Unpublished Report

Document ID: SheepCRC_1_18

Title: Making gains from precision production in sheep

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Key words: within flock selection; sheep; productivity; selection

This report was prepared as part of the Sheep CRC Program 2007-2014. It is not a refereed publication. If the report is quoted it should be cited as:

Sheep CRC Report Sheep CRC 1_18

Making gains from precision production in sheep

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Increasing productivity in the sheep industry

Selection and genetic improvement in most Merino flocks follow simple and traditional guidelines. Maiden ewes and wethers entering the flock are often selected by visual classing and exit the flock as complete age groups. Ram purchases, usually from studs, largely dictate the genetic composition of the flock. Management practices, best described as flock-level management, are designed to manage each class of animal as a single homogeneous group with minimum cost.

Is this best practice for the future as we face the challenge to increase productivity to maintain terms of trade and parity with alternative industries? An alternative view (Rowe and Atkins 2006) is that managing individual animals rather than flocks will lead to greater increases in productivity and profitability for the Australian sheep industry. Putting more emphasis on selection and management of animals according to measured performance is described as 'precision sheep production' and some of the principles and their application were described by Atkins, Richards and Semple (2006).

The purpose of this paper is to quantify the progress that is possible from applying precision production principles, particularly for within flock selection, in three sheep enterprises: fine wool, medium wool and dual lamb/wool production. Since choice or ram dominates flock improvement in most production systems, the paper also provides an analysis of gains possible through ram selection. Precision sheep production and best practice ram selection are complementary and their combination offers the Australian sheep industry the opportunity to achieve accelerated gains in productivity and improved profitability.

Increasing productivity in the sheep industry

The sheep industry has a great opportunity to increase its rate of gain in productivity because of the level of variability that exists within each commercial flock. Table 1 shows the average and the upper and lower quartile production levels for a range of production traits within a Merino flock. This level of variation has three important implications:

Table 1. Variability within a Merino flock of sheep (from Atkins, Richards and Semple 2006)

Trait	***Production level of flock:***		
	Average	***Top 25%***	***Bottom 25%***
Wool traits:			
Fleece weight (kg)	4.6	5.3	3.9
Fibre diameter (µm)	20.4	18.9	21.9
Staple strength (N/ktex)	35	42	28
Meat traits (crossbred lambs)			
Growth rate (g/day)	284	357	200
Fat depth (mm)	10.6	8.9	12.5
Reproduction			
Lambs weaned per ewe joined	0.86	1.43	0.28
Profitability traits			
Fleece value per ewe ($)	$54	$82	$37
Carcase value per ewe ($)	$33	$56	$12

1. Stud selection. The variation indicates the massive scope for selection and genetic improvement within studs. This potential exists because most of the production traits are not only variable but highly heritable and relatively cheap to measure. So, a specialised ram

breeding sector operating efficiently delivering genetic gain will continue to be an important element for the industry.

2. Commercial flock selection. The same variability is important within commercial flocks because we can further increase productivity by using selection within the commercial flock and the benefits complement those provided through stud rams. The same features of variation, high heritability and low cost of measurement – make precision production attractive.

3. Management. In addition to the scope for selection, the variation within a flock offers an important opportunity to identify segments of the flock for specific management and marketing purposes. The aim is to devise strategies that will increase the value of the most valuable 25% of animals and minimise costs of the least valuable 25% of the flock. This is a very different approach to minimising the costs of managing the whole flock.

What progress is possible - where can I be in 10 years time?

We can answer that question by setting up a number of production scenarios and looking at a realistic expectation in terms of costs, returns and flock production levels. We will look at the role of basic genetics – a process we understand as this is standard practice in most commercial Merino flocks. Then we see what we could add to the process by doing a better job of ram selection based on choosing higher quality sires from data available from Sheep Genetics (enhanced genetics) for accelerated genetic gain. Then we will evaluate gains possible through implementing a precision management strategy for smarter within-flock selection in addition to using the best rams. Importantly, the steps of using better rams and precision management are complementary and should not be seen as mutually exclusive. The three approaches are summarised below.

- Basic genetics – buying average grade rams from a recognised ram source and relying on the average industry rate of genetic gain.
- Enhanced genetics – buying superior rams from 1 or a number of ram sources using breeding values supplied through Sheep Genetics (SG) and a selection index that reflects the commercial breeding objective.
- Precision production system – using additional measurement and management processes within the flock to extract additional value through breeding and selection of replacement ewes (and wethers), optimising flock structure and obtaining market advantage through better meeting specifications. The precision strategy was applied to both basic and enhanced genetics models.

Progress resulting from application of these three approaches has been evaluated over ten year periods in each of three production systems: specialist fine wool; medium wool and meat plus wool. For comparison all estimates are based on gross margin per Dry Sheep Equivalent (DSE) accounting for all additional costs (including labour) of applying the smarter management options.

Production modelling and software tools

Prediction was based on a number of software tools. The primary production model was constructed that allowed the impact of selection on fleece and body traits to be tracked within the commercial flock over time. The elements of the model included:

- Production systems – can account for a Merino breeding ewe flock with or without an adult wether flock, and with or without a part of the flock mated to terminal sires for crossbred lamb production.
- Variable age structure and reproduction rate. The user nominates the flock size, reproduction rate and (default) survival rates. The size of each age group (both adult ewes and adult wethers) and the number of surplus animals available for sale are derived as shown in Table 2.
- Selection intensity. The age structure and reproduction rate also jointly determine the numbers of animals required for replacement – that is, the selection intensity. The percentage of ewes selected under a range of age classes and reproduction rates is shown in Table 3.

Table 2 Numbers of available and sale animals in each age class for a flock of 2000 breeding ewes (5 age groups) and 1000 adult wethers (3 age groups)

Age classes	***Ewes***		***Wethers***	
	Available	***Sales***	***Available***	***Sales***
Hoggets - 1 year	760	318	760	413
Adults				
- 2 years	442		347	
- 3 years	420		333	
- 4 years	399		320	307
- 5 years	379			
- 6 years	360	342		
(TOTAL)	(2000)		(1000)	

Table 3 Effect of reproduction rate and number of age groups of breeding ewes on the level of culling (%) available to maintain a stable flock size

Reproduction rate	***Number of age groups***					
	3	***4***	***5***	***6***	***7***	***8***
100%	***26***	***43***	***53***	***60***	***65***	***69***
90%	***18***	***37***	***48***	***56***	***61***	***65***
80%	***8***	***29***	***42***	***50***	***56***	***61***
70%		***19***	***34***	***43***	***50***	***55***
60%		***5***	***22***	***34***	***42***	***48***

- Mean production level for fleece weight, fibre diameter and body weight of the adult ewe flock can be specified separately or set by default given an average flock diameter, and then calculated for all age groups given the known effects of age on production (see example in Table 4). For wethers, the unselected age group mean production levels are inferred from the equivalent ewe levels using adjustment factors derived for Merinos by Atkins, Semple and Casey (1994).

Table 4 Annual death rates and production levels of fleece weight, fibre diameter and body weight by age in Merinos (Sources: Brown et al 1966, Turner et al 1968, unpublished Trangie data)

Age (years)	***Annual death rate (%)***	***Fleece weight (kg clean)***	***Fibre diameter (μm)***	***Body weight (kg)***
Ewe flock average	*4-5*	*3.5*	*19.0*	*49*
1 year	2.5	3.15	17.9	39.2
2 years	2.5	3.39	18.4	44.1
3 years	2.5	3.60	18.8	48.5
4 years	2.5	3.64	19.0	50.4
5 years	3	3.53	19.2	50.9
6 years	4	3.29	19.4	51.4
7 years	5	3.08	19.4	50.4
8 years	7	2.90	19.2	49.9
9 years	9	2.76	19.0	49.5
10 years	12	2.66	18.8	49.0

- Variable selection policies within the flock are possible, ranging from single trait selection on, say, fibre diameter, to multi-trait selection based on variable indexes of diameter, fleece weight and body weight (Table 5).
- Purchasing sires of known breeding value for fleece weight, fibre diameter and body weight (relative to the starting level of the commercial flock) is also included as a variable.
- Genetic and phenotypic parameters for fibre diameter, fleece weight and body weight are specified to track the effects of selection on production within the current generation (selection differentials, phenotypic variances and correlations) and in future generations (genetic variances and correlations). This means maintaining a matrix of dynamic selection effects for current generation and genetic effects for each trait across ages and across time.

Table 5 Selection options for single- and multi-trait selection

Selection index	*Production system*	*Selection outcome*
Single trait		
- FD	All	Fibre diameter (FD) selection only
- FW	All	Fleece weight (FW) selection only
- BW	All	Body weight (BW) selection only
Multiple traits		
- Fine 5%	Specialist fine wool	Mostly increase FW
- Fine 10%	Specialist fine wool	Increase FW – reduce FD
- Fine 20%	Specialist fine wool	Mostly reduce FD
- Mer 3.5%	Purebred wool + surplus animals	Increase FW + moderate BW
- Mer 7%	Purebred wool + surplus animals	Increase FW – reduce FD + moderate BW
- Mer 14%	Purebred wool + surplus animals	Mostly reduce FD + moderate BW
- DP 3.5%	Dual purpose wool + Xbred lambs	Increase FW + increase BW
- DP 7%	Dual purpose wool + Xbred lambs	Increase FW – reduce FD + increase BW
- DP 14%	Dual purpose wool + Xbred lambs	Mostly reduce FD + increase BW

- The flow of genes and production changes are mapped over a 20-year time horizon. The example in Table 6 shows the production changes that flow from selection based on fibre diameter only in a 19 micron flock maintaining both breeding ewes and adult wethers. Changes are mapped separately for each sex and each age group to give a very accurate measure of progress with time. The small but undesirable changes in fleece weight and body weight are a consequence of the low antagonistic correlations of these traits with fibre diameter, which are accounted for in the model.

Table 6 Selection outcomes in a 19μm flock following 10 years of ewe and wether selection on fibre diameter

Years	*Fibre diameter (μm)*			*Fleece weight (kg)*	*Body weight (kg)*
	Hoggets	*Adult ewes*	*Adult wethers*	*Adult ewes*	*Adult ewes*
Year 0	17.7	19.0	19.0	3.52	49.0
Year 1	17.7	18.8	18.6	3.51	48.8
Year 2	17.6	18.7	18.2	3.50	48.7
Year 3	17.6	18.6	17.9	3.49	48.6
Year 4	17.5	18.4	17.9	3.48	48.5
Year 5	17.5	18.3	17.8	3.47	48.4
Year 6	17.4	18.2	17.8	3.47	48.4
Year 7	17.4	18.2	17.7	3.47	48.4
Year 8	17.4	18.1	17.7	3.47	48.4
Year 9	17.4	18.1	17.7	3.46	48.4
Year 10	17.3	18.0	17.6	3.46	48.4

- Clip preparation model that optimises the value of separating sale lots of wool according to fibre diameter measures on individual fleeces (Atkins and Semple 2003).
- Market values for Merino wool and meat were included for 5 annual periods so that average economic responses and market variability in response can be derived. Additional returns were adjusted for the variable costs of management and marketing but the inclusion of costs related specifically to genetics and the application of precision strategies were applied separately. Additional returns over time were re-scaled to a Net Present Value using annual discount rate as a variable, set at 5% to reflect a social discount rather than an alternative investment rate. Predictions of gain were converted to a (discounted) value per DSE, predicted from the specified body weight, reproduction rate and sale age of surplus progeny.
- Costs. The usual variable costs of management are included in the estimated gross margins within the models, excluding the cost of on-farm labour for routine management. Specific costs associated with on-farm measurement and application of the precision production system (including labour requirements) are applied separately for each scenario. Some options include:

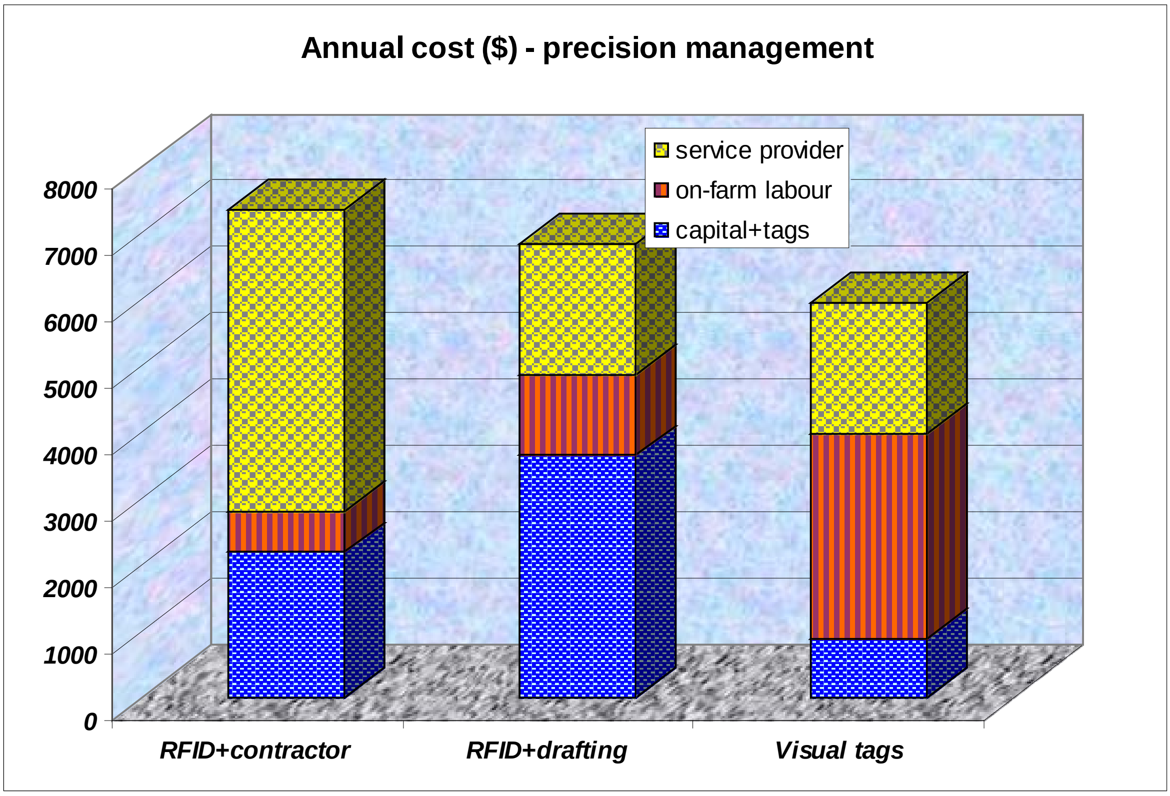
  Visual tags*: contractor provided measurement, on-farm labour for measurement + selection + drafting*

  RFID drafting: *contractor provided measurement, on-farm capital equipment and on-farm labour for selection + drafting*

  RFID contractor: *contractor provided measurement + capital + drafting and on-farm labour assistance*

  The total costs associated with each option within a fine wool flock of 3000 adult animals have been calculated for each year over 10 years and are detailed in Appendix 1. Figure 1 shows that the average annual cost associated with each option. The total costs of the options are not very different, although favouring the simpler models. But the components of the costs vary markedly. The ***visual tag*** model relies on access to substantial farm labour, the ***RFID drafting*** model replaces much of that labour with capital (and its maintenance) while the ***RFID contractor*** model replaces most of the labour and some of the capital with payment for a contractor's service with limited reliance on farm resources.

Figure 1 Annual costs of alternative measurement / identification options



The decision on an appropriate model is an individual one that will recognise both the financial and logistical constraints operating. In the scenarios that follow, costs for the precision production option have been attributed to each system at the highest cost option – use of RFID + contractor. The question of costing labour is often debated as some producers discount the cost if family labour is available. However, for the purposes of this analysis, on-farm labour has been included at $24 per hour. There is a further cost to the use of visual tags that has not been included in the costing which is the cost of making errors in data recording. This error rate can be 5-10% depending on the number of steps involved. Although error rates can be reduced by systematic checking, this adds a further cost in time to the operation.

The various software tools that have been developed and used in this analysis are shown in Table 7. These tools have been used both singly and in combination for the various scenarios modelled. A fuller account of the tools and their availability was given by Atkins, Richards and Rowe (2006).

Table 7 Tools for Precision Management of Wool and Meat

Tool	***Purpose***	***Key input variables***	***Key output***
Selection Assist	Predict genetic progress that can be made using different selection strategies over a 10 year time horizon	Current enterprise production levels – FD, FW, BW, Weaning % Time after initial selection Wool Price (set periods) Meat price	Changes in FD, FW, BW and GM ($/DSE or $/ewe)
Flock Structure	Optimise number of age classes for breeding ewes and adult wethers given a selection strategy	Current flock structure Production levels Selection strategy Wool/meat prices	Profit for alternative age structures
Terminal flock calculator	Calculates the maximum number of Merino ewes that can be mated to terminal sires without affecting flock structure (Kelly et al 2006)	Flock structure	Number of ewes mated to terminal sires
OFFM Calculator	Profitability of using fibre diameter measurement for clip preparation and selection (Atkins, Semple & Pope 2004)	Flock structure Production levels Cost of on-farm fibre measurement	Profitability
Wether calculator	Calculates optimum percentage of wethers to run in self replacing merino flock and compares selection methods for the wethers (Richards & Atkins 2005)	Flock structure Production levels Meat/wool prices	Profitability
Simultaneous assortment	Selects animals most appropriate for wool or meat production from existing flock (Richards & Atkins 2004)	Fibre diameter Body weight (Fleece weight)	Selection lists for meat group and wool group animals
Ram Value Calculator	Estimate and compare value of rams in a commercial flock	Flock structure Production levels Ram breeding values Wool/meat prices	Economic and production value of specified rams

Scenario 1: Specialist fine wool production system

Table 8 Features of the specialist fine wool flock and strategies for improvement

Current production level:	Future production determined by:
18.5 µm adult wool 2000 breeding ewes - 5 age groups 1000 adult wethers - 3 age groups 75% reproduction rate Surplus animals sold @ 18 months ($40 per head value)	***Basic genetics:*** Average industry gains of +2%, -0.7µm and +.8kg in fleece weight, fibre diameter and body weight respectively over 10 years ***Enhanced genetics:*** Genetic gains of +2.6%, -1.0µm and +1.2kg over 10 years and between-flock effects of +5%, -0.15µm and +1.5kg in fleece weight, fibre diameter and body weight respectively, delivered through selection based on a Fine 10% SGA index ***Precision production:*** Select replacement ewes and wethers on measured fibre diameter Optimise age structure and relative flock sizes of ewes and wethers Clip preparation using measured diameter

Financial consequences

Using production models (OFFM Calculator, Selection Assist, Wether Calculator, Flock Structure, Ram Value Calculator) we can accurately predict the consequences of the various improvement strategies (Table 9). The nominated market is the average market over the past 5 years and we have estimated the economic return in Year 10. Genetics, through ram selection, makes a cost-effective contribution to productivity, especially at the enhanced genetics level. The increased value of flock rams is relatively small compared with the production value they contribute. But no matter which genetic strategy is involved, precision production is a powerful contributor to economic gain, for a small increase in cost.

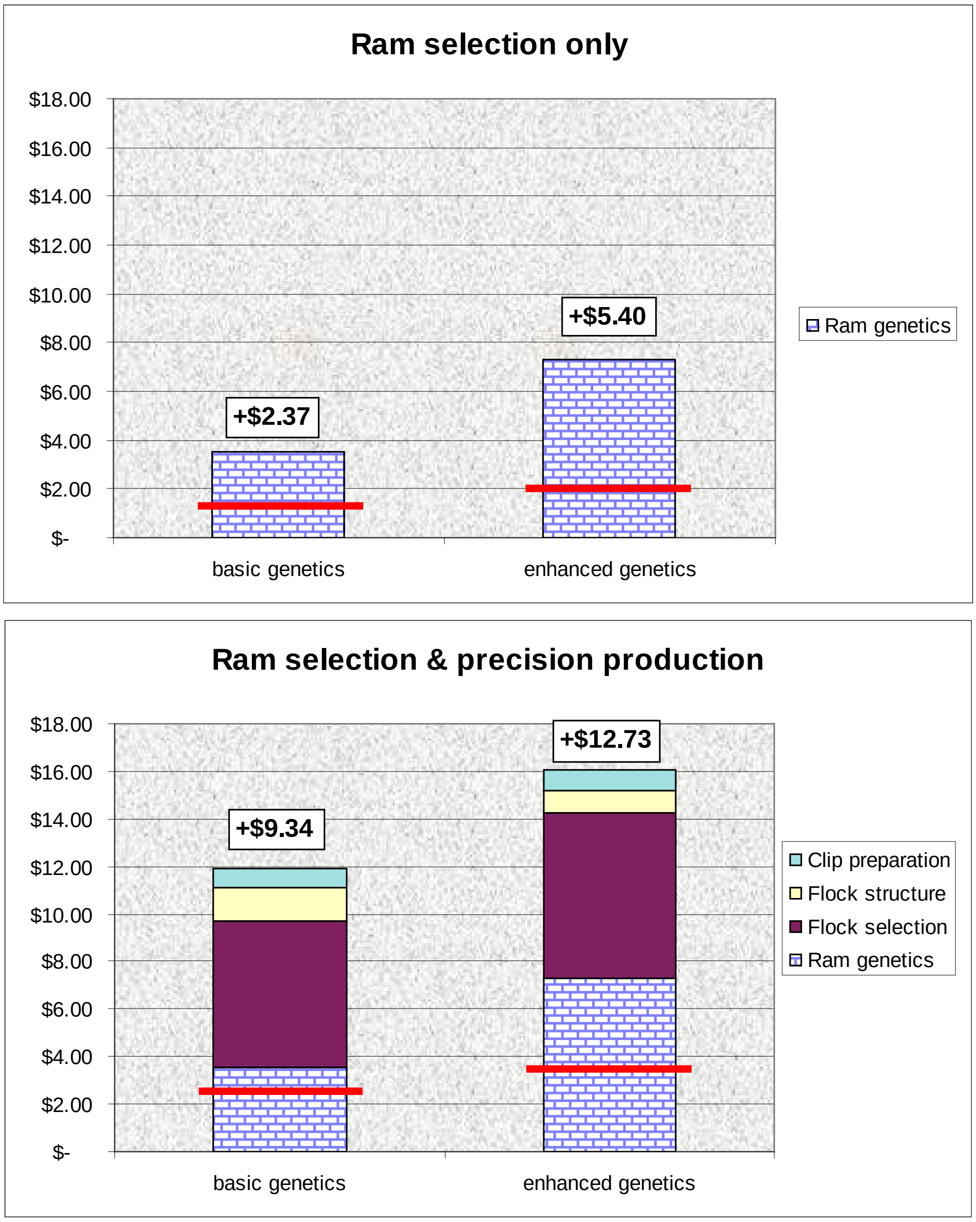
Table 9: Financial consequences in 10 years from now for a specialist fine wool flock with current gross margin of $26.21 per DSE

	Basic genetics	Enhanced genetics
ANNUAL RETURNS (less management costs):		
Ram selection only	+$3.55	+$7.32
Ram selection + precision production	+$11.93	+$16.04
ANNUAL (additional) COSTS:		
Ram selection only†	+$1.18	+$1.92
Ram selection + precision production*	+$2.59	+$3.31

† Ram selection costs represent the value of flock rams purchased
* Precision production costs include allowance for tags, equipment (capital depreciation or contractor costs), measurement costs and data handling. The total outlay for this enterprise was about $7,100 per year.

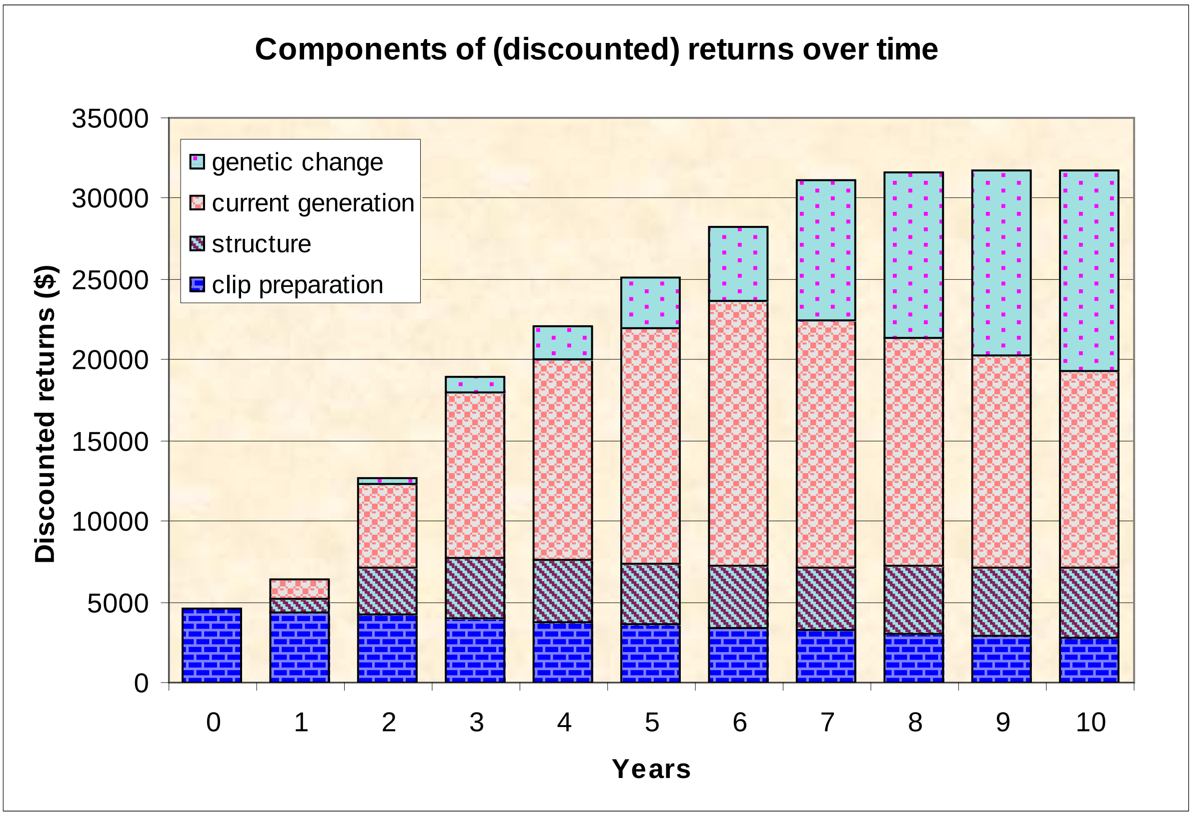
Figure 2 shows the same information graphically as in Table 9 and displays overall profit in Year 10. Within 10 years, profit increased by 21% for enhanced genetics, 28% for precision production and 49% for the combination of enhanced genetic and precision production. Figure 2 also shows the breakdown of the contribution of the various precision production components to overall returns under both ram selection strategies. The greatest contribution to precision production gain comes from flock selection. For both breeding ewes and adult wethers, this gain is greatest from retaining higher fleece value animals within the flock and culling low value animals – that is, current lifetime improvement. These higher fleece value ewes will impact on the genetic merit of their progeny but the effect per year is relatively small and takes time for the benefits to accumulate. The benefits from clip preparation and flock structure optimisation are relatively small. But, given they rely on the same information as the selection benefits, they are easy to obtain and more than cover the additional costs by themselves.

Figure 2 Increase in gross margin per DSE from ram selection alone (upper graph) and from combined ram selection and precision production (lower graph).
Horizontal lines represent the annual cost and the labels show the net benefits.



From an investment viewpoint, discounted profits may give a more reasonable view of the opportunities. Overall discounted profits in year 10 for this fine wool enterprise were estimated as $17,800 from the enhanced genetics strategy and $42,100 from the enhanced genetics + precision production strategy. That is, the profit in year 10 from precision production alone would be almost $25,000 in current values. The accumulation of these additional discounted returns from precision production alone are plotted in Figure 3. The time sequence shows a relatively rapid build-up to a relatively stable Net Present Value per year. The continuing contribution of genetic improvement over time despite the equilibrium, but then declining, contributions of current generation improvement, flock structure and clip preparation causes the returns to continue at a high level despite the discounting. The Net present Value of the cumulative profit over 10 years was estimated as $178,000 for this enterprise. All investment costs were covered within 2-3 years

Figure 3 Change in discounted returns over time



Production consequences

The same tools also give an accurate prediction of the expected production level of the flock in 10 years time (Table 10). The genetic benefits largely come from reduced fibre diameter in all classes of stock by at least 0.5μm in the enhanced genetics option. The precision production strategy further contributes to this benefit by substantially reducing fibre diameter further in adult ewes and wethers by 0.8 and 1.2μm respectively. This is a much greater effect in the current (adult) flock than the relatively smaller genetic effect shown in the diameter of hoggets – an additional reduction of only 0.3μm. This scale of response comes from effective selection on fibre diameter that is enhanced by increasing the selection differential by increasing the number of age groups within the flock. Although the number of age classes for breeding ewes that was an economic optimum was 7, the curve about this optimum was very flat in the range of 6-8 age groups. The increase in the number of age classes to increase selection differential occurs despite the substantially lower average productivity of older animals, particularly for fleece weight and survival (Table 4).

Table 10: Production consequences in 10 years from now for a specialist fine wool flock

	Start values (Year 0)	***+ basic genetics***	***+ enhanced genetics***	***+ enhanced genetics + precision production***
Flock structure				
- breeding ewes	2000	2000	2000	2200
- adult wethers	1000	1000	1000	650
Age groups				
- ewes	5	5	5	7
- wethers	3	3	3	3
Fleece weight (kg clean)				
- hoggets	2.9	3.0	3.1	3.1
- ewes	3.3	3.3	3.4	3.2
- wethers	3.7	3.7	3.8	3.7
Fibre diameter (μ)				
- hoggets	17.2	16.8	16.5	16.2
- ewes	18.5	18.2	18.0	17.2
- wethers	18.3	18.0	17.8	16.6
Body weight (kg)				
- sale wethers	41.0	41.7	43.1	43.2
- adult ewes	48.2	48.3	49.9	49.5

Additional management options to consider:

- Sheep coats in adult wethers
- Grazing management for staple strength in fine diameter hoggets and adult wethers
- Manage reproduction and nutrition for:
  - Twin survival
  - Wool quality
  - Recovery of rearing ewes for next mating

Scenario 2: Medium wool production system

Table 11 Features of the medium wool Merino flock and strategies for improvement

Current production level:	Future production determined by:
20.5 μm adult wool 3000 breeding ewes - 4 age groups No adult wethers 80% reproduction rate Surplus animals sold @ 15 months ($40 per head value)	***Basic genetics:*** Average industry gains of +4%, -0.6μm and +1.5kg in fleece weight, fibre diameter and body weight respectively over 10 years ***Enhanced genetics:*** Genetic gains of +5%, -0.8μm and +2.2kg over 10 years and between-flock effects of +5%, -0.25μ and +2.0kg in fleece weight, fibre diameter and body weight respectively together with a +1% increase in reproduction rate, delivered through selection based on a Merino 7% SGA index ***Precision production:*** Select replacement ewes on measured fibre diameter and fleece weight in an index. Test for selecting wethers on measured fibre diameter. Optimise age structure and relative flock sizes of ewes (and wethers) Clip preparation using measured diameter Sell surplus animals reaching 48kg as Merino lambs prior to 12 months of age – the remainder sold at 15 months

Financial consequences

Using our production models (OFFM Calculator, Selection Assist, Wether Calculator, Flock Structure, Dual Assortment) and the average market over the past 5 years, the economic return in Year 10 has been estimated (Table 12). Genetics, through ram selection, makes a cost-effective contribution to productivity, especially at the enhanced genetics level, although at a lower level than in the fine wool flock scenario. Precision production is a relatively greater contributor to economic gain, for a small increase in cost, in the medium wool flock.

Table 12: Financial consequences in 10 years from now for a medium wool Merino flock with current gross margin of $22.23 per DSE

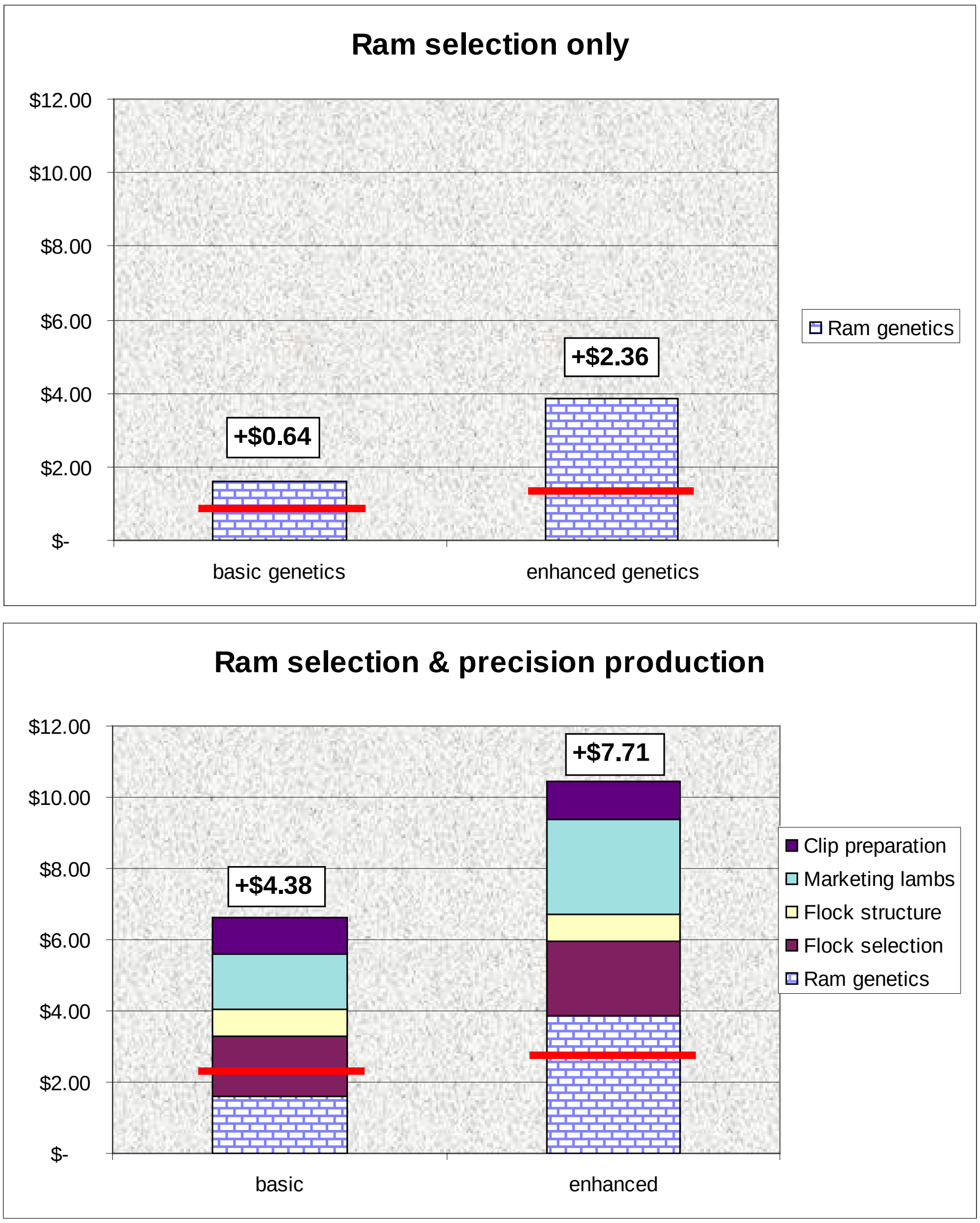
	Basic genetics	Enhanced genetics
ANNUAL RETURNS (less management costs):		
Ram selection only	+$1.62	+$3.87
Ram selection + precision production	+$6.64	+$10.43
ANNUAL (additional) COSTS:		
Ram selection only†	+$0.98	+$1.51
Ram selection + precision production*	+$2.26	+$2.72

† Ram selection costs represent the value of flock rams purchased
* Precision production costs include allowance for tags, equipment (capital depreciation or contractor costs), measurement costs and data handling. The total outlay for this enterprise was about $9,500 per year.

Figure 4 shows the information from Table 12 in graphical form and displays overall profit in Year 10. Taken as a difference between the enhanced genetics returns, precision production returned an increase in profit of +$5.35 per DSE, a 24% increase over 10 years. Figure 4 also shows the breakdown of the contribution of the various precision production components to overall returns under both ram selection strategies. Flock selection makes a significant (but not dominant) contribution to profit through identifying high fleece weight and reduced diameter ewes for retention and a highly selected small numerical size but very fine adult wether flock. The benefits from clip preparation (greater than in fine wools because of the curvilinear price relationship) and flock structure optimisation easily cover the additional costs of measurement and management required to generate precision benefits. Identifying, by weight or weight gain, which animals can meet a Merino lamb specification makes a substantial contribution to overall profitability.

Overall discounted profits in year 10 from the application of a precision production strategy in this medium wool enterprise were estimated as $22,600 in Net Present Value.

Figure 4 Increase in gross margin per DSE from ram selection alone (upper graph) and from combined ram selection and precision production (lower graph).
Horizontal lines represent the annual cost and the labels show the net benefits.



Production consequences

Expected production level of the flock in 10 years time is shown in Table 13. The genetic benefits come from a combination of reduced fibre diameter, increased fleece weight and increased body weight. The precision production strategy further contributed to this benefit by reducing fibre diameter further in adult ewes and wethers. Small changes in market premiums could generate substantial financial benefits for this improved flock in other market scenarios. Relatively small changes in body weight with time have been used to extract a much greater value in sale animals by selling an increasing proportion of animals into the Merino lamb market using within-flock weight recording.

Table 13: Production consequences in 10 years from now for a medium wool Merino flock

	Start values (Year 0)	***+ basic genetics***	***+ enhanced genetics***	***+ enhanced genetics + precision production***
Flock structure				
- breeding ewes	3000	3000	3000	2800
- adult wethers	-	-	-	280
Age groups				
- ewes	4	4	4	6
- wethers	-	-	-	2
Fleece weight (kg clean)				
- hoggets	3.7	3.8	4.0	4.0
- ewes	4.2	4.3	4.4	4.3
- wethers	-	-	-	4.7
Fibre diameter (μ)				
- hoggets	19.2	18.8	18.5	18.1
- ewes	20.5	20.2	20.0	19.3
- wethers	-	-	-	18.0
Body weight (kg)				
- sale wethers	43.6	44.6	46.9	46.7
- % wethers (ewes) sold as lamb	-	-	-	40% (19%)
- adult ewes	50.9	51.6	53.6	53.6

Additional management options to consider:

- Grazing management for wool quality in hogget and adult wethers
- Manage reproduction and nutrition by monitoring body weight and fat score throughout the year for:
  - Twin survival
  - Recovery of rearing ewes for next mating
- Use of scanned foetal number + rearing record (wet/dry or lamb survival from e-sheep MatchMaker) to select current generation ewes on reproductive performance

Scenario 3: Meat plus wool production system

Table 14 A broad wool Merino flock producing purebred and crossbred lambs, and the strategies for improvement

Current production level:	Future production determined by:
22 µm adult wool 2500 breeding ewes - 4 age groups 500 breeding ewes (5^{th} age group) mated to terminal sires No adult wethers 80% reproduction rate Surplus purebred animals sold @ 15 months ($40 per head value) Crossbred animals sold @ 10 months ($80 per head value)	***Basic genetics:*** Average industry gains of +4%, -0.6µm and +1.5kg in fleece weight, fibre diameter and body weight respectively over 10 years ***Enhanced genetics:*** Genetic gains of +5%, -0.8µm and +2.2kg over 10 years and between-flock effects of +5%, -0.25µ and +2.0kg in fleece weight, fibre diameter and body weight respectively together with a +1% increase in reproduction rate, delivered through selection based on a Dual Purpose 7% SGA index ***Precision production:*** Select replacement ewes on measured fibre diameter / fleece weight for wool flock and body weight / reproduction for meat flock. Optimise age structure and relative flock sizes of wool and meat ewe flocks Sell surplus animals reaching 48kg as Merino lambs prior to 12 months of age – the remainder sold at 15 months

Financial consequences

Using our production models (OFFM Calculator, Selection Assist, Merino Vs Terminal Sire Calculator, Flock Structure, Dual Assortment) and the average market over the past 5 years, the economic return in Year 10 has been estimated (Table 15). Genetics, through ram selection, makes a modest contribution to productivity, especially at the basic genetics level, although at a lower level than in the fine wool flock scenario. Precision production is a relatively greater contributor to economic gain in this broad wool flock than ram genetics.

Table 15: Financial consequences in 10 years from now for a dual purpose Merino flock with current gross margin of $23.24 per DSE

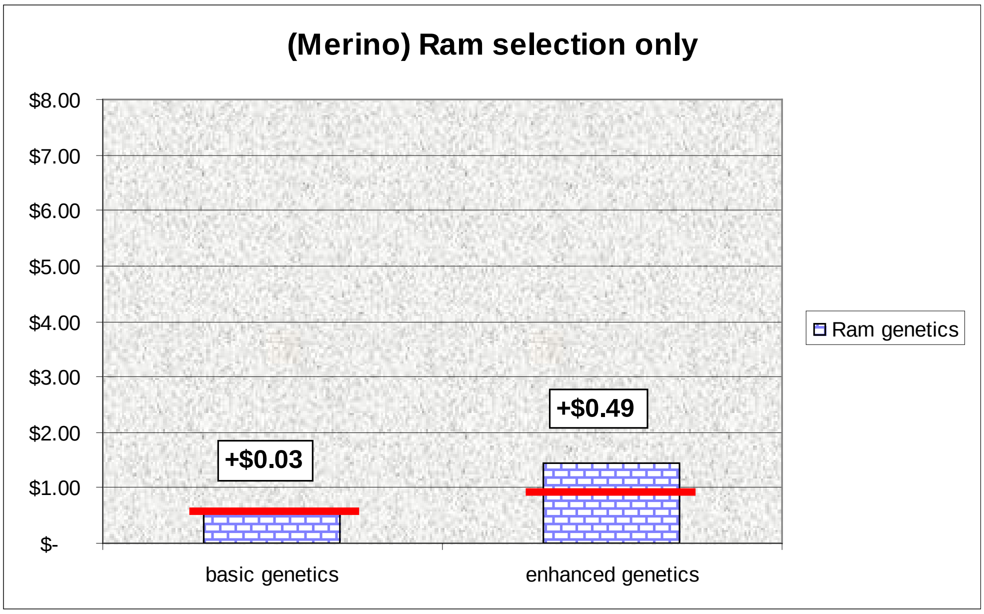
	Basic genetics	Enhanced genetics
ANNUAL RETURNS (less management costs):		
Ram selection only	+$0.57	+$1.43
Ram selection + precision production	+$4.59	+$6.10
ANNUAL (additional) COSTS:		
Ram selection only†	+$0.54	+$0.94
Ram selection + precision production*	+$1.60	+$2.00

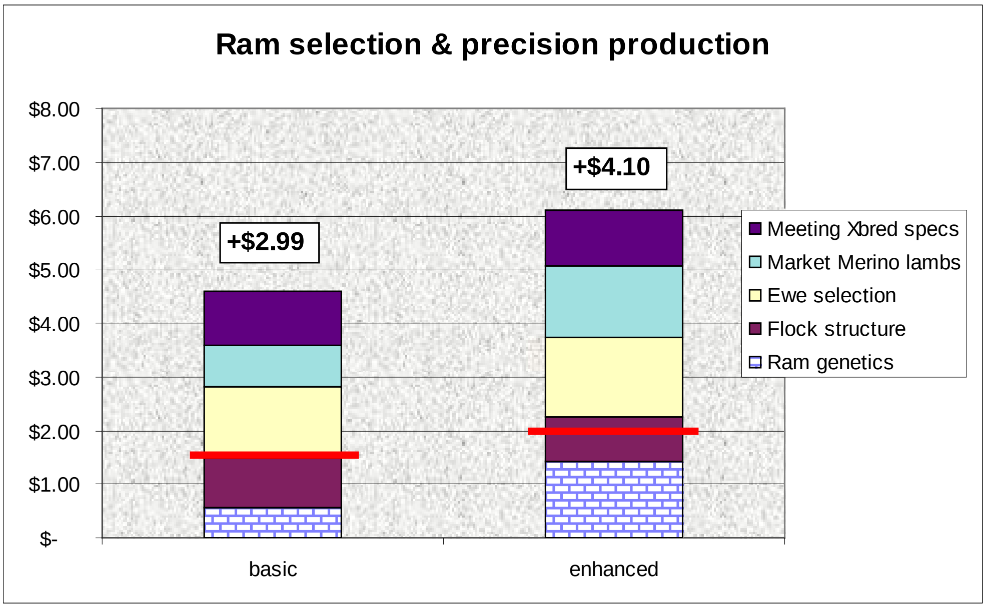
† Ram selection costs represent the value of flock rams purchased
* Precision production costs include allowance for tags, equipment (capital depreciation or contractor costs), measurement costs and data handling. The total outlay for this enterprise was about $9,500 per year.

Figure 5 shows the information from Table 15 in graphical form and displays overall profit in Year 10. Taken as a difference between the enhanced genetics returns, precision production returned an increase in profit of +$3.61 per DSE, a 16% increase over 10 years. Figure 5 also shows the breakdown of the contribution of the various precision production components to overall returns under both ram selection strategies. Flock selection makes a significant (but not dominant) contribution to profit through identifying high fleece weight, reduced diameter and heavier body weight ewes for retention. Allocating ewes to either the wool flock or the meat flock (to be mated to terminal sires) was based on their expected ranking on each objective rather than age alone. Together with optimising the number of groups, these changes in flock structure easily covered the additional costs of measurement and management required to generate precision benefits. Identifying, by weight or weight gain, which animals can meet a Merino lamb specification makes a substantial contribution to overall profitability, as well as identifying cross bred animals that will (fail to) meet specifications..

Overall discounted profits in year 10 from the application of a precision production strategy in this dual purpose meat / wool enterprise were estimated as $15,200 in Net Present Value.

Figure 5 Increase in gross margin per DSE from ram selection alone (upper graph) and from combined ram selection and precision production (lower graph).
Horizontal lines represent the annual cost and the labels show the net benefits.





Additional management options to consider:

- Manage reproduction and nutrition by monitoring body weight and fat score throughout the year for:
  - Twin survival
  - Recovery of rearing ewes for next mating
- Use of scanned foetal number + rearing record (wet/dry or lamb survival from e-sheep MatchMaker) to select current generation ewes on reproductive performance
- Identify animals early in life that will fail to meet specifications for carcase weight &/or carcase fatness by monitoring weight and (assessed) fat over time.
- Finishing / marketing options for groups of animals depending on season, growth and market requirements.

DISCUSSION AND IMPLICATIONS

Benefits of Precision Production

The clear result from this study is that precision management, particularly through the application of improved selection of replacement animals, can have a substantial impact on the productivity of merino flocks across a range of production systems. Over a 10-year time horizon, increases in profit of 28%, 24% and 16% were modelled in specialist fine wool, medium wool and dual purpose broad wool production flocks. These increases were at least comparable with and often exceeded the value of genetic improvement obtained by purchasing average rams or elite rams using across-flock genetic evaluation. Importantly, though, the gains from genetic improvement and from precision production were shown to be additive. Taken together, an enhanced genetic strategy plus a precision production strategy could achieve a total gain in profit of 26-49% across scenarios. Moving the sheep industry from its recent 0.6% annual gain in productivity to a 3-5% annual gain would see it match and surpass some other agricultural industries such as cropping and cattle production (Rowe and Atkins 2004).

The components of precision production for which benefits were derived in this paper were selection of replacements on measurement, optimal flock structure and targeting higher value markets through clip preparation of wool or marketing Merino lambs. It could be argued that each of these components are separate activities and need independent decisions. Indeed, different authors have promoted these activities in isolation, such as selecting breeding ewes on measured fleece traits (Morley 1990), highly selected wether flocks (Richards and Atkins 2005), or objective clip preparation (Atkins and Semple 2003). Separately, the benefits can be modest while the on-farm organisation and often the costs of obtaining the information for each component activity are shared. Thus, the more components included in the precision production strategy the greater the benefits for only marginal increases in cost. This same argument applies to the next series of precision strategies referred to such as precision ewe management, selecting on reproduction, monitoring growth in finishing lambs etc. If the investment in capital and equipment has already been made, the addition of other activities to achieve further benefit becomes more attractive. Thus, this paper is not designed to give a robust estimate of the likely benefits for a given flock. Rather, it has attempted to encourage an investment strategy that will allow multiple benefits to be realised in the short- to medium-term.

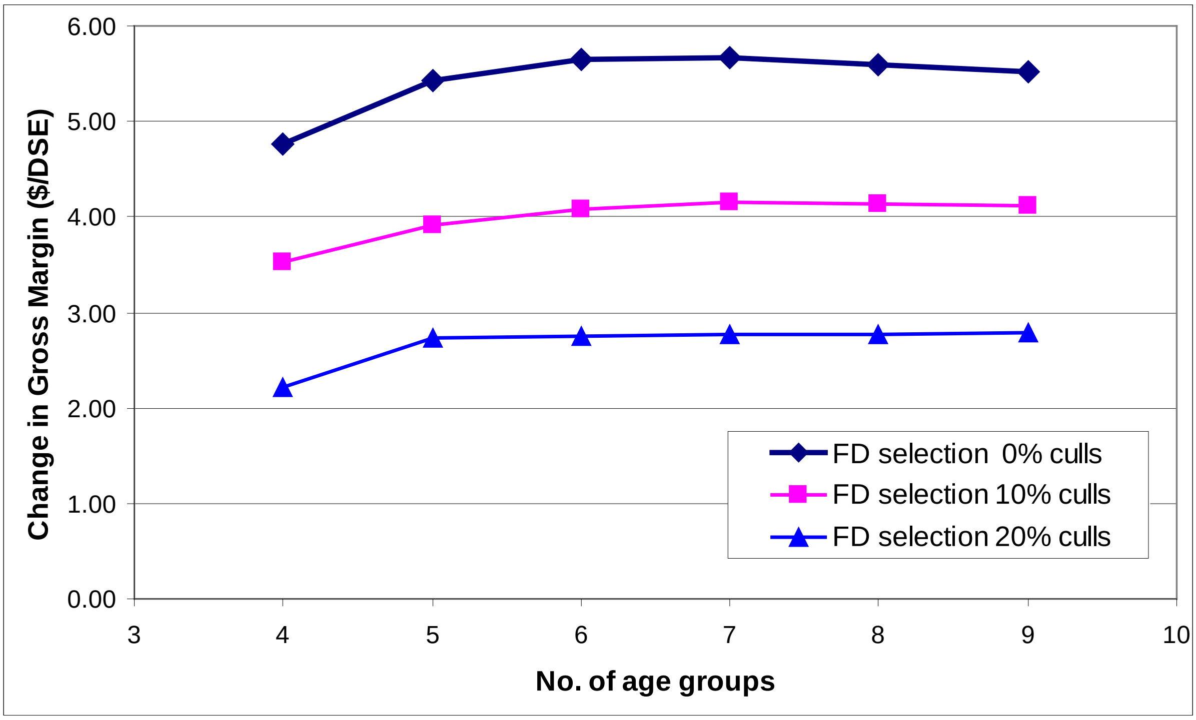
Effective selection in commercial flocks

Selection within the commercial flock to improve the current generation of the flock and effect some additional genetic progress is a different process than selecting in a stud flock to maximise genetic improvement. The stud is largely concerned with intense selection among rams while the commercial producer is intent on moderate selection among young ewes and/or wethers. For studs, selection accuracy is the primary requirement, while for commercial flocks it is primarily selection intensity although selection accuracy can also be an issue.

Selection intensity was shown to be determined by reproduction rate and number of age groups (Table 3), with the lower production of aged animals (Table 4) requiring a procedure to optimise the number of age groups. Figure 5 shows the shape of the curve relating increase in profit to the number of age groups and, therefore, the selection intensity being applied. This example (Figure 5) is of a 19μm flock of breeding ewes only. When all the available selection is applied to fibre diameter (FD selection 0% culls) the optimum number of age groups was 6 but the response curve was relatively flat between 5 and 8 age groups.

But Figure 5 also shows the impact of visual culling before the application of measurement-based selection. The available candidates for selection have been reduced by either 10% or 20% on visual traits unrelated to fleece weight, fibre diameter and body weight. The effect of such culling is to substantially reduce the opportunity for profit improvement, by 27% in the case of 10% culling and by 51% in the case of 20% culling. Increasing the number of age groups in an attempt to “win back” some of this lost selection intensity had little effect on overall responses. So the manner in which visual selection is applied may be important. It may be less detrimental to responses to consider commercial acceptability and performance merit simultaneously in the selection process rather than independent culling firstly on visual acceptability and then selection among remaining candidates on performance.

Figure 5 Impact of variable levels of visual culling prior to fibre diameter selection on 10-year responses in gross margin per DSE

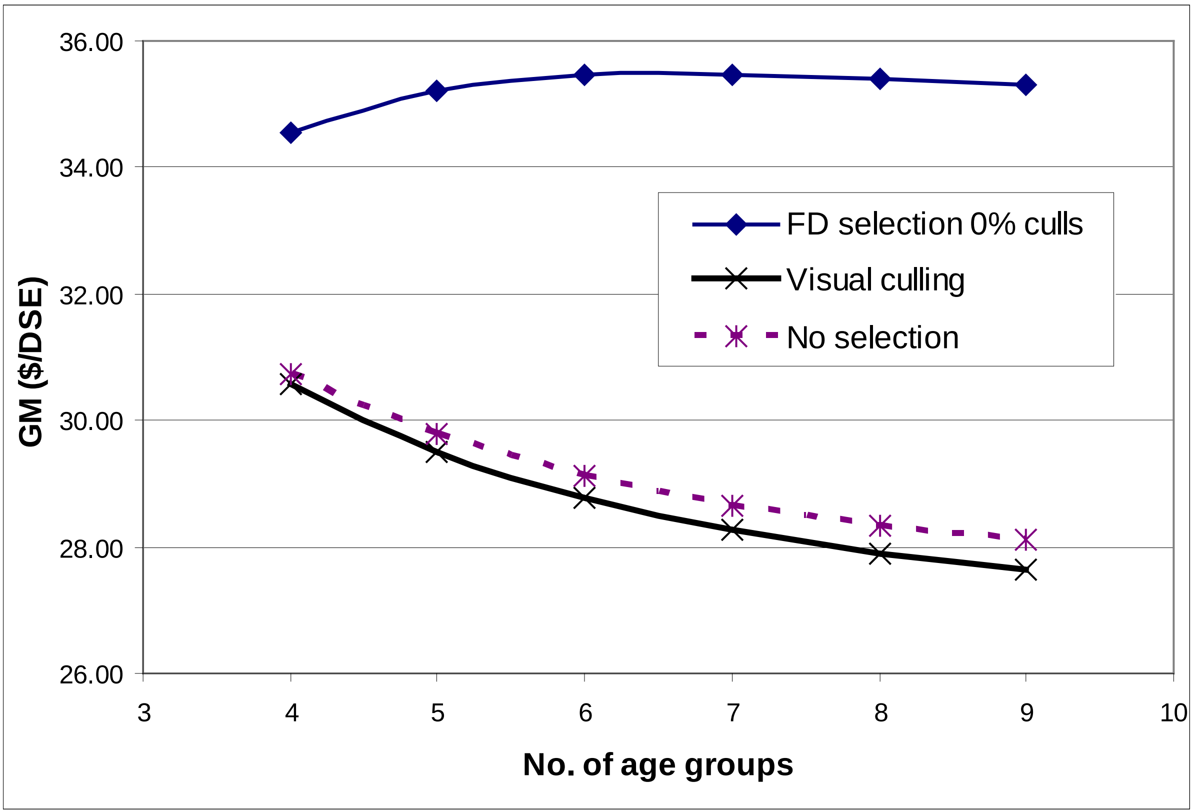


The other aspect of visual selection is its potential role as a relatively low-cost assessment of performance in place of selection on measured assessment. At Trangie, professional classers were employed to provide a performance grade on animals within the QPLU$ selection project. Mortimer et al (2008) reported the correlations between classer grade with fleece weight, fibre diameter and body weight as 0.32, 0.02 and 0.29n respectively. Using these correlations as an index and applying selection over time on visual performance gave the following responses (Figure 6) in the 19μm breeding ewe flock example used previously. Visual selection was slightly worse than no selection (or random selection) principally because increases in body weight led to a slight reduction in gross margin per DSE. Even tolerating changes in body weight without cost, the impact on profit through a slight increase in fleece weight was barely perceptible and would not be cost-effective for non-zero costs of classer assessment. The responses for both no selection and visual selection demonstrate that keeping older animals in the flock is not a productive strategy where very limited or no selection is practised. It is only when accurate selection is undertaken that keeping older age groups becomes an attractive proposition.

Decision support software

The calculation of benefits was possible by linking a large number of decision support tools (Table 7). Future development of this software relies on integrating the specific models so that a solution can be obtained for a production system, using supplied starting flock production levels, a given or default market scenario and a discount rate appropriate to the potential investor. The output will be the likely benefits over a 10-year time horizon, the sources of that benefit and the production consequences for the flock. Developing the integrated software is now well advanced and will be completed in early 2008.

Figure 6 Effect of accuracy of selection on 10-year responses in gross margin per DSE



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Appendix 1: Costs of alternative measurement / identification options

Years		**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	***Average per year***	
RFID contractor													***$ 7,350***	
Capital		$ 5,800												
Tags	*@$2.50 ea*		$ 3,800	$ 3,800	$ 3,800	$ 720	$ 654	$ 654	$ 654	$ 654	$ 654	$ 654	***$ 2,184***	***capital+tags***
Labour-measurement	*@$24/hr*		$ 228	$ 228	$ 228	$ 228	$ 228	$ 228	$ 228	$ 228	$ 228	$ 228	***$ 606***	***labour***
Data management	*@$75/hr*		$ 150	$ 150	$ 150	$ 150	$ 150	$ 150	$ 150	$ 150	$ 150	$ 150	***$ 4,560***	***service***
Service provider	*@$3.00/animal*		$ 4,560	$ 4,560	$ 4,560	$ 4,560	$ 4,560	$ 4,560	$ 4,560	$ 4,560	$ 4,560	$ 4,560		
Selection labour	*@$24/hr*		$ 228	$ 228	$ 228	$ 228	$ 228	$ 228	$ 228	$ 228	$ 228	$ 228		
RFID drafting													***$ 6,832***	
Capital		$ 20,400												
Tags	*@$2.50 ea*		$ 3,800	$ 3,800	$ 3,800	$ 720	$ 654	$ 654	$ 654	$ 654	$ 654	$ 654	***$ 3,644***	***capital+tags***
Labour-measurement	*@$75/hr*		$ 684	$ 684	$ 684	$ 684	$ 684	$ 684	$ 684	$ 684	$ 684	$ 684	***$ 1,212***	***labour***
Data management	*@$75/hr*		$ 300	$ 300	$ 300	$ 300	$ 300	$ 300	$ 300	$ 300	$ 300	$ 300	***$ 1,976***	***service***
Service provider	*@$1.30/animal*		$ 1,976	$ 1,976	$ 1,976	$ 1,976	$ 1,976	$ 1,976	$ 1,976	$ 1,976	$ 1,976	$ 1,976		
Selection labour	*@$24/hr*		$ 228	$ 228	$ 228	$ 228	$ 228	$ 228	$ 228	$ 228	$ 228	$ 228		
Visual tags													***$ 5,947***	
Capital		$ 2,700												
Tags	*@$0.40 ea*		$ 608	$ 608	$ 608	$ 608	$ 608	$ 608	$ 608	$ 608	$ 608	$ 608	***$ 878***	***capital+tags***
Labour-measurement	*@$24/hr*		$ 1,870	$ 1,870	$ 1,870	$ 1,870	$ 1,870	$ 1,870	$ 1,870	$ 1,870	$ 1,870	$ 1,870	***$ 3,093***	***labour***
Data management	*@$75/hr*		$ 600	$ 600	$ 600	$ 600	$ 600	$ 600	$ 600	$ 600	$ 600	$ 600	***$ 1,976***	***service***
Service provider	*@$1.30/animal*		$ 1,976	$ 1,976	$ 1,976	$ 1,976	$ 1,976	$ 1,976	$ 1,976	$ 1,976	$ 1,976	$ 1,976		
Selection labour	*@$24/hr*		$ 623	$ 623	$ 623	$ 623	$ 623	$ 623	$ 623	$ 623	$ 623	$ 623		