals its productivity index.

Two estimation methods were used for the analyses undertaken during the sub-project. Stochastic frontier production analysis (SFPA) is an econometric method suited to situations where there are many years of data available. Data envelopment analysis (DEA) is a linear-programming approach that requires a balanced data set for analysing changes over time but can be used for single-year estimation of technical and scale efficiency. The application of these methods is outlined in Appendix 1, along with a description of the output and input variables used in the estimated models. A crucial part of the analyses entailed the specification of a suitable variable to account for variations in rainfall between years. After testing a number of options, we settled on a set of dummy variables for seasons from excellent to very bad.

Appendix 1 also contains a description of the approach adopted to assess the correspondence between technical efficiency estimates and gross margins for benchmarked farms for each year.

3. Analyses of technical efficiency in sheep production

3.1 Estimates of technical efficiency

Many estimates of technical efficiency were made for four sets of benchmarked farmers using two different models: SFPA and DEA. They covered a range of activities within each benchmarking group. Separate estimates were made solely for specialist wool producers, dual-purpose producers and lamb producers, for sheep production as a whole, and for the whole farm.

Technical inefficiency was found to be present among the sample of each benchmarking group for wool specialists, dual-purpose producers and lamb specialists during the various study periods. There is therefore scope for extension activities to be undertaken to improve the technical performance of the bulk of sheep producers.

In studies over a number of years, an interesting divergence was found to exist between the studies. In the Darkan and HSA results, specialist wool producers tended to become less technically efficient (that is, were located further from the production frontier) over time. That is, the technical performance of the average producers (in terms of their ability to turn inputs into output) fell further behind best-practice producers. Note that this finding does *not* mean that the technical performance of average farmers declined; their performance only declined *relative to that of best-practice producers*. The productivity gains for average producers are a better guide as to their technical performance over time – see section 4. In contrast, inefficient specialist wool producers in the FMP benchmarking group moved closer to the production frontier over time, in contrast to trends in the other two benchmarking groups, but the production frontier did not expand over the study period. Little trend in technical efficiency was found for FMP sheep producers as a whole.

3.2 Comparison of technical efficiency and gross margin estimates

For Darkan farms, high positive correlations were found between technical efficiency/productivity and gross margin estimates per DSE and per hectare grazed to sheep for wool production. For wool production on FMP farms, moderately high positive correlations were found to exist between technical efficiency/productivity and gross margin estimates per DSE and hectare grazed to sheep. The high correlations for Darkan farms suggest that farmers are following similar resource allocation strategies and are facing similar production conditions. In situations such as this, a benchmarker would gain a good idea of productivity change by comparing gross margins over time.

In contrast to the Darkan and FMP correlations, low correlations were found between technical efficiency and gross margin estimates for wool production on farms in the HSA group. The presence of many negative gross margins over the study period, frequently associated with prevailing drought conditions, might explain these unexpectedly low coefficients.

3.3 Stocking rate and technical efficiency

The SFPA models can be used to establish relationships between stocking rates and marginal products (additional output) across a sample of farms, taking into account changes in other inputs used when the stocking rate changes. Currently, stocking rate varies widely across sheep-producing units in benchmarking groups. In the Mackinnon group, for example, stocking rates varied from 6 DSEs per hectare to 26 DSEs per hectare with an average stocking rate was 13.7 DSEs per hectare. Stocking rate was included as an efficiency variable as well as an input in the production function model to assess whether the stocking rate is associated with either higher or lower technical efficiency. The coefficient was strongly significant and of a sign that indicates that the stocking rate is associated with greater technical inefficiency. A plausible explanation for this result derives from the risky nature of wool production. Producers who push their stocking rate to the limit suffer disproportionately when unfavourable climatic conditions prevail given the downside risk that is typical of agricultural production, where the gains in good seasons are outweighed by losses in bad seasons. Recent widespread drought conditions in the study area may well have accentuated this outcome. This result suggests a need for more careful research on the obviously complex effects of stocking rate on output.

At one level, increasing the stocking rate is crucial to achieving maximum output for a given set of inputs, and it is probable that all benchmarked farmers have been successful in achieving most of these gains. Figure 1 shows the additional output achieved in percentage terms for adding another DSE to stocking rate for best-practice and average producers. The fifth DSE adds 5.5 per cent more output for the best-practice producer and 7.2 per cent more output for the average producer. But by the time the average stocking rate for the sample is reached, the increment has fallen to around 4 per cent. The additional output per DSE falls more quickly for the average producer. As a result, maximum output is achieved at 26.5 DSEs for the average producer and at 31.5 DSEs for the best-practice producers, respectively.

Of course, with diminishing returns to inputs, producers can be expected to maximise technical efficiency by choosing a stocking rate well below the rate that maximises output. (Indeed, the average stocking rate is around one-half these levels.) This is because increasing amounts of inputs other than DSEs are required as stocking rate increases. In other words, there is a point beyond which increasing the stocking rate pushes producers below the production frontier.

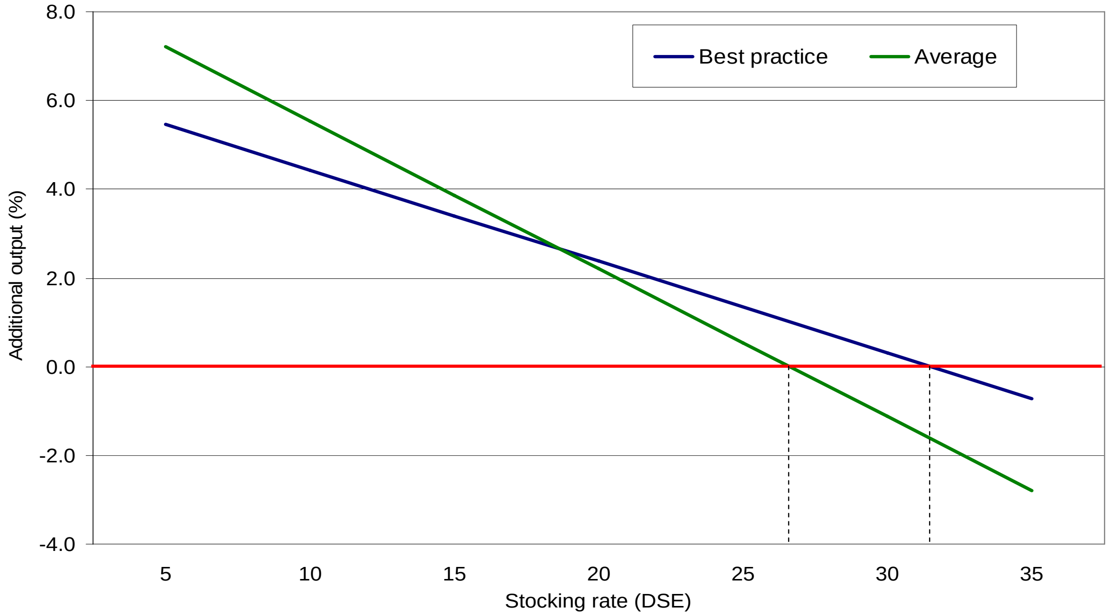

Figure 1 Relationship between the marginal product and stocking rate, Mackinnon, 1999/2000 to 2003/2004

4. Main Findings on Productivity Change

4.1 Estimates of productivity change

Details on estimation procedures used to measure productivity change have been described in detail by Fleming et al. (2005, 2006) and detailed results are available in the technical papers listed in Appendix 3. Estimates of productivity change were made for three of the four benchmarking groups. A lack of observations in the latter years of the Mackinnon benchmarking group meant that any estimates of productivity change were unreliable.

Individual farm estimates of productivity can change over time because a farmer becomes more or less technically efficient and/or because they take advantage of improved technologies. Both of these changes were evident during the study periods in the benchmarking groups, as spelt out below.

Satisfactory estimates were made of the stochastic frontier production functions of farmers in each benchmarking group that enabled calculation of individual technical efficiency indices for each farm in each year. In the Darkan analysis, a separate (and significantly higher) production frontier was estimated for a handful of stud farms in the sample. In the HSA analysis, farms were assigned to eight regions: North-West New South Wales; North-East New South Wales; South-West New South Wales; Central New South Wales; South-East New South Wales and North-East Victoria; South-West Victoria; King Island, Tasmania; and Queensland. A pooled data set was used in order to take into account the different environmental conditions in each region.

Estimates of technical change and productivity change were made for the sheep enterprise as a whole, combining data for different enterprises. First, data were combined on wool and lamb production to estimate multi-input multi-output stochastic production functions. These functions were satisfactorily estimated for FMP and HSA farms.

Second, whole-farm estimates of technical change and productivity change could be made for each farm where mixed farming is important. Such an analysis was successfully undertaken with HSA data, including the crops and beef enterprises. A similar exercise was attempted with FMP farms, aggregating the data on different enterprises. The presence of a large number of zeros for outputs where farms did not undertake a particular enterprise made this exercise less than satisfactory. While it was not attempted, aggregating farm outputs and inputs across all enterprises in a whole-farm analysis is a simple extension for benchmarkers to make when estimating technological change and productivity change.

4.2 Results for benchmarking groups

Best-practice wool producers in the Darkan group experienced a substantial increase in productivity over the study period of 4.9 per cent per year while the productivity of the average producer increased by 3.5 per cent per annum. Although they had a significantly higher productivity level, stud farms achieved a productivity growth rate lower than that of ordinary producers.

Best-practice wool producers in the HSA group also experienced a substantial increase in productivity over the study period of 3.3 per cent per year. The productivity of the average producer in this group, however, increased by around one-half that rate, at 1.7

per cent per year. The lower growth rate for the average farmer may be due in part to the different effects of drought across regions. A rainfall variable was successfully included in the estimated model but it is likely that the adverse consequences of severe drought were felt in following years for many farms, possibly depressing the average productivity growth rate.

The productivity levels of some producers fell well behind those of best-practice producers over the study period. In fact, a handful of producers in 2004/2005 were at an absolute level of productivity that was still lower than that achieved by the most efficient producers in 1997/1998. This trend is reflected by the less compact distributions in later years of the period. Two possible reasons are the effects of drought on the performance of some producers and the entry of some less efficient producers into the benchmarking process in later years. A farmer sample that constantly changes over time is a major concern for the accurate measurement of productivity change.

Different productivity levels were found to exist between most regions in the HSA group. These differences were in line with expectations about variations in land and climatic conditions from one region to the next. This finding is explored in section 5.

Estimates of productivity change were made for individual farms in the FMP benchmarking group for the period from 1994/1995 to 2004/2005. They were derived for two sets of farmers. One set comprised only those farmers who specialise in wool production. The other set also included farmers who have a lamb enterprise. The inclusion of this second set in the analysis was based on the observation that many farmers changed from being specialist wool producers to producing lambs as well as wool over the study period, which is likely to have influenced the efficiency and productivity estimates. The data sets of prime lamb production among sampled wool producers show that the number has increased dramatically over the study period.

While the positive trend in productivity for specialist wool producers is similar to that achieved in the Darkan group, its composition is different. The average annual rate of productivity growth was around 2 per cent was generated primarily by improved technical efficiency. Technical change was strongly positive until 1997-1998 after which the index declined until 2002-2003 before slightly increasing in the final two years of the study period.

The composition of changes for all FMP wool producers is more in line with that on Darkan farms although the magnitude is considerably lower. The mean annual rate of productivity growth was marginally less than 1.5 per cent, slightly below that for average HSA producers. Technical change was strongly positive to 1997-1998 after which it experienced a gradual decline.

The shift to joint production of wool and prime lamb production is a possible explanation of the trends outlined above. The overall lower rate of productivity growth compared reasonably closely to the rate achieved by average producers in the Darkan and HSA benchmarking groups. Previously less efficient specialist wool producers would now have been left on the contracting frontier whereas in earlier years they would have been below it. Their improvement in performance is consistent with the level of productivity growth achieved by average farms in the Darkan and HSA benchmarking groups.

Another possible explanation for the downward trend in productivity for specialist wool producers in the latter half of the 1990s and early 2000s is the decline in fine wool (19 micron and less) prices relative to medium wool (19-23 micron) prices that occurred in the period between 1995 and 2001. The average micron declined steadily throughout the study period, and it would be expected that better wool producers would have been more prominent in this shift towards finer wool production.

Models were separately estimated for prime lamb producers in the FMP and HSA benchmarking groups. In the FMP group, there was an unexpected and startlingly high productivity decline among both best-practice and average producers. This surprising result may be due to the substantial changes in the sample during the study period, but nevertheless needs further investigation. In the HSA estimates, the frontier was estimated to be virtually static. But mean technical efficiency increased significantly, leading to a productivity growth rate similar to that achieved for wool production. An estimated model for the aggregated sheep enterprises (wool, dual-purpose and lamb) for HSA producers provided a similar result, with a slightly lower productivity growth rate.

Two examples follow in Figures 2 and 3 for benchmarked HSA producers. They show how the distribution of scores of annual technical efficiency and productivity change of the producers over a number of years can be visually presented.

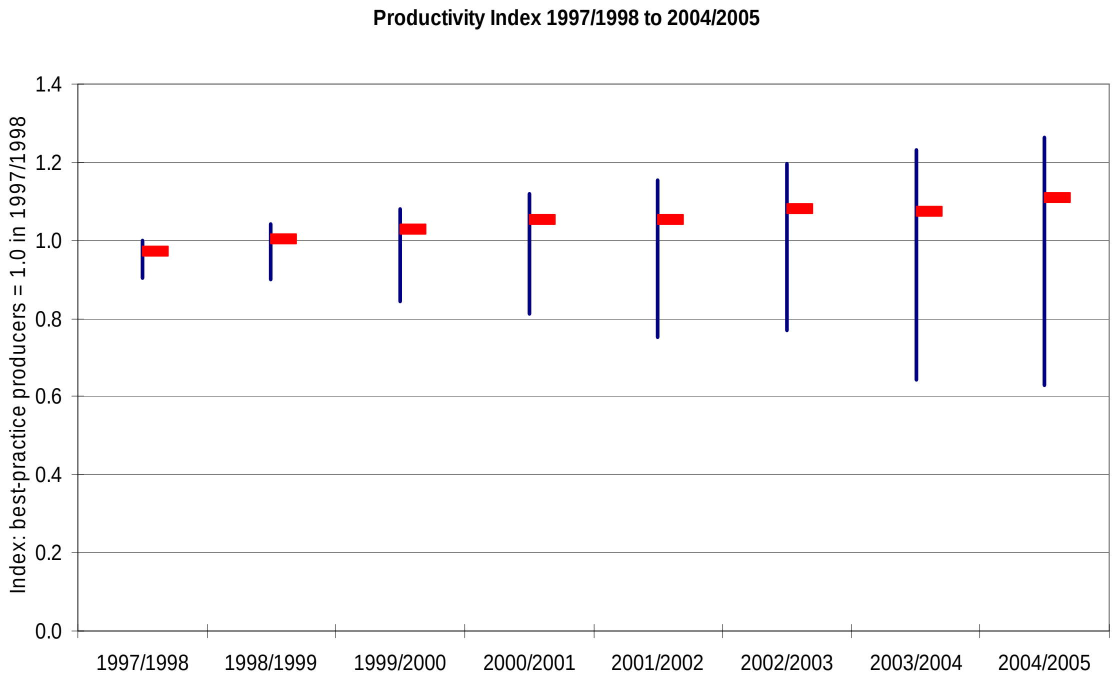

Figure 2 Productivity trends by year, HSA: 1997-1998 to 2004-2005.

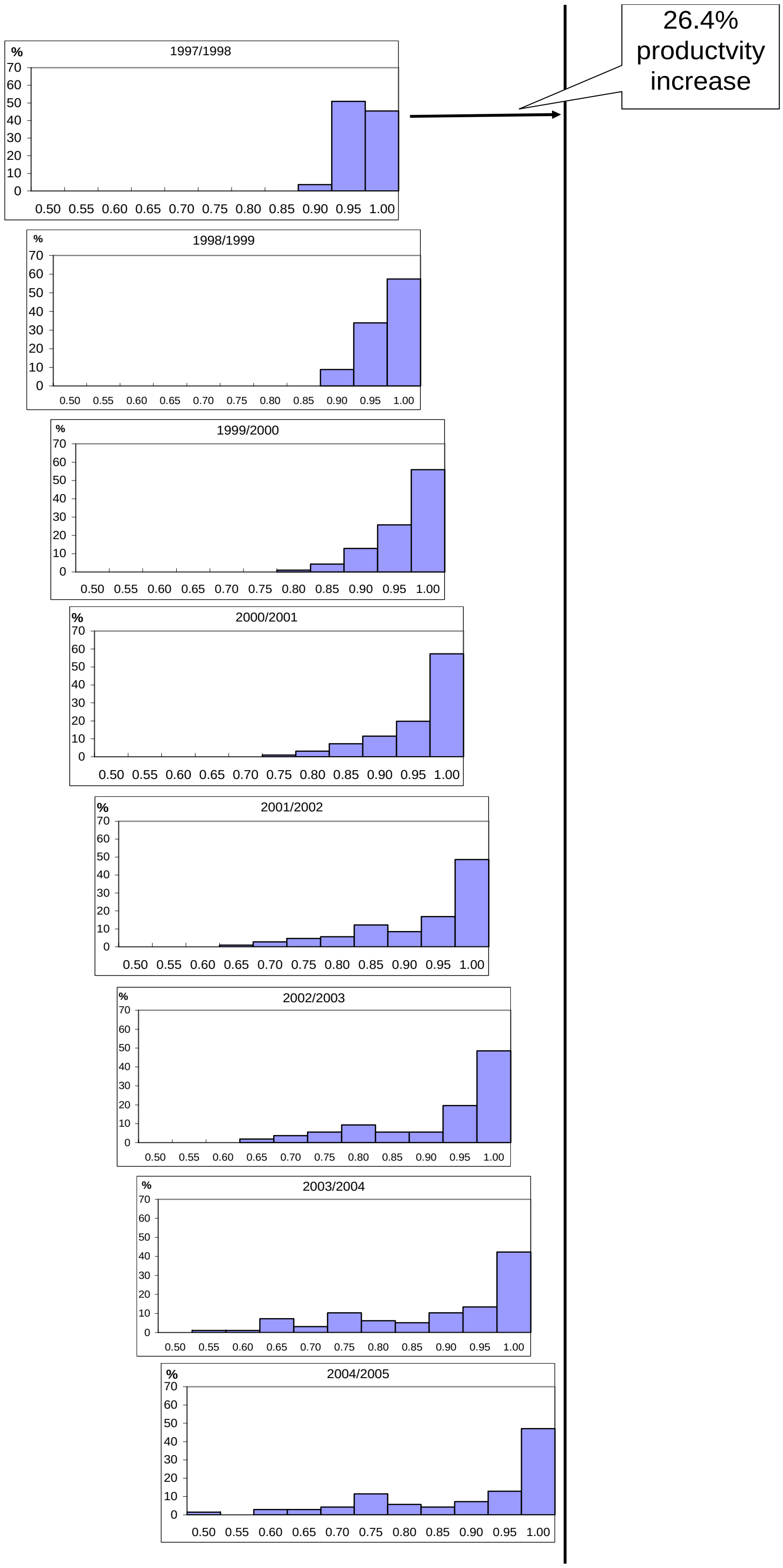

Figure 3 Distribution of technical efficiency estimates by year, HSA: 1997-1998 to 2004-2005.

4.3 Accounting for quality changes in wool and lamb production

An attempt was made to take into account the quality improvements made in wool and lamb production when measuring productivity growth on farms over the study periods of the different benchmarking groups. In the case of wool production, the concern is that analysts have previously underestimated productivity growth rates because they failed to account for the higher quality production implicit in the move to finer wool. The finer wools fetch higher prices, and so the wool price index used to deflate wool revenue to implicit outputs overstates the extent to which prices are higher due to exogenous market factors. The same situation is likely to have prevailed in estimates of lamb production with a move to lamb products more highly desired by producers and therefore fetching higher prices.

In the case of wool, the appropriate price deflator should be based on the original weights for wool types included in the regimens of the regional indicators at the start of the study period. These regimens were regularly rebased over the period. The divergence between price series over recent years can be gauged from AWEX (2006). The average annual increase in the Eastern Price Indicator from mid-2003 to mid-2006 was around 1 per cent, while the average annual increase in the regional indicator for Western Australia was around 1.3 per cent. Assuming this rate applied over the whole decade when the productivity estimates were made for benchmarking groups, it was estimated that the productivity growth rates reported above were underestimated by as much as 0.5 per cent per annum depending on the region.

5. Analysis of data across benchmarking groups and regions

There are three reasons why pooling data from a number of benchmarking groups to obtain one set of technical efficiency indices might be preferred to individual estimation procedures for each group. First, there might not be sufficient annual observations on farm inputs and outputs in a particular group to obtain reliable technical efficiency estimates. Second, if benchmarkers within a group are acting upon the same advice, there might be only a small difference in their production practices, making it difficult to discern factors explaining why one wool producer in the group is more technically efficient than another. Third, comparisons can be made of the levels of productivity and technical efficiency across a wider group of farms. A pooled model was estimated for Victorian farms in the FMP and HSA groups in order to test the proposition that farmers in different benchmarking groups can be satisfactorily combined as if they are one group.

This estimation procedure was successfully completed. A surprisingly strong contrast in results is observed in the two benchmarking groups in terms of the estimates of both technical change and productivity change. While these estimates are not vastly different from estimates obtained in the individual analyses, the rates of growth on HSA farms are improbably high. The reason for this exaggeration is most likely a result of the fairly crude way of differentiating between production relations on the two groups of farms.

An alternative approach is to use a larger set of benchmark dummy variables to allow for differences in production response to each input between benchmarking groups. Following this approach can help overcome the exaggerated differences in growth rates between groups, but it defeats the purpose of the first reason for pooling data across benchmarking groups, namely a shortage of observations. Nevertheless, it might still provide benefits in discerning variations in technical efficiency between farms where production practices differ between the groups.

Unless there is a problem of a small number of observations for an individual benchmarking group, the gains from pooling data across groups in different regions are likely to be slight while the potential for inaccurate estimates of technical efficiency becomes much greater when pooling is undertaken. The pooling of data among groups in the same geographical region is more likely to yield benefits, as indicated by the analysis of farms from two benchmarking groups in Victoria.

The strongest argument generally articulated against pooling data across regions is the difficulty in capturing the substantial environmental variations between benchmarking groups in estimating the stochastic frontier production function. These environmental variations exist in many dimensions, such as rainfall, sunshine, humidity, soils, topography, pests, diseases and infrastructure support. It is argued that if they are not captured fully in model estimation, any knowledge gleaned from model estimates that production frontiers or technical efficiency levels are higher in one region than another is of little use. This nullifies one of the main advantages of pooling data. In some instances, the environmental differences are technologically based but in most cases they are a function of spatial and temporal variations in the environmental conditions in which farms operate.

We explored the extent to which regional variations in technical performance in wool production are due to environment-technology gaps in wool-producing regions of Australia rather than simply differences in technical efficiency. Our aim was to assess the extent to which pooling across regions results in incorrectly attributing inferior performance to technical efficiency when it is a gap in performance that could not have been bridged under any circumstances given environmental factors. While environmental differences in wool production are a function of spatial and temporal variations in the conditions in which producers operate, they are also technologically based in that producers adjust their production technologies to suit the environment in which they operate. Even so, the ability of producers to adjust their production technology to the environment is unlikely to bridge the productivity gap between a producer operating in a favourable environment and one operating in a difficult environment, with poorer resources and greater production uncertainty brought about by climatic variability.

The evidence on technology gaps is not conclusive in that, while technology gaps differ between regions, these differences are likely not any greater than technology gaps within regions and over time as climate imposes constraints on production possibilities, Nevertheless, using a panel data set pooled across different benchmarking groups and regions should be avoided providing sufficient data are available for analysis within each benchmarking group. It is possible to pool data for more than one benchmarking group if farmers are from the same geographical region and benchmarkers are using consistent data sets. Otherwise, the gains from pooling are likely to be slight while the potential for inaccurate estimates of technical efficiency becomes much greater.

6. Estimates of Scope Economies

Scope economies are a measure of synergies between different farm enterprises. They exist between two farm enterprises when, for a given level of resource use, more can be produced by combining the production of the enterprises than by operating the enterprises as separate systems. Two types of scope economies were estimated: between wool and lamb output, and between sheep output, grain output and beef output. Estimated scope economies were derived from models based on stochastic input distance functions for the farms in the FMP and HSA benchmarking groups.

Significant scope economies were detected between livestock activities on FMP benchmarked farms. Strong synergies were found to exist between wool and lamb production and weaker synergies were identified between wool and beef production, and between lamb and beef production.

For HSA benchmarked farms, evidence was found of significant scope economies between wool and lamb production, similar to the finding for FMP farms, but they were in the moderate rather than strong range. Strong synergies were found to exist between sheep and crop enterprises and between beef and crop enterprises, while significant but weaker synergies were detected between sheep and beef enterprises.

7. Training Sessions for Benchmarkers in Productivity and Efficiency Analyses

The analyses undertaken to date have required benchmarkers to provide data to staff in the School of Economics at the University of New England, who have then manipulated the data and analysed it. This was a necessary first step but is cumbersome and costly in time, so a more expedient method of analysis was explored.

Two sets of exercises were undertaken to gauge the ease of extending the analytical methods for operation by benchmarking groups themselves:

1. Collaboration with benchmarking staff in performing data manipulation according to a simple set of instructions.

2. Two training sessions in running models and interpreting results.

The aim of the first exercise was to assess the ease with which data manipulation could be undertaken by the benchmarker, based on existing *Excel* files kept for the purpose of providing farm accounts and calculating other benchmarking indicators. Results showed that the extraction of data for conducting productivity and efficiency analyses was exceedingly quick and easy, provided two relatively straightforward conditions hold. First, the data need to be recorded in *Excel* spreadsheets in a manner similar to the procedure followed by HSA. Second, there must be a staff member in the benchmarker's office who is competent in the use of spreadsheet techniques, especially pivot tables.

Once data were in a format ready for analysis, the next step to undertake the analysis was more challenging and called for a staff member in the benchmarker's office being competent in the operation of the SFPA software (FRONTIER 4.1c) and DEA software DEAP 2.0), as used in the analyses discussed in this report. Training in the two methods took two forms. First, a one-day training session was run in Perth with staff from two of the benchmarking groups. Second, a distance training session was attempted with a staff member of a third benchmarking group applying the same two techniques. The first session was very successful in enabling the benchmarking staff to run the models. Much of the day was spent interpreting results and comparing subjective judgments held by one of the benchmarking staff from JRL Hall and Co. with the technical efficiency scores calculated for farmers in the group. After this training was completed, a Powerpoint presentation was prepared to guide people through the various steps needed to run FRONTIER and DEAP models and interpret basic results.

The dissemination of the analytical methods to other benchmarkers in the sheep industry is a potentially valuable outcome of the sub-project. The experiences gained from data collection and the ease with which data sets were assembled and models run by staff members of benchmarking groups should help streamline the processes for other benchmarking groups to estimate technical efficiency and productivity change.

An alternative approach would be for a benchmarker to provide the data in an appropriate spreadsheet form and send it for analysis to an organisation such as the School of

Economics at the University of New England. It is estimated that this analysis, together with a summary of results and report, could be completed in three working days providing no follow-up work is required to get the data set into a format ready for analysis.

Finally, the establishment of a bureau to process data and provide results on efficiency and productivity measures is not considered a desirable strategy. In-house estimation should be comfortably handled if a benchmarker wishes to obtain such measures.

8. Analysis of Factors Influencing Technical Efficiency and Gross Margins

An important part of the sub-project was to analyse factors influencing technical efficiency and profitability in sheep production (see Figure 5). From a technical viewpoint, the work involved was to ascertain why one farm has a higher level of technical efficiency or productivity than another farm. This analysis was initially carried out for three benchmarking groups using principal components analysis, with only limited success.

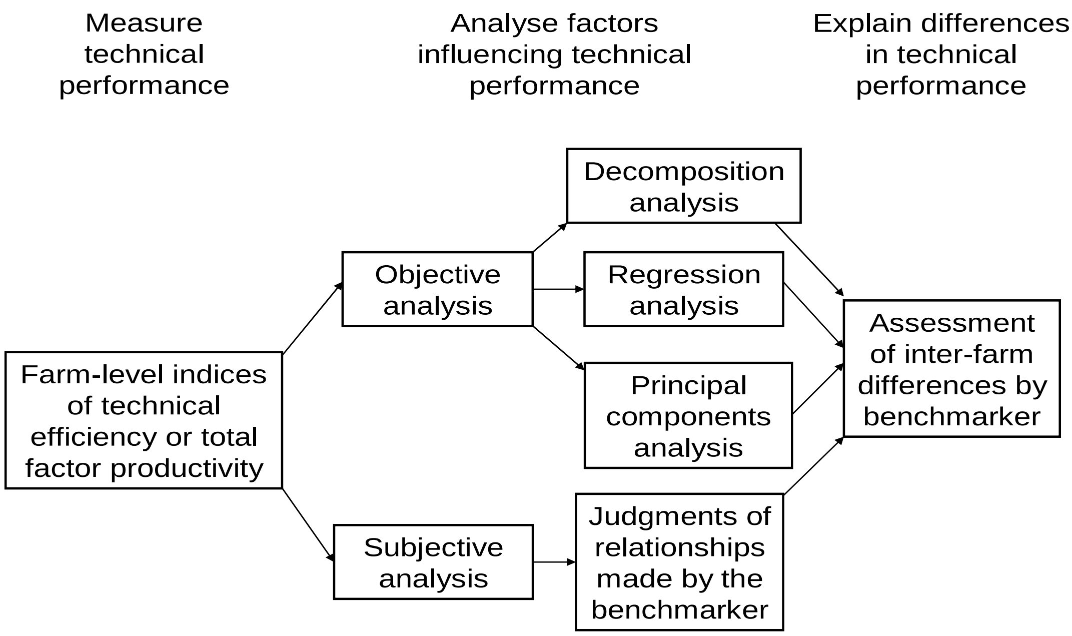

Figure 5 Alternative ways to explain differences in technical performance by wool producers.

Five factors limited this analysis:

1. Probably the most important limitation has been that there is no ‘magic bullet’ solution to improve the technical aspects of wool production in Australia. As Scott (2004) observed, livestock farmers need to be on top of a multitude of aspects of the farming system, which means that differences in technical performance among farms boils down to a large number of ‘1 per cent’ gains that can be made rather than a single action that leads to a quantum leap in technical efficiency.

2. The nature of the farms in the benchmarking groups is such that most of the wool producers have been receiving the same advice from the benchmarker for many years and have been acting on this advice. All the major gains in technical performance that could be made have already been achieved, and benchmarkers face a situation of heavily diminishing returns to their advice on further improvements. Therefore, little variation occurs in production practices that would cause differences in technical efficiency or productivity.

3. Some of those factors that might lead to variations in efficiency and productivity are not readily quantifiable, and do not appear in the list of variables included in the set used in the principal components analysis. Examples are attitudes to work, knowledge of sheep production systems, work practices, attention to detail in planning and scheduling farming tasks, effort put into physical work on the farm and motivation.

4. It is difficult to purge the so-called ‘key performance indicators’ used as variables influencing technical efficiency and productivity of elements already incorporated in the estimation of the production functions from which the technical efficiency and productivity indices have been derived. Many if not most of these indicators contain at least some elements of input-output relationships that have already been captured in the estimated production functions.

5. Estimating technical efficiency indices for an individual farm requires the prediction of trends over time. This prediction process results in indices that are approximations, given that variations between years are not estimated precisely,

and could restrict the efficiency of the estimations made in the principal components analysis. But the substitution of gross margins for technical efficiency indices did not improve the ability to draw inferences from the results.

Regression analysis is an alternative approach that can be conducted simultaneously with the estimation of the stochastic frontier production function (Figure 5). However, it has the disadvantage of assuming independence among variables explaining differences in technical efficiency between farms and suffers from some of the shortcomings of principal components analysis, outlined above.

Third, there is always the option of relying on the judgment of the benchmarker who is likely to understand intimately why one farmer is performing better than another. Knowledge of best-practice farmers can assist benchmarkers in selecting peers against which to compare inefficient farmers. This knowledge should also help a benchmarker select demonstration farms for sessions from which other farmers can learn how to improve performance. This approach should continue to be followed in all analyses as a means of comparing quantitative estimates with the performance level that the benchmarker subjectively believes each producer is achieving.

The final, and potentially most effective, approach is to decompose technical efficiency into its component influences and use regression analyses for understanding causal relations in each of the components making up technical efficiency. This was the approach adopted in the sub-project, except that gross margins were used instead of technical efficiency so that financial as well as technical influences on performance could be taken into account. The same approach could be adopted for decomposing technical efficiency scores into their component parts and determining their causal relationships. Rutley (2007) has published a separate report on the factors influencing production performance in the sheep industry. The report focuses on results from a decomposition analysis of gross margin.

9. Conclusion

This benchmarking sub-project has amassed a rich set of data that provides a valuable reference source for conducting efficiency and productivity analysis in Australian wool and sheepmeat production. The results reported above have provided some findings that should prove useful to benchmarkers in generating indicators of farm performance, enhancing the advice and information they provide to farmers. They also provide a valuable basis for assessing future initiatives to improve the flow of information on performance by wool producers.

Estimates of technical efficiency and scale efficiency, technological change and productivity were successfully calculated for each farm in each year of the respective study periods for four benchmarking groups individually and as a group. These estimates accord reasonably closely to results obtained from earlier work in Australia. The most challenging task arising from the results is to explain why different trends in productivity and technical efficiency occurred between benchmarking groups over time. We suspect two factors are at play. First, our attempts to capture both spatial and regional variations in climate have not been fully successful; nor are they likely ever to be perfect. Second, the most recent years of the study period have not been kind to either the farmers or the analysis. Attempts to estimate realistic technical efficiency indices in the midst of a drought, the severity and timing of which vary between regions, is a challenge that is extremely difficult to meet.

Scope economies were also successfully estimated. These estimates were made between wool and sheepmeat production within the sheep industry and between sheep output, beef output and grain output.

The future direction of efficiency and productivity analysis in wool production would appear to offer most benefits by focusing on individual regions or benchmarking groups rather than attempting to pool data across farms that experience a wide range of environmental conditions. In particular, much valuable work remains to be done for these individual groups by following a whole-farm approach to efficiency measurement by modelling all activities on the farm instead of simply wool production. There is also considerable scope for exploring in more depth the factors that influence technical efficiency. It is this information that is likely to be most valuable in enabling inefficient producers to improve their technical and financial performance through a better understanding of production methods.

The extension of analytical methods to more benchmarkers offers some potential gains to the industry. It was shown that staff members in benchmarking firms are quite capable of running the necessary models and interpreting results. On the whole, most farm efficiency and productivity scores appear to be in line with the expectations of benchmarkers, but a few are not. More work is needed, however, in reconciling why some individual scores do not correspond to the expectations of benchmarkers before these methods are recommended for implementation in the field.

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Appendix 1
Summary of Methods to Measure Efficiency and Productivity

A1 Measuring technical efficiency, scale efficiency, technological change and productivity

A beneficial feature of the technical efficiency and productivity measures reported in this study is that they identify the best-practice producers, and measure the performance of other producers in relation to these best-practice producers.

In order to calculate measures of technical efficiency, scale efficiency, technological change and productivity, a production frontier needs to be established. This frontier can be considered as an envelope around the relations between all inputs and outputs in sheep production, as shown in Figure A1 for the simple case of a production process with a single output and a single input. The production function for the average producer, who is technically inefficient, lies beneath the production frontier.

The technical efficiency measure is simple in that the best possible performance is given an index measure of 100 per cent (or 1.0) and producers who are not at the best-practice level obtain an index less than 100 per cent. The distance they are below 100 per cent measures the extent to which these producers are capable of improving farm performance if they were able to reach the standard of the best-practice producers in a technical sense. For example, a producer with an output orientation who has a technical efficiency index of 0.7, or 70 per cent, should be able to increase output of the farm activity being benchmarked by 30 per cent (1.0 minus 0.7), using the same amount of inputs, by reaching best-practice standard. An alternative way of looking at the index is with an input orientation. That is, by achieving best practice the producer could reduce the amounts of all inputs used by 30 per cent and still maintain the same level of output.

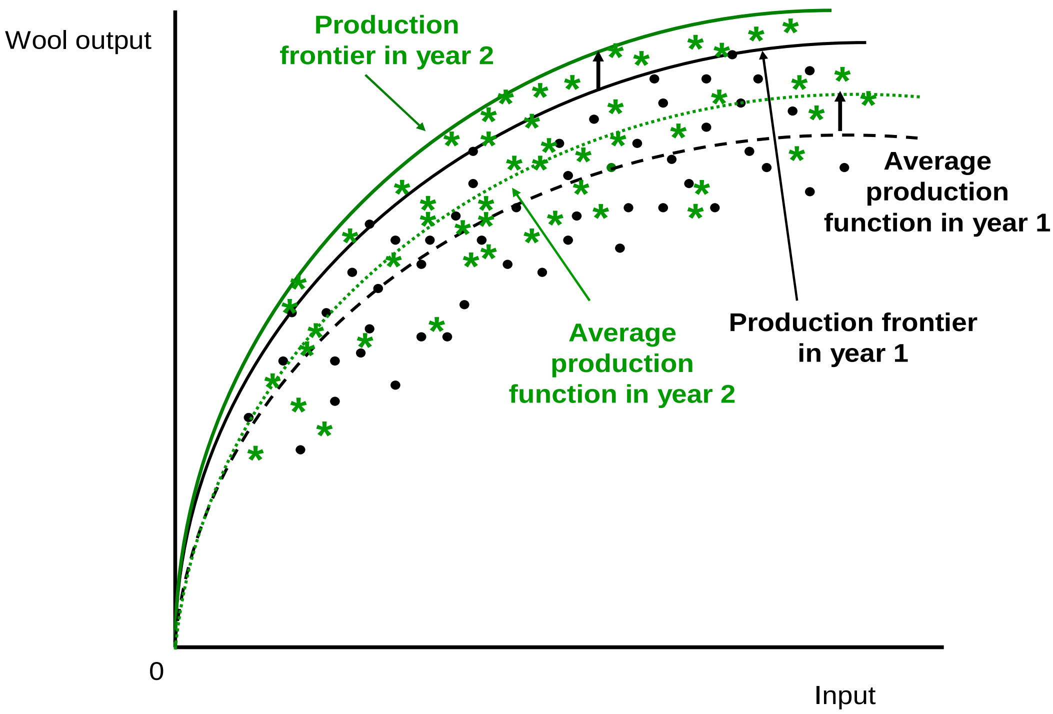


Figure A1 Production frontier for a single output before and after technological change.

Scale efficiency effects can be separated from technical efficiency, depending on the analytical method used. A scale-efficient farm is one that is closest to the point of optimal scale – where the long-run cost per unit of output is at its lowest level (or productivity is highest). As for technical efficiency, scale efficiency can be simply measured where the most scale-efficient farm is given an index measure of 1.0. Producers who are not at this level (have higher average costs) obtain an index less than 1.0. The distance of their scores below 1.0 measures the extent to which they are capable of improving farm performance if they can change the size of their farming operations to the perfectly scale-efficient level.

Productivity is the most relevant indicator to use when looking at changes over a number of years. The frontier shifts outwards as research output leads to new production technologies becoming available to farmers over time,. That is, more can be produced for the same amounts of inputs used. Productivity can change from one year to the next as a result of technological change as well as any change in mean technical efficiency (inefficient producers on average moving closer to or further away from the production frontier).

Technological change is represented by a shift of the production frontier between years. This is illustrated in Figure A1 where the black dots represent farms in year 1 and green asterisks the positions of farms in year 2. Best-practice farms have increased output per unit of input over the year, lifting the production frontier.

The average production function has also gone up by an amount roughly equivalent to the shift of the production frontier, suggesting that mean technical efficiency has probably not changed significantly in this case. Some farms might have remained at about the same level of productivity but, because the frontier has shifted, their technical efficiency index would have fallen.

A2 Estimation methods

Two estimation methods were used for the analyses:

- Stochastic frontier production analysis (SFPA) is an econometric method suited to situations where there are many years of data. This method allows unbalanced data sets to be analysed, an important advantage when changes over time are being measured and not all farmers have provided benchmarking data for all years in the study period. Technical efficiency indices are calculated by estimating what is called a stochastic frontier production function to allow for random events. This method does not easily allow scale efficiency to be measured separate from technical efficiency, which means that productivity and technical efficiency in any given year can be regarded as the same on the grounds that farmers have access to the same set of production technologies.
- Data envelopment analysis (DEA) is a linear-programming approach. It requires a balanced data set for analysing changes over time but can be used for single-year estimation of technical and scale efficiency so long as there are at least 30 observations given the number of input and output categories used in the analyses.

A detailed description of these techniques is not presented here because its widespread use means there are numerous descriptions already available in the efficiency and productivity literature. Coelli, Rao and Battese (2005) is a good reference for those interested in finding out more about the theoretical properties and modelling methods used in this approach. The SFPA models were estimated using the program, FRONTIER Version 4.1c and the DEA models were estimated by DEAP Version 2.1.

While a number of flexible functional forms can be used to portray the production function, we settled for a simple power function, familiarly termed the Cobb-Douglas function. Despite the fact that it entails some restrictive assumptions, the Cobb-Douglas production function was specified for two main reasons. First, it is easy to estimate, being linear in logarithms. Because it is intended that benchmarkers are able to do their own calculations of technical efficiency indices, ease of use is vital. Second, the Cobb-Douglas has proved to be very robust in estimation, especially when compared with flexible functional forms. This is an admirable attribute for use in benchmarking because it means the people estimating the frontier production function are not faced with a set of results that make little sense and require a good deal of re-estimation until a satisfactory function is estimated.

A3 Output and input variables

For wool enterprises, output is defined as either two variables – the implicit quantity of wool produced per annum and the annual net profit on the mature sheep trading account – or an aggregate of these two variables. The implicit quantity of wool was calculated as the value of wool output deflated by a wool price index from the Commodity Statistics published by the Australian Bureau of Agricultural and Resource Economics (ABARE). The advantage of using an implicit wool quantity rather than actual quantity in kilograms of wool is that it takes into account variations in wool quality while eliminating the effects of inter-year wool price variations by using the price deflator. For dual-purpose and lamb enterprises, an additional output variable – profit on the lamb trading account – was also included.

Inputs in all forms of production were aggregated into the following categories (data on which varied to a minor degree between groups): effective grazed pasture area, grazed stubble area, health inputs, pasture inputs, feed inputs, agistment, selling inputs, shearing inputs, labour and overheads. Outputs and inputs were expressed in dry sheep equivalents

(DSEs) in FMP analyses, and both DSEs and per farm in analyses for other benchmarking groups. All variables expressed in costs were deflated by the ABARE farm input price index to enable them to be expressed in implicit inputs. Imputed values were made by the benchmarkers for operator and family labour in the FMP and HSA groups, and total labour costs were allocated to the wool enterprise on the basis of the proportion of total grazed area used for each enterprise. Labour was measured as the number of full-time adult-equivalent workers in the Darkan group.

A3 Accounting for environmental factors influencing production

Rainfall and trend over time were two other variables that needed to be included in models where data spanned many years. We included a trend variable to account for any productivity trend. The most dominant trend effect is likely to be changes in production technology over the decade. Another possible factor is scale economies due to larger farm sizes that enable producers to take better advantage of existing production technologies. The likely productivity gains by producers over the period suggest a positive coefficient on the trend variable. A trend dummy variable for stud producers was also included in the Darkan analysis to determine whether the rate of productivity change on these properties was significantly different from that for ordinary producers.

Considerable effort was put into the calculation of a suitable rainfall variable. After testing a number of options, we settled on a set of dummy variables for seasons from excellent to very bad. In the Darkan analysis, these variables representing the type of season experienced by farmers were successfully included in the estimated model as JRL Hall and Co. was able to identify accurately the impact of seasonal conditions on output. The seasons were defined as very bad, bad, average, good, very good or excellent. It was expected that the worse the season the higher the negative impact on production.

In the FMP and HSA models, an attempt was made to account for variations in rainfall by specifying a set of dummy variables for different seasonal conditions that were measured according deviations from the long-run historical average for the four months of the main growing season, which varied according to region. These seasonal dummy variables were defined using the same terminology as for Darkan farms.

The resulting set of dummy variables was successfully included in the estimated model for HSA farmers. A similar approach was followed for the Mackinnon model but in this case annual rainfall had to be used rather than the four months of the main growing season. In the FMP analyses, use of rainfall deviations for the main growing season was unsuccessful in capturing the effects of seasonal variations on wool output. In the absence of subjective estimates of the type of season, statistical methods were used to define seasons using the same seasonal dummy variables as for the other benchmarking groups.

A4 Relating technical efficiency to gross margin

An assessment can be made of the correspondence between technical efficiency estimates and gross margins for benchmarked farms in each year by examining the correlation coefficient and the rank correlation coefficient. Correlation coefficients can be estimated between technical efficiency and various gross margin estimates. The two most common estimates in the sheep industry are gross margin per DSE and gross margin per hectare grazed to sheep for wool production.

Correlations should not be perfect, for two major reasons. First, technical efficiency indices represent only one of the two components of economic efficiency, for which gross margin is proxy, namely the technical aspects of production. They exclude allocative efficiency, or how a farmer selects a mix of inputs to produce a given quantity of output at minimum cost given prevailing input prices, pertinent to an input orientation, and output prices, pertinent to an output orientation (Coelli, Rao and Battese 1998, p. 5). Second, the two gross margins are partial measures only, in that each is expressed per unit of one factor of production, whereas technical efficiency indices take into account all inputs used in production.

Appendix 2
Glossary

A **production technology** is the set of methods used on the farm to produce wool and other sheep outputs.

A **production function** is the numerical relationship between an output, wool (or set of sheep outputs), produced on the farm and the set of inputs used to produce that output or set of outputs. It expresses farm output as a function of the inputs used to produce output.

The **production frontier** measures the output that can be produced by farmers who are technically efficient (use 'best-practice' farming methods). The production frontier function used in this study can be considered as an envelope around the relations between all inputs and outputs in wool production after allowing for random events. The allowance for random events leads to use of the term, **stochastic production frontier.**

Inputs refer to the farm resources (grazed pasture land, stubble land and labour) and purchased goods and services (agistment, feed inputs, pasture inputs, health inputs, shearing inputs, selling inputs and overheads) used in production of wool or set of sheep outputs.

Scale efficiency refers to the ability of a farm to achieve a level of scale of operations that allows it to produce at the highest productivity (lowest cost per unit of output). A scale-inefficient farm produces output at a unit cost less than maximum productivity.

Scope economies are a measure of synergies between different farm enterprises.

Technical efficiency is using all the inputs available to the farmer to produce the maximum possible output for a given production technology and scale of operations. A farm is **technically inefficient** if it produces less than this maximum possible output.

Technological change is a change in production methods that shifts the production frontier.

Total factor productivity (referred to simply as productivity) also measures the output produced from all inputs available to the farmer. But it takes into account the fact that not all farmers have access to the same production technology. For an individual farm, it is its technical efficiency index multiplied by the maximum output achievable from using all available inputs.

Appendix 3
Articles and Technical Papers

Articles

Fleming, E., Villano, R., Farrell, T. and Fleming, P. 2005, *Efficiency and Productivity Analysis, Report on Benchmarking Sub-Project*, Australian Sheep Industry CRC, Armidale.

Fleming, E., Villano, R. Farrell, T. and Fleming, P. 2006, 'Is benchmarking the new acceptable face of comparative analysis?', *Australasian Agribusiness Review* 14, Paper 12.

Geenty, K.G., Fleming, E.M., Rutley, D.L. and Kemp, D.R. 2006, 'Farm benchmarking: the next level', in P. Cronjé and D. Maxwell (eds), *Wool Meets Meat: Tools for a Modern Sheep Enterprise, Proceedings of the 2006 Australian Sheep Industry CRC Conference*, Orange, August, pp. 72-77.

Rutley, D.L., Geenty, K.G., Fleming, E.M. and Villano, R.A. 2006, Defining the future sheep enterprise: the role of benchmarking, Poster paper presented at Horizons in Livestock Sciences: Research for the Farm of the Future, Gold Coast, 8-11 October.

Department of Primary Industries 2007, 'Feature article: efficiency and productivity: evidence from the Farm Monitor Project in South West Victoria', in *South West Monitor Project: Summary of Results 2005/2006*, Victoria Department of Primary Industries, Melbourne, pp. 26-31.

Villano, R., Fleming, E., Farrell, T. and Fleming, P. 2006, Productivity change in the Australian sheep industry revisited, Contributed paper accepted for presentation at the 26th International Conference of International Association of Agricultural Economists, Brisbane, August.

Villano, R., Fleming, E., Farrell, T. and Fleming, P. 2006, Productivity change in the Australian sheep industry revisited, Contributed paper to the 50th Conference of the Australian Agricultural and Resource Economics Society, Sydney, February.

Villano, R., Fleming, E. and Fleming, P. 2007, Accounting for environmental differences in efficiency measurements in the Australian wool industry, Contributed paper to the 10th European Workshop on Efficiency and Productivity Analysis, Lille, June.

Technical Papers

1. Technical efficiency and productivity estimates for wool production on farms in the JRL Hall benchmarking group, Darkan
2. Technical efficiency and productivity estimates for wool production on farms in the Holmes Sackett and Associates benchmarking group
3. Technical efficiency and productivity estimates for the wool enterprise on farms in the Farm Monitor Project benchmarking group, South-West Victoria
4. Technical efficiency and productivity estimates for the wool enterprise on farms in the Mackinnon benchmarking group, Victoria
5. Estimates of technical efficiency and productivity change in wool production on farms pooled across two benchmarking groups
6. Estimates of technical efficiency and technology gaps in wool production on farms pooled across regions
7. Technical efficiency and productivity estimates for dual-purpose and lamb production on farms in the Holmes Sackett and Associates benchmarking group
8. Technical efficiency and productivity estimates for joint wool and lamb production on farms in the Farm Monitor Project benchmarking group in south-west Victoria
9. Estimates of scope economies in sheep production
10. A procedure for estimating relations between stocking rate, technical efficiency and additions to output in wool production

11. Accounting for quality changes in wool and lamb production when estimating productivity change
12. Powerpoint training file for estimating efficiency and productivity in sheep production

THE UNIVERSITY OF ADELAIDE AUSTRALIA

Livestock Systems Alliance

PROJECT REPORT

JUNE 2007

Sheep CRC Project 1.2.6 Farm Enterprise Benchmarking

Prepared by
David Rutley

Scientist - Livestock Systems

For The **University of New England**

Table of Contents **Page**

Table of Figures **Page**

1. Executive Summary

This report is the culmination of statistical analysis over the period of the project, with interpretation based on several approaches and methodologies. These approaches have included multiple regression and principal components analyses that lead to development of the final cause and effect process model with its series of general linear mixed models included in this report.

Variation in the ultimate performance indicator, Gross Margin per Hectare, was explained by combining series of general linear models. These linear models describe the relationship between basic performance indicators (PIs) and components of income and stocking rate.

Nineteen performance indicators could be considered 'Keys' of the sheep production process model developed. These 19 KPIs are a subset of 49 PIs used to define the production process model. Of the other 30 PIs several reasons exist for their exclusion:

1. 15 could not be tested due to insufficient records. This may suggest that industry does not deem these records to be important;
2. nine were part of the expenses part of the process model, that requires further work, and;
3. six were tested but found not to be important.

It is hypothesised that the enterprises of this study are industry leaders and provide 'Bench Marks' for other sheep production enterprises. However, to continue to advance, the sheep enterprises of this study must improve many aspects of their production simultaneously.

To enable sheep production enterprises to make further productivity gains it would be useful to incorporate the sheep production process model and its component linear models into a computer aided expert system. This would allow managers to test scenarios prior to implementation of change. Such an expert system would allow managers to reduce the risks associated with incorporating changes by providing a tool to assist managers conduct sensitivity analysis of proposed management changes. Without such a tool, the complexity of sheep production will limit productivity improvements as the ramifications of management changes cannot be easily ascertained for such a complex process.

2. Introduction

Previous studies for this project have used methods such a principal components analysis and multivariate regression analysis using all biological performance indicators (PIs) simultaneously to attempt to develop an understanding of which indicators are key for comparing and thus improving enterprise performance. These previous analyses found that sheep, wool and lamb production could only be described by very complex models of the many (>20) different biological PIs, and that there were very little differences in the relative importance of the different biological PIs. As the initial aim of this project was not easily fulfilled (to determine which indicators may be the keys to describing enterprise performance) it was necessary to divide sheep enterprises into their discrete processes and study the processes separately to see if some key PIs could be elucidated.

3. Aim

To determine if any of the biological sheep enterprise performance indicators can be considered to be key for comparing enterprise performance.

4. Materials and Methods

The first part of this task was to define the general enterprise process model, also known as a cause and effect model (Deming, 1986; Brocka and Brocka, 1992). The second part of the task was to develop series of linear models for each data set to explain variation in Gross Margin per Hectare (GMHa) using the basic PIs defined by the process mode, such as fleece weight, fibre diameter, wool yield etc.

Forty nine different basic PIs were used to define the sheep production process model developed in conjunction with Bob Hall, David Sackett and Jonathon Tocker, with constructive comments from Ken Geenty, David Kemp, Euan Fleming and Kimbal Curtis.

General Linear Mixed models were developed for each data set using SAS Proc Mixed (SAS, 1992), to allow the repeated records of different enterprises to be correctly modelled. The repeated records were accounted for by fitting farm and year as random effects with year fitted as a repeated variable. All performance indicators were treated as non-random covariates. As well as testing linear terms in all models, quadratic terms were tested along with all first order interactions. Quadratic terms test for optimal or sub-optimal relationships, while interactions indicate conditional relationships. No interactions were tested with either year or farm. Figures of equations were plotted with R software (2006).

Models were developed from the maximum possible model, based on the process model, with linear, quadratic and first order interaction terms. Terms in the model were removed one by one, if they were not significant at the 5% level. Care was taken to ensure that the marginality requirements described by Nelder (1994) were satisfied. For some extremely complicated models the significance level was reduced from 5% to 1%, 0.1% and finally 0.01% in an attempt to simplify the models. This treatment was partially successful.

Study of sheep trading profit involved many explanatory terms (PIs (15), quadratic terms (15) and interactions (105)). The complexity of this analysis required the use of an automated model development routine (SAS Proc GLMSelect, SAS, 2005) to partially simplify the model before correcting for marginality requirements and removing non significant terms in a backwards stepwise manner.

4.1. Season

The definition of season is a complex matter but is known to affect enterprise production. The local and consistent nature of the Hall Wool data set allowed season to be given a categorical value of ‘very bad’, ‘bad’, ‘average’, ‘good, ‘very good’ and ’excellent’. This data set also had an average rainfall figure for each year for the region. The categories were converted to percentiles from the top to bottom $1/6^{th}$ for analysis. The HSA and FMP data sets had individual annual rainfall records. Season was calculated as the number of standard deviations above or below the long term average rainfall for a particular enterprise. The record for the previous season was also used to model seasonal effects as it is known that a lag in stock numbers or feed availability and quality may exist from time to time due to extreme seasonal conditions.

5. Results

5.1. The Sheep Production Process Model

The sheep production process model (Appendix 1) contained three intermediate levels between GMHa (level 1) and the basic (level 5) PIs. The model between GMHa and the basic PIs was defined by simple addition, subtraction or multiplication of the lower level indicators. Expenses per Dry Sheep Equivalent (DSE) were simply the sum of its component expenses, which were, in turn, simple sums of their components.

Variation in Wool Income, Lamb Trading Profit, Sheep Trading Profit and Stocking Rate were explained using general linear models of the basic (level 5) PIs. All other relationships in this model were direct summations requiring no parameter estimation.

Of the 49 basic PIs only 19 were required to explain variation in GMHa. These could be considered to be the 'KEY' Performance Indicators. Of the other 30 PIs,

1. 15 contained insufficient data for analysis, which may suggest that industry deems them not to be important
2. nine were part of the expenses part of the process model, that requires further work, and;
3. six were tested but found not to be important.

5.2. Relationships between KPIs and GMHa

The relationships between each of the 19 KPIs and GMHa are presented graphically in Figures 2 to 20 below and numerically in Appendix 2. The important information from these relationships is the rates of change or trends. To present these trends simply in the figures, the intercept terms have been altered. For Figures two to 20 below, standard line types were used for the six benchmarking data sets (Table 1 and Figure 1).

Table 1. Standard line types.

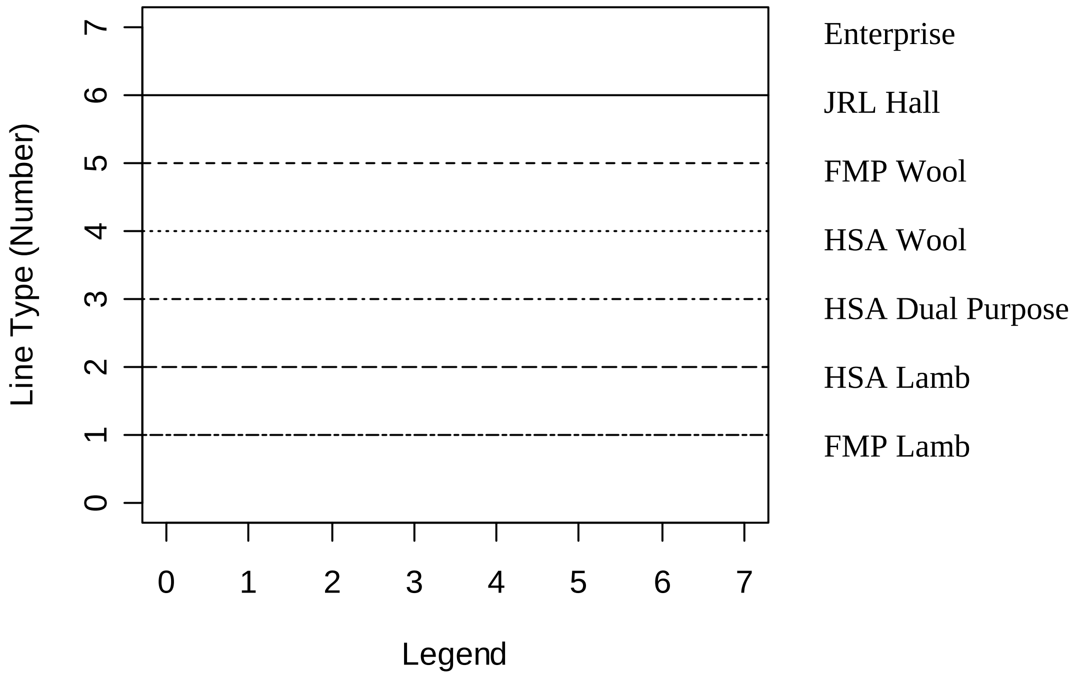
Enterprise Data Set	Line Type	Line Number
JRL Hall Sheep	Solid	6
FMP Wool	Dashed	5
HSA Wool	Dotted	4
HSA Dual Purpose	Dot Dash	3
HSA Lamb	Long Dash	2
FMP Lamb	Two Dashes	1

IN THE FIGURES NOTE:

THE RELATIVE DIFFERENCES (RANGE OF VALUES) PROVIDE THE IMPORTANT INFORMATION

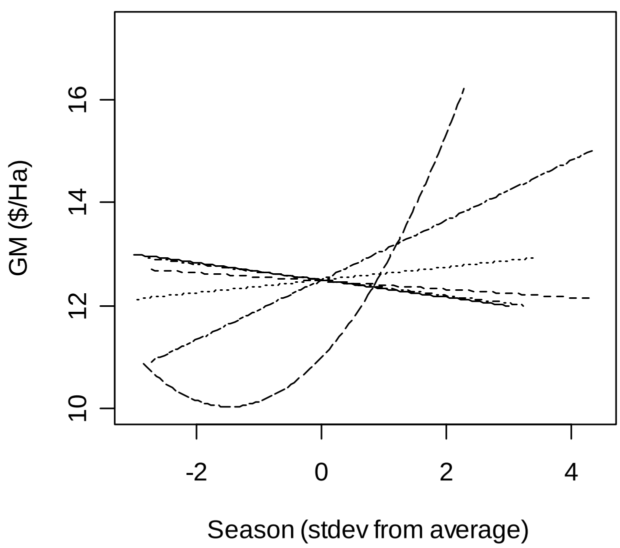
THE ABSOLUTE GROSS MARGIN IS NOT IMPORTANT. IT HAS BEEN ALTERED SO THAT ALL RELATIONSHIPS CAN BE GRAPHED TOGETHER.

Figure 1. Legend for Figures 2 to 20



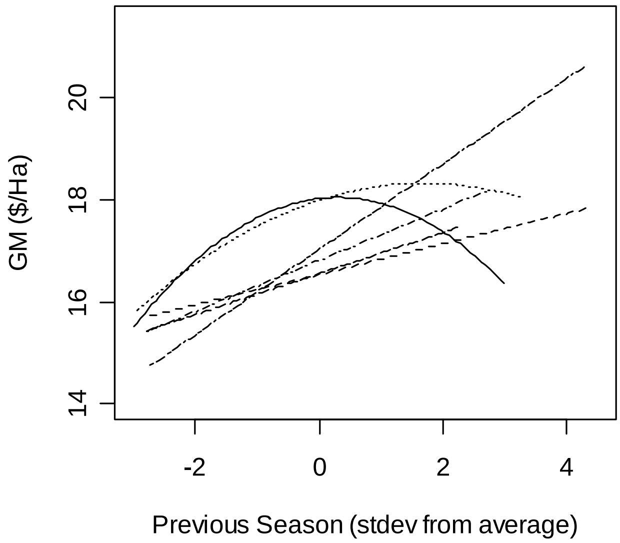
The effect of season and previous season were significant for all data sets with variable effects (Figures 2 and 3). For the HSA Lamb enterprises a sub-optimum was found for the current season with between average to poor conditions, which is probably associated with managers' undecided as to whether the season is bad enough to manage accordingly. In this case they may delay decisions in the hope that the season will recover.

Figure 2. The effect of Season (standard deviations from average) on GM/Ha



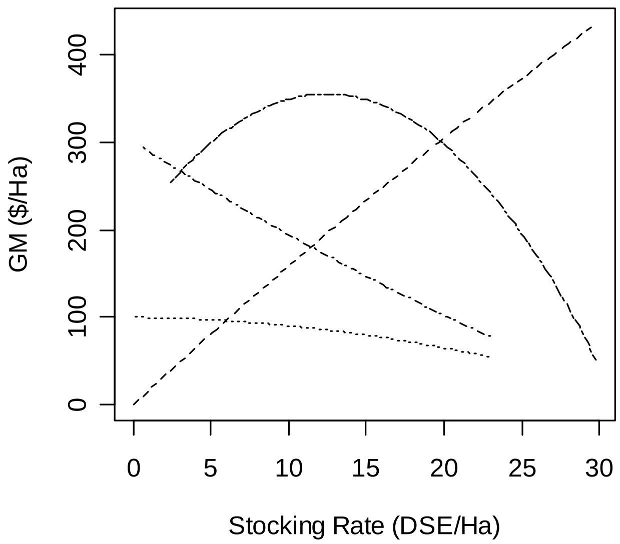
In two cases (JRL Hall and HSA Wool) an optimum was found when the previous season was average to good (Figure 3). In these circumstances managers may have decided not to increase stock numbers to take advantage of a good season, leaving excess feed or sheep in above average condition. The value of the extra feed or improved sheep would then have been realised in the following year.

Figure 3. The effect of Previous Season (standard deviations from average) on GM/Ha



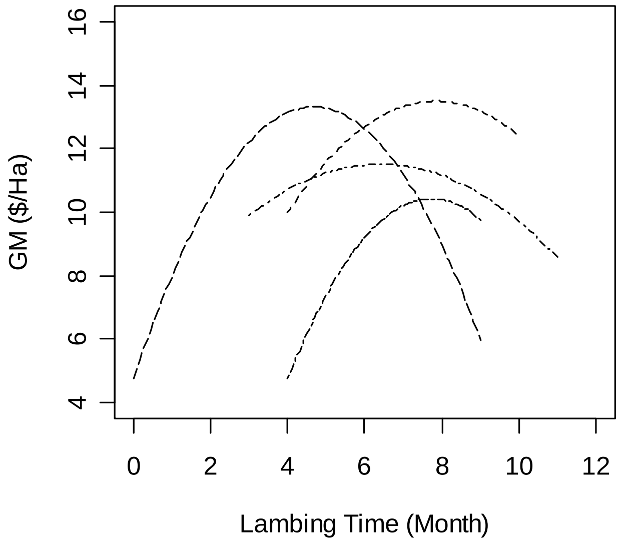
Stocking rate had a variable influence on GMHa depending on enterprise type (Figure 4). It was not important for JRL Hall or HSA Lamb enterprises but it was for all others. Increased stocking rates reduced GMHa for HSA Wool and Dual Purpose enterprises but increased GMHa for FMP Wool enterprises. FMP Lamb enterprises had an optimal stocking rate at 12.4 DSE/Ha.

Figure 4. The effect of Stocking Rate (DSE/Ha) on GM/Ha



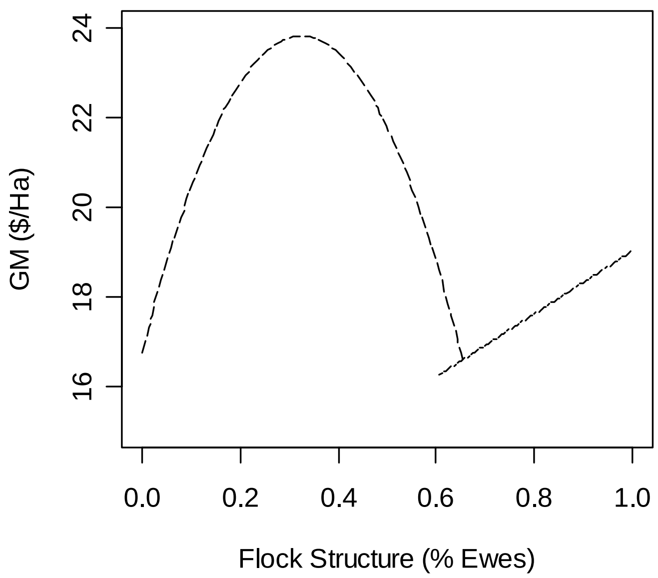
Lambing time showed an optimum for the four enterprises for which it was significant (Figure 5). The optimum was earlier (late April) for HSA Lamb enterprises, possible to allow maximum use to be made of seasonal feed availability. For HSA Dual Purpose enterprises this optimum was mid June, while for FMP Wool and Lamb enterprises the optimum was mid July, possible reflecting a later or longer feed growing season.

Figure 5. The effect of Lambing Time (month) on GM/Ha



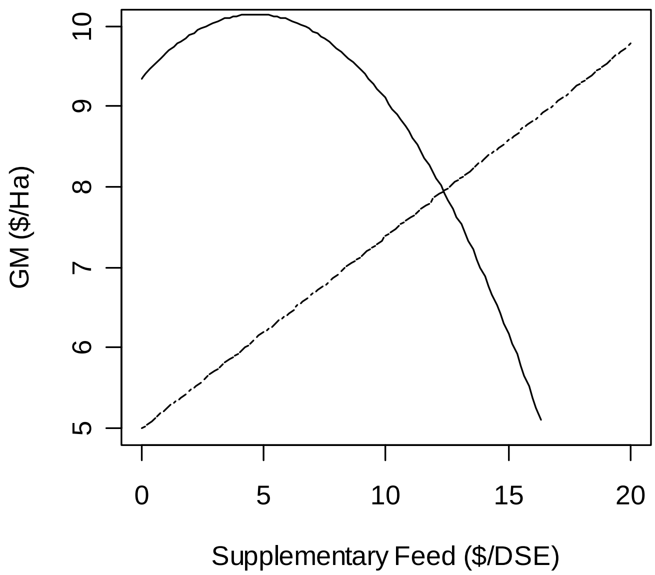
Flock structure (% ewes) was only important in lambing enterprises (Figure 6). It was tested but found not to be important for other sheep enterprises. The HSA Lamb enterprises had an optimum at 33% ewes, while FMP Lamb enterprises improved as the ewe percentage increased.

Figure 6. The effect of Flock Structure (% Ewes) on GM/Ha



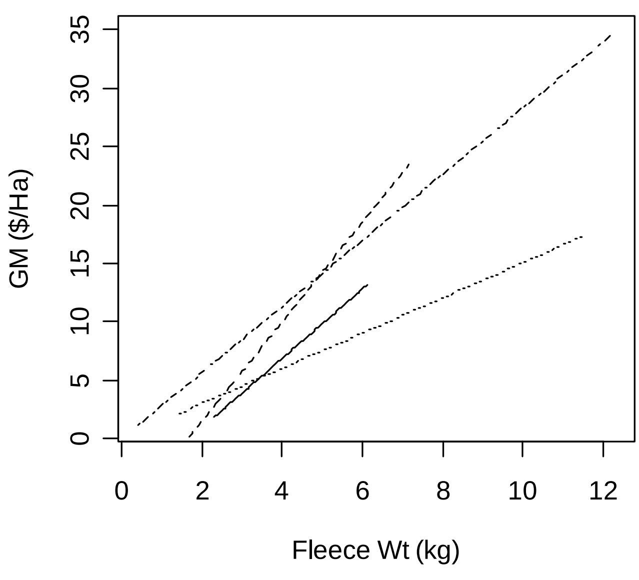
The effect of supplementary feed was positive at low levels for JRL Hall enterprises but reached an optimum at $4.64/DSE then had a major detrimental effect as more feed was supplied (Figure 7). In contrast additional supplementary feed continued to improve the performance of FMP Lamb enterprises.

Figure 7. The effect of Supplementary Feed ($/DSE) on GM/Ha



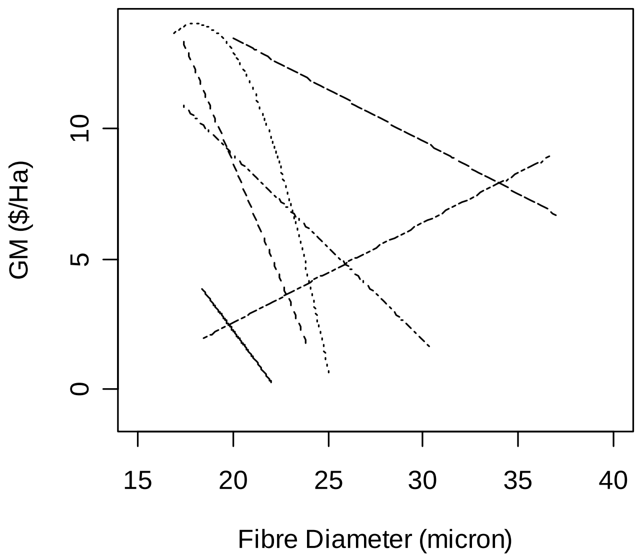
The effect of fleece weight was positive for JRL Hall Sheep, FMP Wool, HSA Wool and HSA Dual Purpose enterprises (Figure 8), but not important for either of the specialist lamb production enterprise data sets.

Figure 8. The effect of Fleece Weight (kg) on GM/Ha



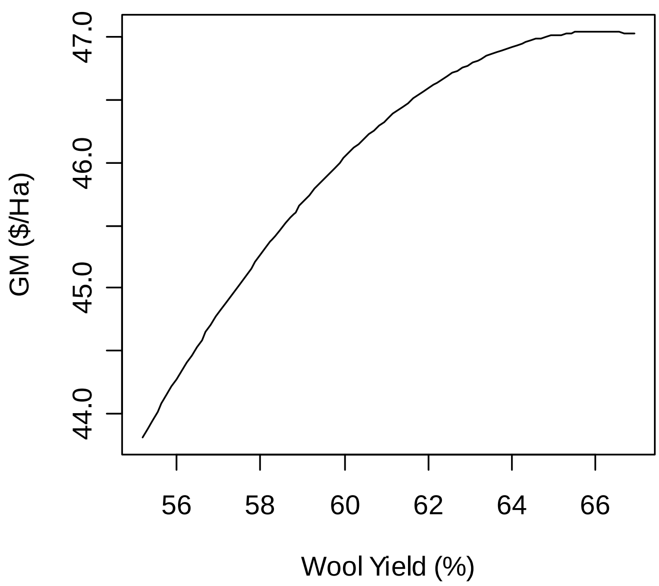
As fibre diameter reduced enterprise performance increased for all enterprises except (FMP Lamb (Figure 9). The reason for the exception is not certain. An optimum was found for HSA Wool enterprises at 18 microns. The reason performance falls away with finer diameters for these enterprises is not certain but may be due to wool value decreasing with increased dust or some other factor in dryer climates.

Figure 9. The effect of Fibre Diameter (micron) on GM/Ha



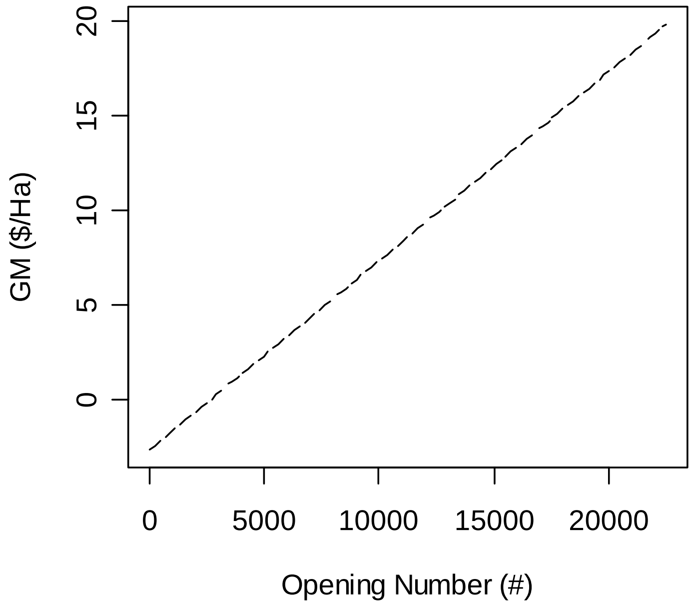
Wool yield could only be tested in the JRL Hall data set (Figure 10). In this data set an optimum was found at 66% wool yield.

Figure 10. The effect of Wool Yield (%) on GM/Ha



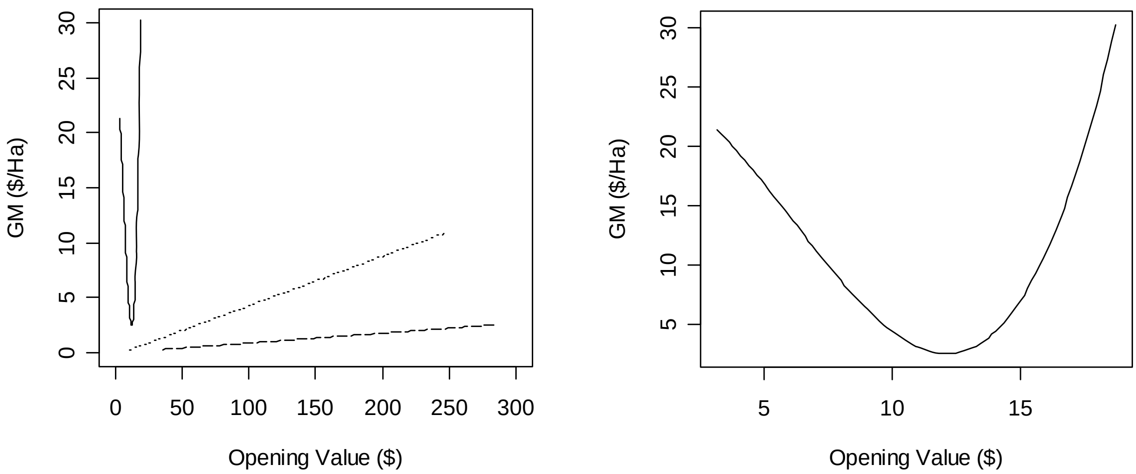
Opening sheep number had a positive linear relationship with GMHa for HSA Lamb enterprises (Figure 11), but this effect was not found to be significant for any other data sets.

Figure 11. The effect of Opening Sheep Number on GM/Ha



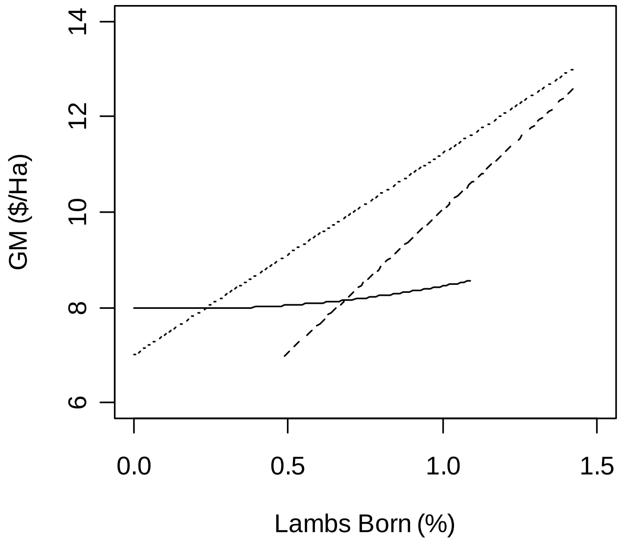
The effect of opening sheep value could not be tested for either FMP data set. This effect was not important for HSA Dual Purpose enterprises, but had a positive association with GMHa for HSA Wool and Lamb enterprises (Figure 12). Opening sheep value had a sub-optimal relationship with GMHa for JRL Hall enterprises, the reason for this relationship is not obvious.

Figure 12. The effect of Opening Sheep Value ($/DSE) on GM/Ha



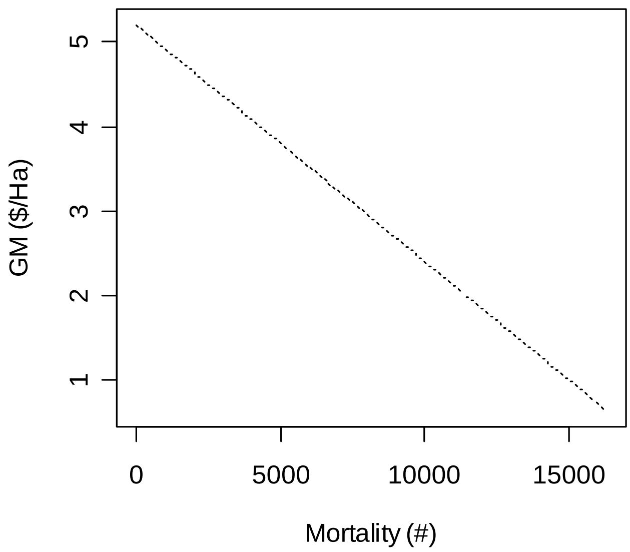
Lambing percent had a positive effect on GMHa for JRL Hall, and HSA and FMP Wool enterprises (Figure 13). Lambing percent was tested but found not to be significant for explaining variation in sheep trading profit for the other three data sets. The reason that it was not important for these other data sets needs to be considered, but may be due to the higher lambing percentages in the dual purpose and lamb enterprises.

Figure 13. The effect of Lambing Percent on GM/Ha



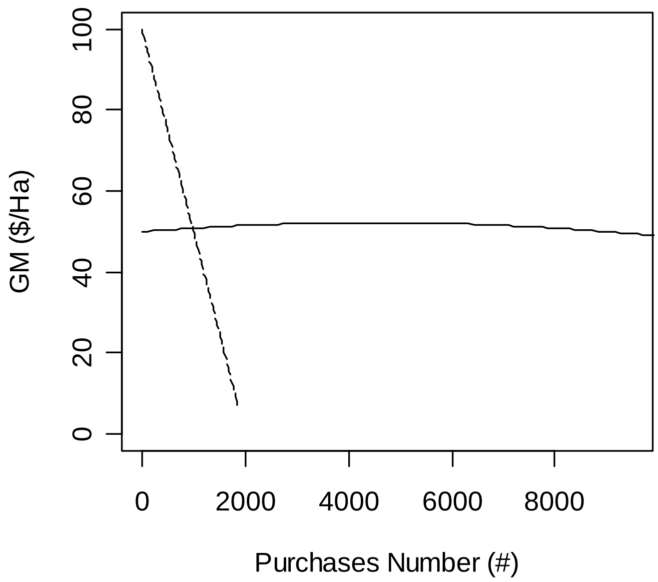
Sheep losses were only found to be significant for HSA Wool enterprises (Figure 14). The influence of losses could not be tested for FMP data sets and was not important for any other data sets.

Figure 14. The effect of Sheep Losses (number) on GM/Ha



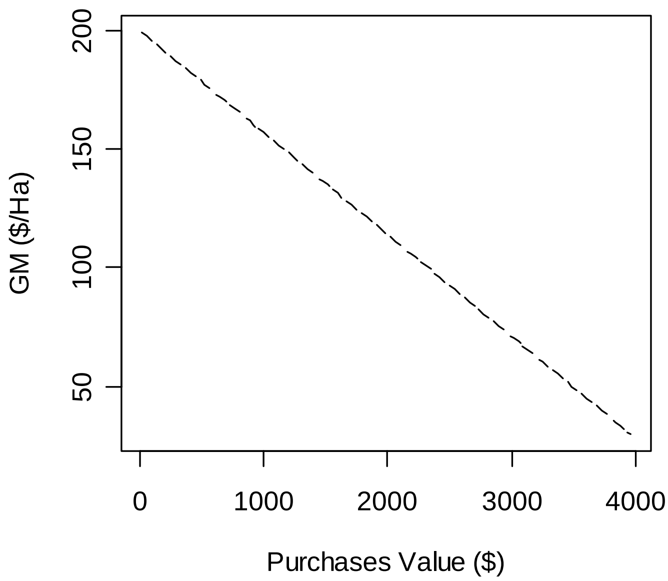
Sheep purchases had a negative effect on GMHa for HAS Lamb enterprises but an optimal (4,500) effect for JRL Hall Sheep enterprises (Figure 15). This effect could not be tested for the FMP data sets.

Figure 15. The effect of Number of Sheep Purchased on GM/Ha



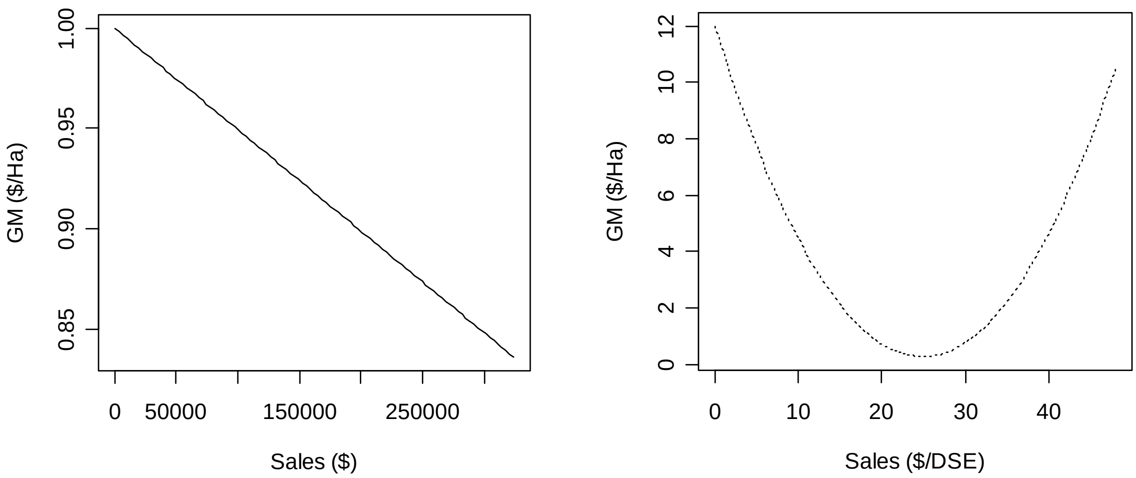
Increasing purchase value had a detrimental effect on GMHa for HAS Lamb enterprises (Figure 16), was not important for other HSA or JRL Hall enterprises but could not be tested for FMP data sets.

Figure 16. The effect of Total Sheep Purchase Value ($) on GM/Ha



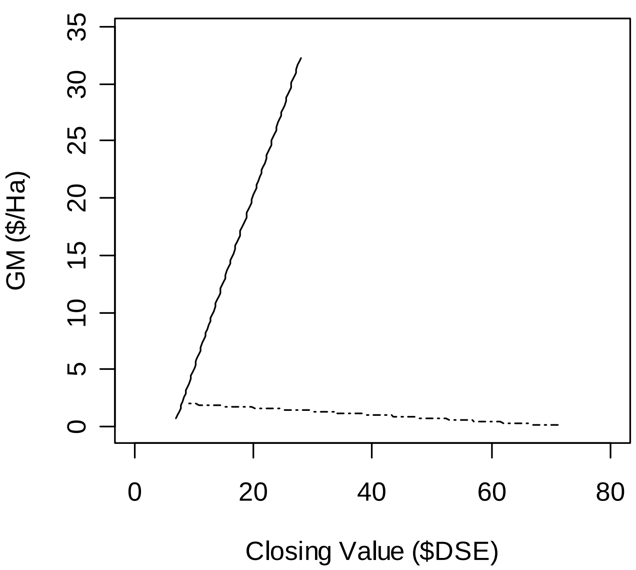
The effect of sheep sales on GMHa could not be tested for FMP data sets. It was found for JRL Hall Sheep enterprises that increasing total sales actually reduced GMHa (Figure 17). In the first instance the negative relationship may be considered counter intuitive, but it is possible that if a large number of sheep are sold the enterprise could become beholden to the market when it has to replace the sheep it has sold. For HSA Wool enterprises there was a sub-optimal ($24.84/DSE) influence of sheep sales on GMHa. A mechanism for is sub-optimal relationship is not obvious. Sales did not significantly affect sheep trading profit for the HSA Dual Purpose and Lamb enterprises.

Figure 17. The effect of Sheep Sales on GM/Ha



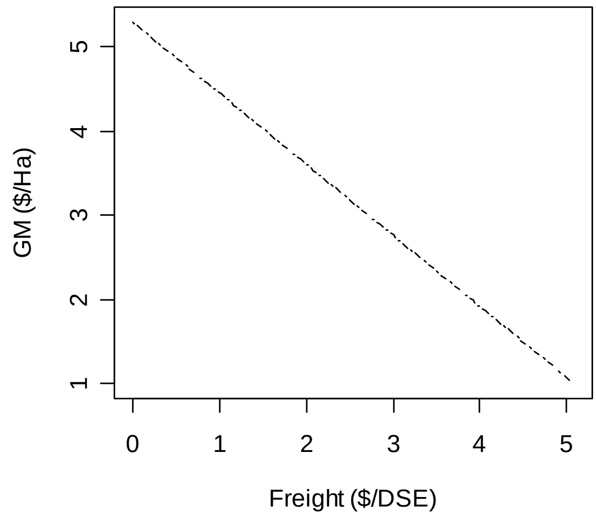
It was found that closing sheep value had a positive association with sheep trading profit and GMHa for JRL Hall Sheep enterprises but a negative association for HSA Dual Purpose enterprises (Figure 18). This relationship could not be tested for FMP or HSA Lamb enterprises and was not significant for HSA Wool enterprises.

Figure 18. The effect of Closing Sheep Value ($/DSE) on GM/Ha



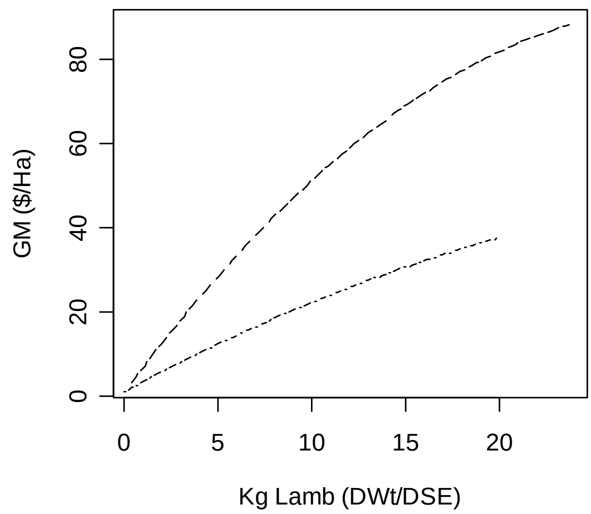
The effect of freight costs per DSE was to reduce GMHa for HSA Dual Purpose enterprises, as would be expected. This was not significant for other HSA data sets and cold not be tested for JRL Hall or FMP data sets.

Figure 19. The effect of Freight Costs ($/DSE) on GM/Ha



Lamb production per DSE had a positive decreasing relationship with GMHa for HAS Dual Purpose and Lamb enterprises (Figure 20). This suggests that lamb production per DSE may be approaching a limit, though it has not yet reached the limit. For the HSA Wool and FMP Wool and Lamb enterprises this PI was included in sheep trading profit and found not to be significant, as lamb trading profit was not considered to be part of these enterprises for the wool enterprises and was not separated from sheep trading profit for the FMP Lamb enterprises.

Figure 20. The effect of Lamb Production (Dressed Weight/DSE) on GM/Ha



6. Discussion

To consider 19 PIs as Key PIs infers that the system of sheep production is very complex. Thus this study of the sheep production process model across all six benchmarking group by enterprise data sets confirms the findings of previous studies in this project, that:

1. sheep production is a complex process;
2. in the data sets studied improvements cannot simply be made by altering only one or a few PIs, and;
3. to improve sheep enterprise production performance requires improving many factors that have important effects on all aspects of the enterprise.

Furthermore, even though the production process model was able to break down the production process into discrete parts, performance indicators were found to influence more than one aspect of the model. For example stocking rate affects GMHa both directly and indirectly. The indirect influence of stocking rate acts through all components of income, wool income and lamb and sheep trading profit. Similarly season and the previous season affect all aspects of income directly as well as indirectly, through stocking rate.

The use of season as a performance indicator may be considered questionable as the enterprise manager has no control over the season. However, the manager has total control over how they respond to the season, as it unfolds and in the following year.

6.1. Stocking Rate

Season, previous season, lambing time, flock structure and supplementary feed were all found to affect stocking rate and are therefore important PIs. Shearing time and risk management were also considered to be important factors affecting stocking rate but no data was available to test these affects. In light of the production process model developed, it may be valuable to collect data to determine whether these two factors should be targeted for data collection for commercial bench marking services.

6.2. Wool Income

Generally wool income was affected by season, previous season, stocking rate, fleece weight and fibre diameter. Wool yield and percent vegetable matter were only available for one data set for which wool yield was important, thus it may be valuable to include wool yield in future benchmarking data collection. Staple strength, style and vegetable matter type were also identified as indicators that could affect performance but data was not available to test the importance of these PIs.

6.3. Sheep Trading Profit

Sheep trading profit was shown to be a very complex interaction of many factors. Of the 19 PIs identified in the production process model 12 were important for explaining variation in this aspect of an enterprise. These 12 PIs were involved in 17 interactions. This level of ‘simplification’ was reached after increasing the statistical stringency from $P<0.05$ to $P<0.0001$ for JRL Hall Sheep and $P<0.001$ for HSA Wool and Lamb data sets. Of the remaining seven PIs identified as potentially important for sheep trading:

- four could not be tested due to insufficient data. These were Ram Purchases (number and value), Total Rams (number or proportion), Lamb Losses and Ration (number or value);
- closing sheep number was essentially the same as opening sheep number, and;
- two (supplementary feed and selling costs) were not important, though supplementary feed costs was important for describing stocking rate.

6.4. Lamb Trading Profit

Lamb trading profit data was only available for HSA Dual Purpose and Lamb enterprise data sets. Season, previous season, stocking rate and lamb produced per DSE were all significantly associated with lamb trading profit. Carcass weight was not important fro describing this income stream. In two data sets, FMP Wool and Lamb, carcass weight was included as a PI to explain variation in sheep trading profit, but was found not to be significant.

6.5. Expenses

The PIs defined in the production process model as important descriptors of components of expenses were all related through simple mathematical calculations and so modelling to estimate equation parameters and their importance was not necessary. This suggests that the production process model may need to be reconsidered as the expense PIs such as fertiliser, seed, labour and other expenses that can be managed, though they act dollar for dollar through the expenses side of the model need to be estimated for their contribution to the income side of the model. The influence of these PIs could perhaps be allocated to stocking rate or one or other component of income in order to determine their net value to the enterprise for bench marking purposes. It would not be expected that a manager would expend resources if they were not associated with some reward.

6.6. Future Enterprise Improvement

Due to the complexity of the sheep production process, to continue to advance the sheep enterprises of this study must improve many aspects of their production simultaneously.

To assist these sheep production enterprises it would be useful to incorporate the sheep production process model and its component linear models into a computer aided expert system. This would allow managers to test scenarios prior to implementation of change. Such an expert system would allow managers to reduce the risks associated with incorporating changes by providing a tool to assist undertake sensitivity analysis of proposed management changes.

Without such a tool the complexity of sheep production will discourage productivity improvements as the ramifications of management changes cannot be easily ascertained for such a complex process.

7. Conclusion

The statistical analysis of sheep bench marking enterprise data, with the intent of identifying key PIs has been a long, detailed and interesting process. This process has used three different analyses, each of which has confirmed that sheep production is complex.

The process has found, from enterprises that have been bench marking for a significant time, that there are NO simple KEY PIs that will produce dramatic improvements in enterprise performance (Gross Margin per Ha).

This analysis has developed a sheep enterprise production process model to which further improvements can and should be made.

It is expected that the enterprises who supplied data for these studies are in the top 20% of sheep enterprises. They are in this position because they are carefully monitoring and managing their production processes. Thus it is not surprising that these enterprises would have already made any changes that would have a major impact on their gross margin.

Hence the ultimate conclusion of this series of studies:

> That for the subjects of these studies future gains will come from many small and well considered modifications to their production, taking into account the ramifications of such changes on all aspects of the complicated system of sheep production.

is completely sensible

8. References

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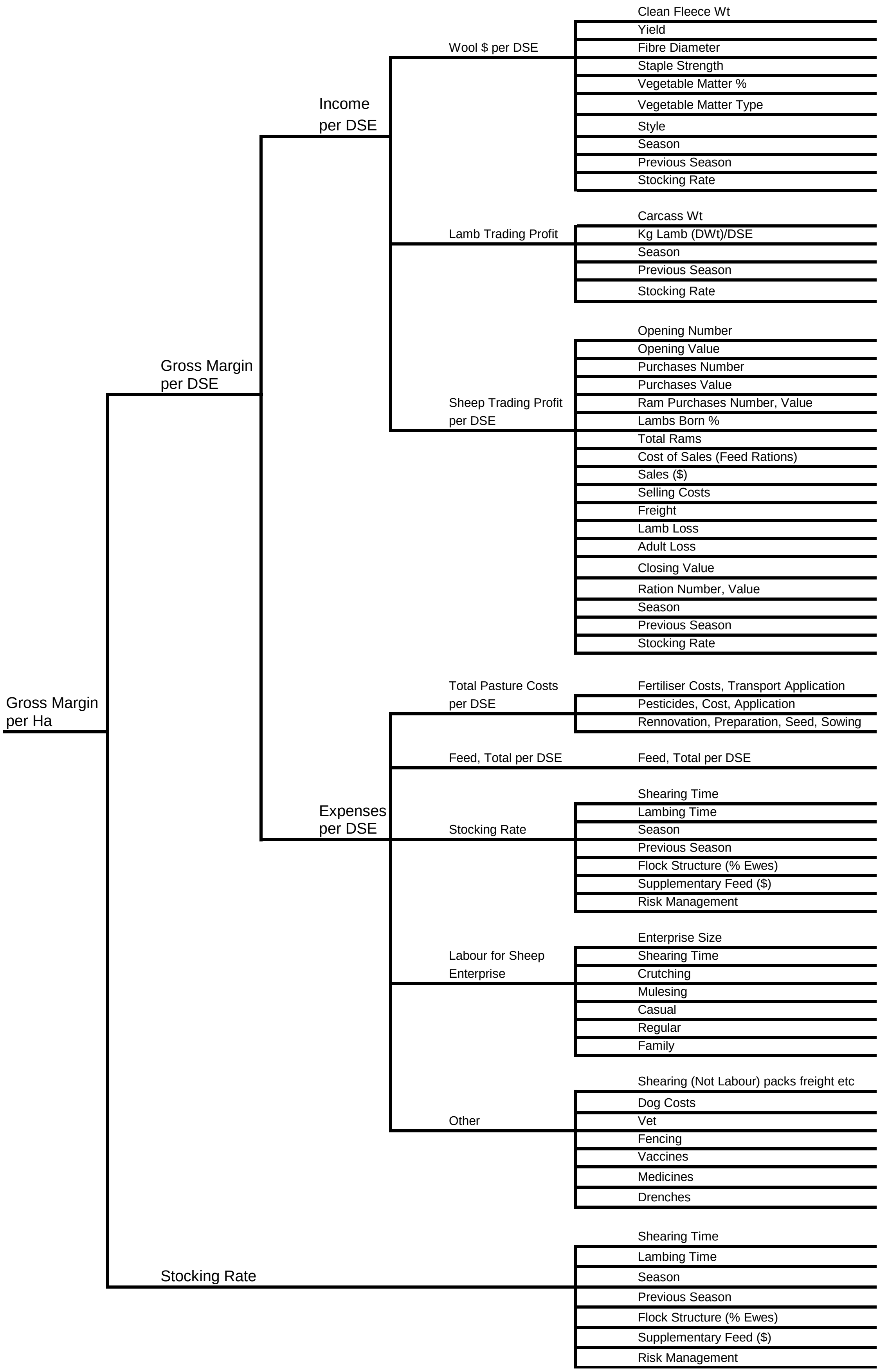
9. Appendix 1. Sheep Production Process Model



10. Appendix 2. Equations for Relationships

Equation Term	X^3	X^2	X	Intercept	Optimum		Min	Max
Season (standard deviations from average)								
JRL Hall Sheep*			-0.17	13.00			-3.0	3.0
FMP Wool			-0.080	12.48			-2.7	4.3
HSA Wool			0.13	12.50			-2.9	3.4
HSA Dual Purpose			-0.15	12.50			-2.8	3.2
HSA Lamb		0.44	1.30	11.00	-1.5	Sub-optimum	-2.9	2.3
FMP Lamb			0.58	12.50			-2.7	4.3
Previous Season (standard deviations from average)								
JRL Hall Sheep*		-0.23	1.54	15.50	3.3	Optimum	-3.0	3.0
FMP Wool			0.30	16.54			-2.7	4.3
HSA Wool		-0.12	0.39	18.00	1.7	Optimum	-2.9	3.2
HSA Dual Purpose			0.50	16.82			-2.8	2.8
HSA Lamb			0.40	16.56			-2.8	2.3
FMP Lamb			0.84	17.03			-2.7	4.3
Stocking Rate (DSE/Ha)								
FMP Wool		-0.065	16.54	0	127	Optimum	0.0	29.8
HSA Wool		-0.077	-0.20	100	-1.3	Optimum	0.1	23.0
HSA Dual Purpose		0.070	-11.28	300	81	Sub-optimum	0.6	23.1
FMP Lamb		-1.01	24.97	200	12.4	Optimum	2.4	29.8
Lambing Time (Month)								
FMP Wool		-0.24	3.72	-1.07	7.8	Optimum	4	10
HSA Dual Purpose		-0.14	1.78	5.82	6.4	Optimum	3	11
HSA Lamb		-0.39	3.67	4.75	4.7	Optimum	0	9
FMP Lamb		-0.41	6.29	-13.88	7.7	Optimum	4	9
Flock Structure (% Ewes)								
HSA Lamb		-66.79	43.45	16.75	33%	Optimum	0%	66%
FMP Lamb			7.02	12.00			61%	100%
Supplementary Feed ($/DSE)								
JRL Hall Sheep		-0.037	0.34	9.35	4.64	Optimum	0	16.30
FMP Lamb			0.24	5.00			0	20.00
Fleece Weight (kg)								
JRL Hall Sheep			2.97	-5.00			2.3	6.1
FMP Wool			4.25	-7.00			1.7	7.2
HSA Wool			1.51	0.00			1.4	11.6
HSA Dual Purpose			2.83	0.00			0.4	12.3

Equation Term	X3	X2	X	Intercept	Optimum		Min	Max
Fibre Diameter (Micron)								
JRL Hall Sheep			-0.99	22.00			18.4	22.0
FMP Wool			-1.79	44.48			17.4	24.0
HSA Wool		-0.28	10.00	-76.19	18	Optimum	16.9	25.0
HSA Dual Purpose			-0.71	23.28			17.4	30.3
HSA Lamb			-0.40	21.51			20.0	37.0
FMP Lamb			0.38	-5.12			18.5	36.6
Wool Yield (%)								
JRL Hall Sheep		-0.027	3.57	-71	66	Optimum	55	67
Opening Number (#)								
HSA Lamb			0.0010	-2.69			0	22515
Opening Value ($)								
JRL Hall Sheep	0.026	-0.48	0.094	25.00	12.11	Sub-optimum	3.17	18.69
HSA Wool			0.045	-0.201			10.62	246.12
HSA Lamb			0.0090	0.00			35.32	286.54
Lambs Born (%)								
JRL Hall Sheep		0.72	-0.28	8.00	19%	Sub-optimum	0%	109%
FMP Wool			5.99	4.07			49%	144%
HSA Wool			4.23	7.00			0%	142%
Mortality (#)								
HSA Wool			-0.00028	5.20			0	16285
Purchases Number (#)								
JRL Hall Sheep		-1.11E-07	0.0010	50	4519	Optimum	0	10902
HSA Lamb			-0.050	100			0	1874
Purchases Value ($)								
HSA Lamb			-0.043	200			15	3961
Sales								
JRL Hall Sheep ($)			-5.06E-07	1.00			0	324150
HSA Wool ($/DSE)		0.019	-0.94	-0.20	24.84	Sub-optimum	0	47.99
Closing Value ($/DSE)								
JRL Hall Sheep			1.52	-10.00			7.04	27.87
HSA Dual Purpose			-0.031	2.30			9.06	71.54
Freight ($/DSE)								
HSA Dual Purpose			-0.84	5.30			0	5.08
Kg Lamb (Dressed Weight/DSE)								
HSA Dual Purpose		-0.029	2.41	1.00	41.6	Optimum	0.0	19.9
HSA Lamb		-0.098	6.02	0.82	30.7	Optimum	0.4	23.7