How to think about what climate change might mean for a wool producer in Yass, New South Wales

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Abstract

Many future climate scenarios suggest that much of southern Australia could potentially experience higher temperatures and less rainfall. Consequently, livestock production is likely to become more challenging in the future. Managing these risks by examining the potential economic impact of alternative futures is a sensible approach for wool producers to consider in the face of predicted changes in climate. In this paper a way of thinking about the impacts of climate change is presented for wool producers in Yass, New South Wales. Continued genetic improvement will assist in reducing the impact of climate change on operating profit. The long term outlook for wool production and the demand from global markets needs to be considered in a whole farm approach.

Keywords: wool production**,** climate change, alternative futures

Introduction

Climate variability is a significant source of risk for farming businesses. Managing this risk involves recognising and assessing the impact of climate variability and making both strategic and tactical decisions to minimise the risk.

A method to think about what climate change might mean for a wool producer in Yass, New South Wales is presented in this paper. The economic principles of whole farm budgeting and price sensitivity analysis are applied to current and future scenarios in the face of predicted biophysical responses to climate change in the Yass region. The underlying premise is that there will be hotter, dryer, more extreme weather. Increasing temperature and reduction in moisture during the growing season will impact on pasture growth, animal production and profitability of wool enterprises.

Historical climate trends and climate change projections for this region will provide the platform for consideration of a whole farm approach to increasing the resilience to climate change of Yass wool growing farm businesses.

Malcolm (2004) believes that modelling farm systems using the whole farm approach, with emphasis on the risky elements, can be very useful. The method applied in this paper is to do a simple form of analysing a sheep wool business by establishing 'what has been' (baseline) and then exploring 'what might be' the situation in the future with and without change (business as usual in 2030, compared to business incorporating resilience in 2030). The comparison is between alternative futures. The status quo is not a future option.

Whilst no one can predict the future, it makes sense for a wool producer to examine the impacts of possible future climates and what this might mean for the farm business. By utilising management economics (looking forward), it is clear that 'now' is not an option for the future. In order to make informed decisions about how to run an efficient business experiencing hotter, dryer, more extreme weather, graziers will need to compare different future scenarios. The 'thinking' behind this approach is to think in terms of alternatives. Most important, the focus of the whole farm approach is on return and risk. Both matter to decision makers (Heard, Malcolm, Jackson, Tocker, Graham and White 2013).

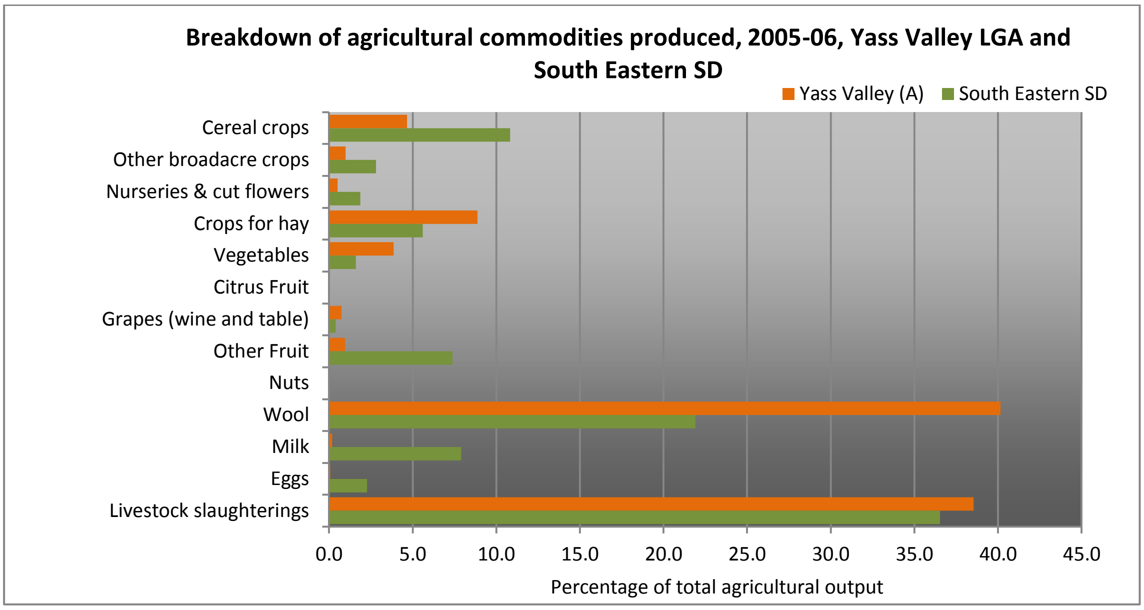
This paper provides a starting point for those interested in gaining a better understanding of how to consider the implications of climate change from an economic perspective, bearing in mind that uncertainty still remains.

Wool production in Yass

The area of interest is the fine wool growing region of the Yass Valley in the southern tablelands of NSW. The region has long been known for its suitability for fine wool production. As is the nature of wool businesses, there is often also a secondary meat production business (either prime lamb or live export).

Figure 1 illustrates the relative proportions of agricultural outputs within the Yass Valley local government area (LGA). The importance of wool and livestock production is apparent.

Figure 1. Agricultural commodities produced in the Yass Valley LGA compared to South Eastern Statistical Division benchmark[1] (Source: 2005-06 Agriculture Census, ABS)



With the majority of future climate scenarios suggesting that much of southern Australia could potentially experience higher temperatures and less rainfall, livestock production is likely to become more difficult in the future (Southern Livestock Adaptation 2030 – SLA2030).

Improved knowledge of the regional impacts of climate change on grazing systems is needed, along with a better understanding of how adaptation and mitigation strategies will affect farm productivity (SLA2030).[2]

Climate trends

A key task of farm management is to make choices between alternatives (Malcolm, Makeham and Wright 2005). Key elements that determine outputs from livestock activities are rainfall and temperatures and variation in seasonal conditions (Heard et al. 2013).

It is useful to consider observed climate trends and climate change projections to inform our understanding of climate change impacts on wool businesses in Yass.

Observed climate trends – looking back

Climate data across the period 1910 – 2013 is presented to illustrate the long term trends in New South Wales/ACT over this period.

[1] Statistical Divisions are large sub-state regions. South Eastern SD comprises Bega Valley, Bombala, Boorowa, Cooma-Monaro, Eurobodalla, Goulburn Mulwaree, Harden, Palerang, Queanbeyan, Snowy River, Upper Lachlan, Yass Valley and Young LGAs.

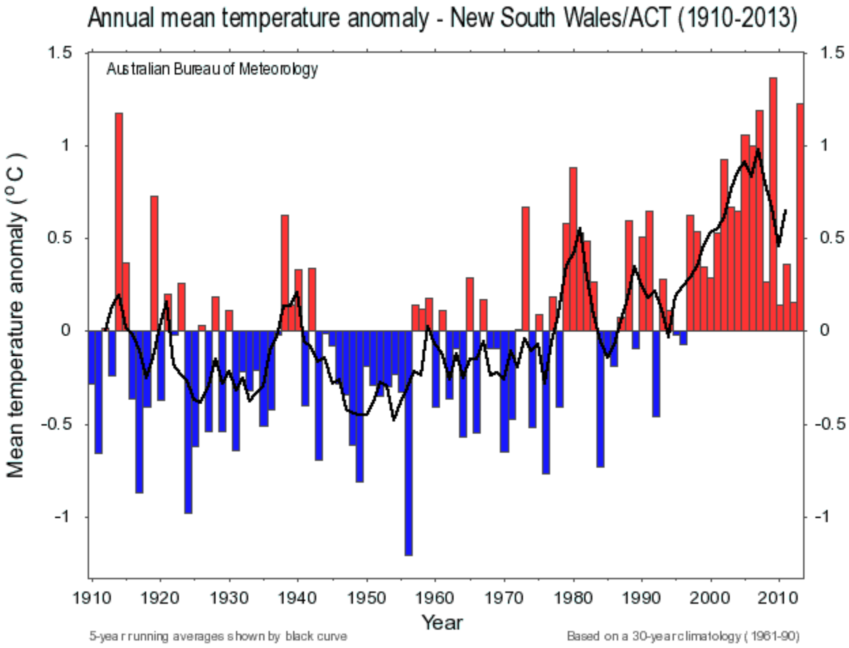
[2] The Southern Livestock Adaptation 2030 (SLA2030) project brought researchers, extension experts and producers together to look at a range of future climate scenarios and the potential impact on farm productivity and profitability.

Temperature

Whilst there has certainly been inter-annual variability in the change in annual mean temperature over the long term, the trend overwhelmingly has been hotter than average years in the past few decades for New South Wales/ACT (Figure 2). The five year moving average shows a rise in temperature change of almost 1.0 °C around the middle of the last decade.

The rise in annual mean temperature anomaly is due to both increases in the maximum and minimum temperature anomalies (Figures 3).

Figure 2. Annual mean temperature anomaly for New South Wales/ACT (1910-2013), with a 5-year running average shown by black line (BOM 2014)



Rainfall

The trends in rainfall are less certain. When considering the long term change over time the total annual rainfall has varied in the order of 0mm to 20mm per decade (1910-2013) across New South Wales/ACT (Figure 4). However this changes dramatically, diminishing in the order of -10 to -50mm per decade for the most recent period, 1970-2013 (Figure 5).

Variability in rainfall inter-annually and between decades makes it difficult to predict future trends. Autumn and early winter rainfall have mostly been below average in the south east since 1990 (CSIRO and Bureau of Meteorology 2014). The southeast has experienced a 15% decline in late autumn and early winter rainfall since the mid-1990s, with a 25% reduction in average rainfall across April and May (CSIRO and Bureau of Meteorology 2014).

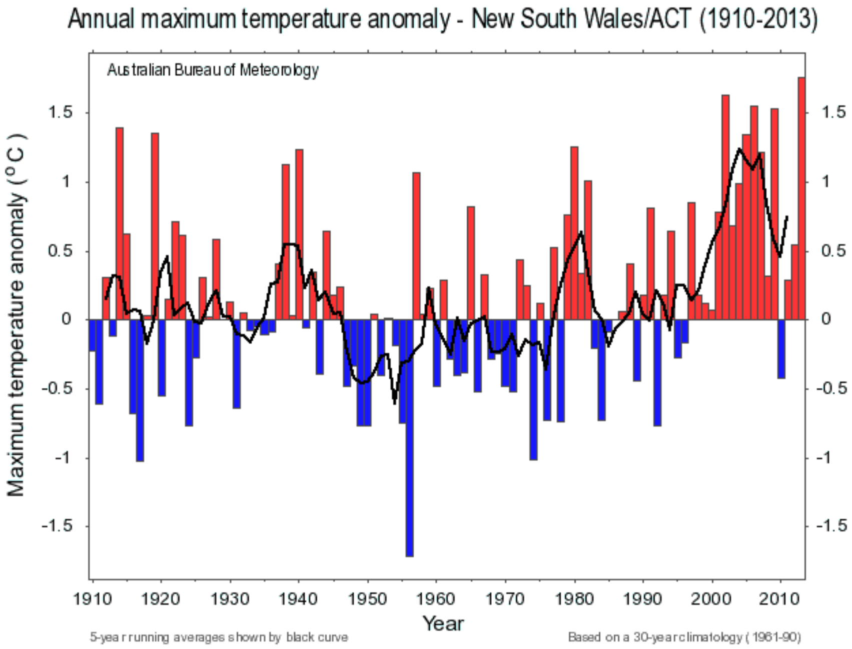
The increasing temperature and reduction in moisture during the growing season will impact on pasture growth, animal production and profitability of wool enterprises.

Outlook for wool production

Australian Bureau of Agricultural Economics and Sciences (ABARES 2014b) has indicated that the gradual strengthening of economic growth in global markets, particularly the European Union and the United States, are having a positive influence on demand for wool and this should support prices over the medium term (Figure 6). Demand will also be supported by the depreciation of the Australian dollar, which makes Australian commodities more affordable on the world market, and hence, more competitive.

Dry conditions have led to lower production of wool due to a significant increase in drought-induced turn-off of livestock. Shorn wool production is expected to fall 4% this year to 345,000 tonnes because of fewer sheep shorn and lower fleece weights, given the poor pasture conditions in the eastern states. Australia's shrinking clip is helping to put upward pressure on prices. Over the medium term, shorn wool production is expected to increase gradually, in line with the rate of flock expansion and no real forecast weakening of the demand for wool is expected (ABARES 2014b).

Figure 3. Annual maximum temperature anomaly (top) and annual minimum temperature anomaly (bottom) for New South Wales/ACT (1910-2012), with a 5-year running average shown by black line (BOM 2014)



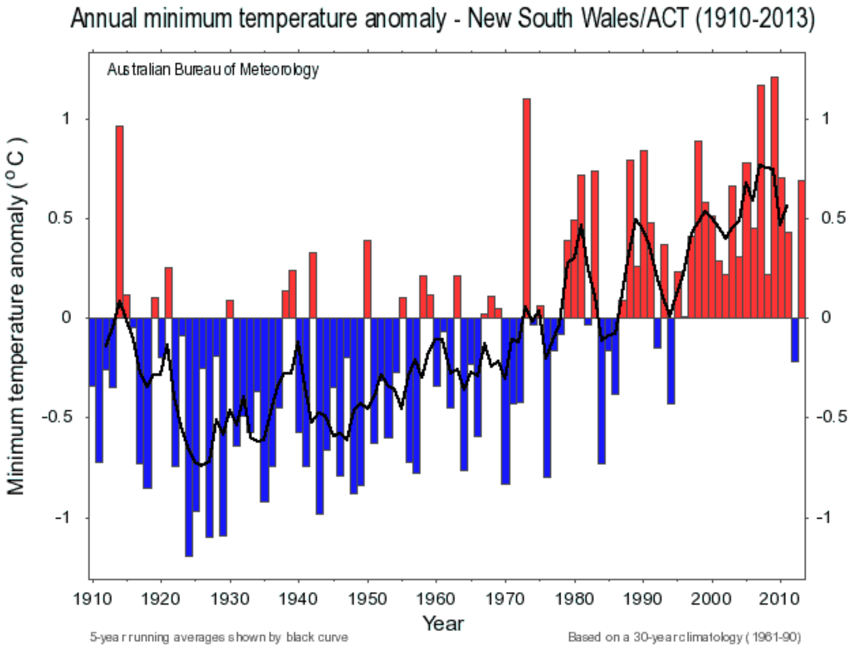


Figure 4. Trend in Annual Total Rainfall for New South Wales/ACT 1910 to 2013 (BOM 2014)

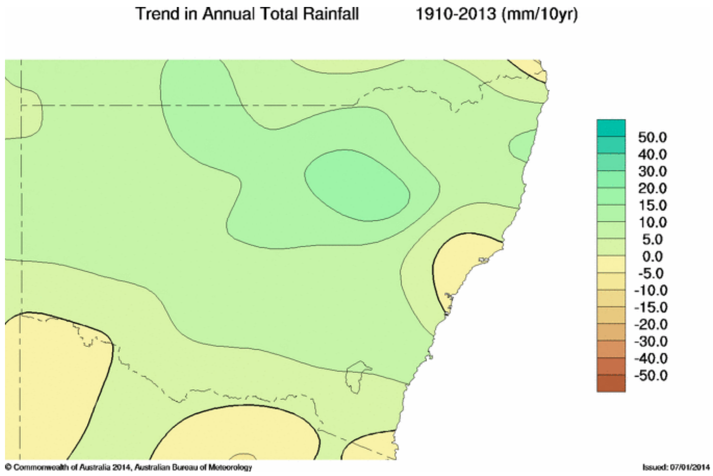
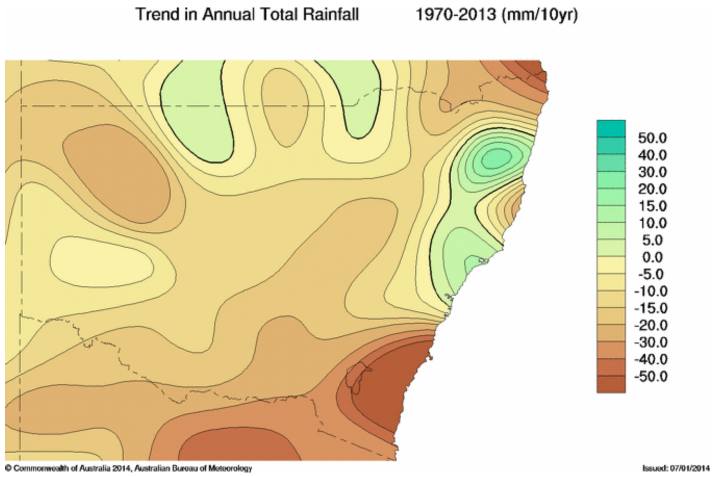


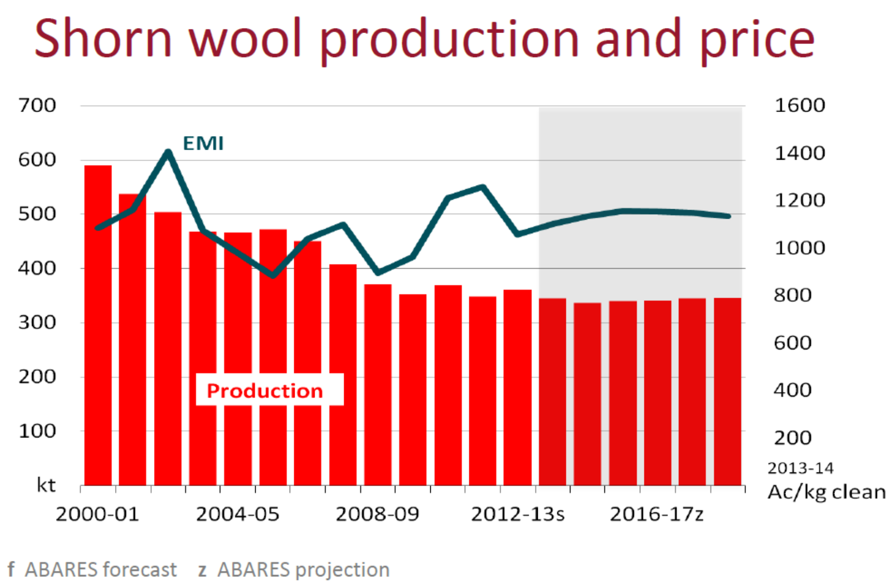
Figure 5. Trend in Annual Total Rainfall for New South Wales/ACT 1970 to 2013 (BOM 2014)



Clearly the longer term outlook for wool production is an influential factor determining the prices received by producers. In the long run, the demand for wool is likely to be price elastic as there are substitutes available.

China is the major buyer of Australian wool (Figure 7). Demographic and income factors are transforming China into a wealthier and more sophisticated market. Chinese consumers assess wool as being environmentally friendly and sustainable, with synthetics viewed as the least sustainable, and this represents a great opportunity for Australian wool (AWI 2014a).The recent China-Australia Free Trade Agreement, may also impact on demand for Australian wool over the next 5-10 years. China's consumers are becoming increasingly worried about pollution and land degradation and Australian wools clean, green image along with the increasing affluence in China's middle class may have a positive influence on demand for Australian fine/super fine wools in this region.

Figure 6. Shorn wool production and price actual and projections (ABARES 2014b)[3]



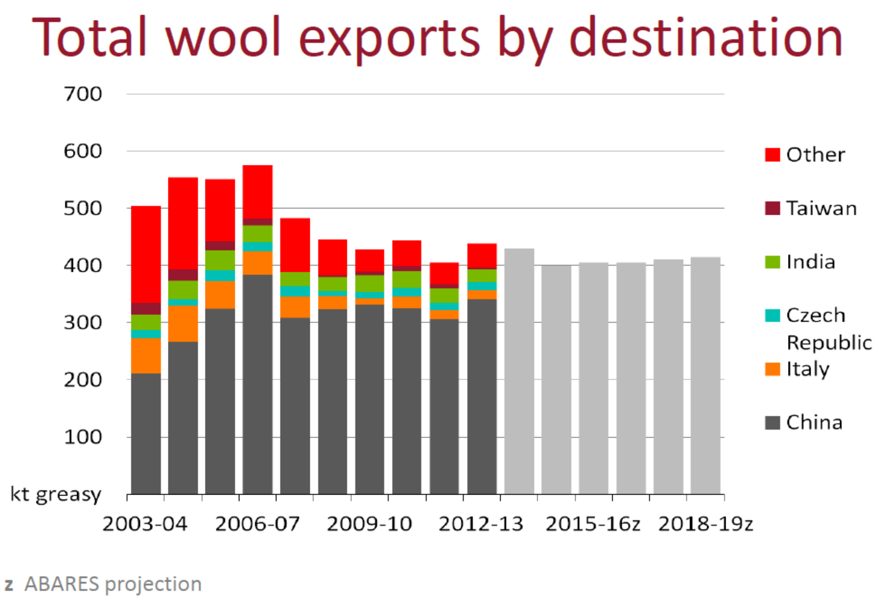
Method and approach

Considering alternative futures with predicted climate impacts

Given the historical decline in growing season rainfall and higher temperatures experienced in the region, considering possible future climate scenarios is essential to prepare farm operations for what potentially lies ahead.

A range of future climate scenarios and the potential impact on farm productivity and profitability have been investigated by The Southern Livestock Adaptation 2030 (SLA2030) project. Yass was one of 46 regional locations across southern Australia targeted for research under this program. The data from this project has been drawn upon in the following sections.

Figure 7. Total Australian wool exports by destination (AWI 2014a)



[3] EMI (Eastern Market indicator) is made up of a basket of wool types and microns, averaging around 19 micron.

How does a wool business look without change to the farm system in the expected changed future conditions (Business as Usual - BAU)

A wool sheep enterprise at Yass was modelled using producers' own production and financial data, looking ahead to 2030, using four different climate scenarios (Global Climate Models – GCMs) (Table 1). Compared to the base period 1970 – 1999, the four climate scenarios showed:

- Average daily temperature increase is pretty consistent across the four scenarios by about 1°C (+9%).
- Average annual rainfall was far more variable – averaging 10% lower but ranging from no change to a 20% decrease.
- This leads, on average, to a 7% decrease in annual pasture production (but ranges from 19% lower to 7% higher). Winter pasture production is increased but autumn and spring pasture production is decreased.
- Predicted pasture production in 2030 is, on average, not dissimilar to that experienced during 2000 – 2009 (a very dry period).

Using the modelled pasture production figures the impacts on livestock production and farm profitability were then calculated. A gross margin was developed using Grassgro® and overhead costs applied. Prices and costs used were a five year average from 2005 – 2009 (P Graham, pers.comm 2014) (Table 2). These impacts are based on a BAU case, that is, no changes were made to farm management practices.

Looking forward to 2030, compared to the base period 1970 – 1999, the four different climate scenarios showed:

Table 1. Weather predications and pasture production for Yass, NSW. Figures in parentheses are the % change compared to the base period, 1970-1999 (SLA2030)

	1970 - 1999	2000 - 2009	2030 Climate USA 1	2030 Climate German	2030 Climate USA 2	2030 Climate English	2030 Average 4 GCMs
Rainfall (mm/pa)	698	613 (-12%)	614	562	679	670	631 (-10%)
Temperature (°C average)	13.8	14.4 (+4%)	15.1	15.2	15.1	14.7	15.0 (+9%)
Pasture (kg DM/Ha/yr)	9067	7869 (-13%)	8155	7184	8798	9494	8408 (-7%)

Table 2. Impacts on production and profitability. Figures in parentheses are the % change compared to the base period, 1970-1999 (SLA2030)

	1970 - 1999	2000 - 2009	2030 Climate USA 1	2030 Climate German	2030 Climate USA 2	2030 Climate English	2030 Average 4 GCMs
Pasture (kg DM/Ha/yr)	9067	7869 (-13)	8155	7184	8798	9494	8404 (-7%)
Stocking Rate (DSE/Ha)	13.2	10.9 (-17%)	9.6	5.7	10.3	11.8	9.4 (-29%)
Profit ($ /Ha)	228	124 (-46%)	146	29	166	198	135 (-41%)

- To maintain minimum ground cover, a substantial decrease in stocking rate (DSE/ha) was needed (average 29%),
- The reduced stocking rates lowered profits by 41% on average, with a range of 14% to 87%. The impacts on profitability were similar in 2030 compared to the dry 2000 – 2009 period.

This study provides a best guess of what climate change impacts could be on the ground for Yass wool producers into the future. A reduction in stocking rate is essential if there is no change to the farm system (no adaptations). Continuing as BAU means that the farm business will be increasingly worse off.

This analysis is very insightful for the industry in this region. The profit/ha figures include overhead costs of $100/ha and no discounting was applied (P Graham, pers.comm 2014). The inclusion of overhead costs is very important in analysing alternatives as activity gross margins (gross income minus variable costs) are only partial representations and have limited value in determining the pros and cons of alternative investment opportunities.

The study provided a comparison of various adaptations and the impact on profitability of a wool sheep enterprise in Yass (Table 3). Note that the inclusion of discounting would have allowed for the fact that capital has an alternative use through the process of adjusting the value of a benefit or cost to be received in the future to their equivalent value in the present time.

The SLA2030 findings show that continued genetic improvement between now and 2030 is critical to offset the decreased stocking rate. The combination of summer feedlots, when required and current genetic improvement has benefits now and in the future. Other changes may need to be implemented in the future as pasture conditions change. A combination of factors will most likely give the best outcome.

Table 3. Impact of adaptations on profitability of wool sheep enterprise at Yass (SLA2030)[4]

	Adaptations	Profit ($/ha) 1970-1999	Profit ($/ha) 2030 Average 4 GCMs	Profit ($/ha) 2030 as a % of 1970 - 99
1	Business as usual	228	135	59%
2	Sell wether lambs at weaning instead of 15 mths		153	67%
3	Increase marking % by 13% due to genetics not feeding		141	62%
4	Trading instead of breeding		203	89%
5	Use summer feedlot – cost of grain included		162	71%
6	Ensure genetic gain from now to 2030 +1kg flc wt, -0.7µ		196	86%
7	Combine genetic gain and feedlot		244	107%
8	Convert to Prime lamb enterprise – no change over costs		112	49%

The sixth adaptation strategy identified by the SLA2030 study, of ensuring genetic gain from now to 2030 (+1kg fleece weight and reduction in 0.7µ fibre diameter) is considered in further detail in this analysis alongside a BAU option using a whole farm budget approach. This level of genetic gain is

[4] For more information regarding the SLA2030 Yass case study, see: http://sla2030.net.au/producer-locations/new-south-wales/yass/yass-sheep-wool-impacts-adaptations/

very plausible over a 20 year timeframe. Sheep Genetics (2012) indicate after 10 years of using Fibre Production Indexes the likely response is a 1.7 µ reduction in fibre diameter and a 5.2% increase in fleece weight. With more emphasis placed on fleece weight and less on fibre diameter reduction over a longer period of 20 years this combination of genetic gain is quite realistic.

Applying a whole farm approach

A whole farm budget that provides a 'first look' at alternatives is an informed basis upon which to determine decisions on changes to farm management. This simplified approach of investigating two steady states was the chosen method to examine alternative futures. Whilst it is important to allow for the fact that resources have alternative uses (the opportunity cost), and benefits and costs occurring in the future are valued differently, discounting was not applied in order to keep this 'first look' simple. It is a starting point upon which more complex economic principles could be applied.

This approach is used to compare the performance of an 800 hectare self replacing merino wool business today (baseline), compared to two alternative futures:

i. Business as Usual 2030 (BAU 2030) in today's dollars (no change to the management system), and
ii. Alternative Future 2030 incorporating resilience via management (genetic gain), in today's dollars (AF_GG 2030)

The baseline budget was developed using the NSW DPI (2012) Farm Enterprise Budget Series and applying the previous 12 month wool market reports to obtain an average clean fleece price for 18 micron (µ) wool (AWI 2014b, Appendix Table A7). The average clean fleece price was converted to a greasy clip price (the price used in the NSW DPI Farm Enterprise Budget Series) using the following method (advised by P Graham 2014):

average clean fleece price	x	0.7	=	greasy fleece price
greasy fleece price	x	0.91	=	greasy clip price

The overhead costs are adapted from Heard et al. (2013), with the 'operator's allowance' inclusive of all fixed labour cost requirements.

The flock parameter assumptions applied to all scenarios are provided in Table 4.

Table 4. Flock parameter assumptions applied to all scenarios (baseline; BAU; Alternative Future) for developing enterprise budgets

Flock Parameter Assumptions			
Flock mortality	4%	Ram %	2%
Productive life	5 years	Marking %	86%
Ewe body weight	50 kg	Weaning %	83%
DSE rating / ewe	2.05	Weaning age	3 months
Stocking rate/ha	10 dse's (Baseline) 7 dse's (BAU 2030, AF_GG 2030)		

A 29% reduction in stocking rate was applied to the baseline budget to determine the stock numbers for the BAU 2030 option. This figure was taken from the SAL2030 study that predicted a reduction of stocking rate of 29%, on average, would be required to maintain minimum groundcover in a BAU case. An additional 1kg of greasy wool/head was included for adult sheep (prorata for younger animals) and prices adjusted to reflect the reduction in micron (-0.7µ) for the AF_GG 2030 option (refer to Appendix; Table A4).

Whole farm budgets for baseline (now), BAU 2030 and AF_GG 2030 are shown in Table 5. Complete farm enterprise budgets for these three steady states are found in the Appendix, Tables A1-A3.

Price sensitivity analysis

In order to consider what increase in price is required to offset the impact from changes to climate, a price sensitivity analysis was developed (Table 6).

Incremental increases of 5% were applied to the AF_GG greasy clip price in order to determine the price required to offset the impact on operating profit from changes to climate.

To consider whether this increase in price is possibly attainable, or completely ludicrous, the previous five years wool prices were analysed from 2009 to 2013 (ABARES 2014a). The average and median prices for 17µ and 18µ wools were compared together with the average prices for 2011, a high priced market, and 2013, a low priced market for wool (Table7). All prices are clean fleece prices with greasy clip prices in parentheses. From this, wool prices were extrapolated for the 17.3µ clip attained by the AF_GG 2030 (Table 8). The full workings are shown in Table A8 of the Appendix.

Table 5. Whole farm budget comparisons: baseline (now); BAU 2030; Alternative Future_Genetic Gain 2030

Whole Farm Budget	**Baseline (now)**	**BAU 2030**	**AF_GG 2030**
Income			
Wool	$208,706	$148,171	$183,004
Sheep sales	$283,362	$201,079	$201,079
Gross Income	**$492,068**	**$349,250**	**$384,083**
Variable Costs			
Replacement ram purchase	$22,400	$15,400	$15,400
Wool harvesting and selling costs	$47,961	$34,046	$34,743
Commission, warehouse and trading charges	$12,093	$8,587	$10,161
Sheep health	$62,489	$44,362	$44,362
Livestock Selling Costs	$27,859	$19,770	$19,770
Pasture maintenance	$10,000	$10,000	$10,000
Supplementary feed costs	$17,856	$12,678	$12,678
Total Variable Costs	**$200,659**	**$144,843**	**$147,114**
Overhead Costs			
Depreciation	$15,000	$15,000	$15,000
Rates	$7,000	$7,000	$7,000
Administration	$3,000	$3,000	$3,000
Other (Electricity, Insurance, etc)	$9,000	$9,000	$9,000
Operator's allowance	$52,000	$52,000	$52,000
Total Overhead Costs	**$86,000**	**$86,000**	**$86,000**
Operating Profit(EBIT)	**$205,409**	**$118,407**	**$150,969**

Results

The SLA2030 study provides a best guess of what climate change impacts could be on the ground for Yass wool producers into the future. Continuing as BAU means that the farm business will be increasingly worse off.

In today's dollars the 800ha self replacing merino business modelled has an operating profit of $205,409 (Table 5). With no alteration to farm management (BAU), the predicted reduction in stocking rate required (29%) to maintain groundcover reduces this profit by 42%, to $118,407. If changes to the farm management system via genetic gain achieve an increase of 1kg of fleece weight per head together with a reduction of 0.7µ, operating profit improves by 28% compared to BAU.

Table 6. Sensitivity analysis showing the increase in price ($/kg) required to offset the impact on operating profit from changes to climate

Whole Farm Budget	Baseline	AF_GG 2030	AF_GG 2030 +5%	AF_GG 2030 +10%	AF_GG 2030 +15%	AF_GG 2030 +20%	AF_GG 2030 +25%	AF_GG 2030 +30%	AF_GG 2030 +35%
Greasy Clip Price ($/kg)	**$7.96**	**$8.25**	**$8.66**	**$9.08**	**$9.49**	**$9.90**	**$10.31**	**$10.73**	**$11.14**
Income									
Wool	$208,706	$183,004	$192,148	$201,467	$210,564	$219,661	$228,758	$238,077	$247,175
Sheep sales	$283,362	$201,079	$201,079	$201,079	$201,079	$201,079	$201,079	$201,079	$201,079
Gross Income	**$492,068**	**$384,083**	**$393,227**	**$402,546**	**$411,643**	**$420,741**	**$429,838**	**$439,157**	**$448,254**
Variable Costs									
Replacement ram purchase	$22,400	$15,400	$15,400	$15,400	$15,400	$15,400	$15,400	$15,400	$15,400
Wool harvesting and selling costs	$47,961	$34,743	$34,925	$35,112	$35,294	$35,476	$35,658	$35,844	$36,026
Commission, warehouse and trading charges	$12,093	$10,161	$10,161	$10,161	$10,161	$10,161	$10,161	$10,161	$10,161
Sheep health	$62,489	$44,362	$44,362	$44,362	$44,362	$44,362	$44,362	$44,362	$44,362
Livestock Selling Costs	$27,859	$19,770	$19,770	$19,770	$19,770	$19,770	$19,770	$19,770	$19,770
Pasture maintenance	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000
Supplementary feed costs	$17,856	$12,678	$12,678	$12,678	$12,678	$12,678	$12,678	$12,678	$12,678
Total Variable Costs	**$200,659**	**$147,114**	**$147,297**	**$147,483**	**$147,665**	**$147,847**	**$148,029**	**$148,215**	**$148,397**
Overhead Costs (Depreciation, Rates, Admin, Operator's allowance, Electricity, Insurance, etc)									
Total Overhead Costs	**$86,000**	**$86,000**	**$86,000**	**$86,000**	**$86,000**	**$86,000**	**$86,000**	**$86,000**	**$86,000**
Operating Profit(EBIT)	**$205,409**	**$150,969**	**$159,931**	**$169,063**	**$177,978**	**$186,894**	**$195,809**	**$204,941**	**$213,856**

Table 7. Comparison of average and median clean wool prices ($/kg) for the period 2009 to 2013 for 17 and 18 micron wool, contrasted with prices from a high (2011) and low (2013) market. Figures in parentheses are greasy clip prices (adapted from P Graham 2014)

	Wool price ($/kg)			
Micron	Average	Median	High	Low
	2009 to 2013	2009 to 2013	2011	2013
17µ	$15.15 ($9.65)	$13.55 ($8.63)	$21.39 ($13.63)	$13.48 ($8.59)
18µ	$13.69 ($8.72)	$12.60 ($8.03)	$18.50 ($11.78)	$12.65 ($8.06)

Table 8. Comparison of average clean wool prices ($/kg) for the period 2009 to 2013 for 17.3 micron wool, contrasted with prices from a high (2011) and low (2013) market. Figures in parentheses are greasy clip prices

	Wool price ($/kg)		
Micron	Average	High	Low
	2009 to 2013	2011	2013
17.3µ	$14.71 ($9.37)	$20.52 ($13.07)	$13.23 ($8.43)

The purchase of rams to obtain this genetic gain may only be at an increase of about 10% in price, so the impact of the extra costs on the business will not be noticeable (P Graham, *pers.comm* 2014). However, this alternative future is still 27% less than today's baseline operating profit.

Clearly, business as usual is not an option. The impacts of climate change even with improvements in production per head outweigh the higher prices and wool volumes per head, achieved by the genetic gains.

The question arises then, what increase in price is required to offset the impact from changes to climate?

Just over 30% increase in price was required to offset the impact of climate change ($10.73). This is equivalent to a clean fleece price of $16.84/kg.

Whilst an increase of 30% (equivalent to a $10.73 greasy clip price) in wool price seems large it is not beyond the realms of possibility and has actually been exceeded in the past five years during the high market prices experienced in 2011. It is impossible to be certain that the high market prices of 2011 will be experienced in the future, but it is feasible.

It is important to reflect upon why 2011 was such a good market. Undoubtedly the millennium drought of the previous 10 years would have had an impact on supply, which would have had a flow on effect on prices experienced post drought. Climate variability and market forces (price) are beyond the control of the wool producer, however an understanding of the relationship between these and other influences beyond the farm gate, informs decision making.

Whilst it is generally thought that relying on price increases to offset declines in output in an exporting industry is not a sensible approach, the wool produced in the Yass district is described as fine (18.6–19.5 µ) and superfine (15–18.5 µ) in the market place. Being at the fine end of the scale is an advantage.

ABARES (2014b) prediction for a positive demand for wool over the medium term are based on the Eastern Market Indicator (EMI), which is made up of a basket of wool types and microns, averaging around 19 micron. It is realistic to suggest that 17.3 micron wool will fare better than the EMI outlook.

Discussion

It is clear from the whole farm budgets presented that to continue as business as usual in the face of climate change will result in the farm business being increasingly worse off. The adaptation strategy of attaining increased genetic gain has merit and certainly provides a buffer to the impacts of climate change on operating profit. It is not unrealistic to consider that a future price could be achieved in the upper levels of the market that would offset the impacts of climate on the business.

McKay, Small and Malcolm (2010) reported that farm productivity growth is crucial for the future viability of the farm enterprise. It is reasonable to assume that past productivity increases will continue into the future. These productivity gains, in addition to the genetic gains described in this paper, will assist in reducing the impact of climate change on operating profit. Additionally, there will be new technology that has not yet been thought of which will enhance operating profit into the future. Most analyses of future climate effects assume today's technology, which will not be the case.

Farmers could change the size of their operations to reduce the average cost per unit of output, thereby spreading fixed costs by expansion. The option of changing activity mix has not been investigated in this paper, however work by McKay et al. (2010) suggests that changing enterprise mix to 40% cropping has significant impacts on the profit of the business. Scope for changing activity mix towards a cropping enterprise will be somewhat limited within the Yass region due to landscape constraints and managerial capacity. Incorporating prime lamb production into the enterprise mix could be considered, however Graham and White (2010) found that improving the genetic performance of a current enterprise might be just as profitable as changing to another enterprise. The risks associated with changing an enterprise are generally greater than from improving an existing one. Changing enterprises incurs changeover costs, which would need to be fully examined.

This analysis is a simple 'first look' at alternative approaches to manage the impacts of climate change. There are many other alternatives that are not considered in detail here, and would need to be, for a wool producer in Yass to make an informed decision on how to incorporate resilience to climate change into their business. Jackson et al. (2014) investigating 16 alternative approaches in a lamb production system, found that the estimate of net benefit may still have to also cover some currently undefined and uncounted capital and operating costs associated with a change in the steady state. In other words, not all of the costs of establishing the changed system are known. Analysing and understanding the performance of livestock activities is important for an effective assessment of how management changes might influence farm returns and risk (Heard et al. 2013).

The choice between alternative actions is made in light of the business and personal goals of the decision makers. Decision makers usually have multiple goals, none of which are dominant and each of which must somehow be acknowledged (Sinden and Thampapillai 1995). A benefit-cost analysis is a useful approach to thinking about alternatives, and provides a logical way in which to assess the advantages and disadvantages. A benefit-cost analysis doesn't make the decision of which alternative future is the 'best', it just informs the debate. The attitude of farmers to taking and bearing risk in changing circumstances is also part of a whole farm analysis (Heard et al. 2013).

A more complex approach would consider the rates of return for each alternative future. These rates of return reflect the efficiency of use of capital in the business, and can be directly compared with alternative investment opportunities. A potential alternative future might be to leave farming altogether. The analysis of a benefit-cost ratio in conjunction with budgeting that provides a rate of return, should be considered in a more complete analysis. Regardless of the complexity of analysis used, utilising farm management economics is a rational means to prepare for the future.

Consideration of the long term outlook for wool production and the influence on demand for wool from global markets needs to be taken into account as part of the decision making process.

Conclusion

Regardless of the actions that we take today, some degree of global warming is inevitable so adaptation will be an essential risk management strategy (Intergovernmental Panel on Climate Change 2007).

Informed decisions are based on the best available information in association with the goals of the business. There are many uncertain and uncontrollable factors such as climate, prices and exchange rates that will impact on the decision.

Successful adaptation to climate change will require flexible, risk-based approaches that deal with future uncertainty and provide strategies that are robust enough to cope with a range of possible local climate outcomes and variations. Potential adaptation options should be, prioritised as part of a whole farm approach to ensure the best information is used within the analysis.

An element of economic understanding, application of some economic principles and the benefit – cost way of thinking about solutions to a climate related problem is required by wool producers, when making informed choices between alternative actions (Malcolm 2011).

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Appendix

Table A1. Baseline farm enterprise budget (template sourced from P Graham 2014; figures derived from DPI Farm Enterprise Budget Series – Dec 2012 and adjusted to reflect 2012/2013 average prices and a representative property size of 800 ha for the Yass area)

Farm Enterprise Budget - Baseline					
Flock size:	**3900**	**ewes**			
Ewe body weight:	**50**	**kgs**			
DSE rating:	**2.1**	**dse's / ewe**			
INCOME					**Budget ($)**
Wool	**number**	**class**	**kg /hd**	**$/kg**	
Shear	4589	ewes	5.00	$7.96	$182,697.39
	78	rams	7.00	$7.96	$4,347.53
	1586	ewe lambs	3.00	$3.14	$14,926.92
Crutch	7030	mixed ages	0.30	$3.19	$6,733.91
Sheep Sales	**number**	**class**	**$ /hd**		
	689	CFA ewes	$100.00	(20.5 kg cwt)	$68,900.00
	16	CFA rams	$120.00		$1,872.00
	1619	weth weaners	$70.00	(6 months)	$113,330.00
	709	ewe hoggets	$140.00	(18 months)	$99,260.00
Fodder	**tonnes**	**type**	**value per tonne**		
Hay	0 t	lucerne hay @	$200 /t		$0.00
Fodder crop grain	0 t	oats @	$150 /t		$0.00
			A. Total Income:		**$492,067.74**
VARIABLE COSTS					
Replacements	**number**	**class**	**cost ($)**	**reps**	
	16	rams	$1,400.00		$22,400.00
Wool Harvesting & Selling Costs					
Shearing	6175	ewes/hoggets	$6.00	1	$37,049.67
	78	rams	$8.61	1	$671.85
Crutching	6952	ewes/hoggets	$0.85	1	$5,932.10
	78	rams	$1.71	1	$133.11
Wool tax			2.00%		$4,174.11
Commission, warehouse, testing charges			$42.99/ bale		$7,264.71
Wool - cartage	169	bales	$17.43		$2,945.67
- packs	169	packs	$11.14		$1,882.66
Sheep health					
Drenching following WormKill					
Broadspectrum	5444	adults/hoggets	$0.75	3	$12,248.88
	3354	lambs	$0.75	4	$10,062.00
Narrowspectrum	5444	adults/hoggets	$0.38	1	$2,068.70
	3354	lambs	$0.21	1	$704.34
Dipping	6253	adults/hoggets	$0.90	1	$5,627.65
Jetting	5444	adults/hoggets	$1.65	1	$8,982.51
	1619	ewe weaners	$1.38	1	$2,234.22
Vaccination- 6 in 1	4634	adults/hoggets	$0.32	1	$1,482.86
	3354	lambs	$0.32	1	$1,073.28
Mules + Mark	3354	lambs	$4.00	1	$13,416.00
Scanning	4589	ewes	$1.00	1	$4,588.95
Livestock Selling Costs					
Livestock cartage	3,033	sale sheep	$3.00		$9,097.80
Commission on sheep sales			5.00%		$14,168.10
Levies (Yard dues, MLA Transaction levy and RLPB rates)					$4,593.27
Fodder					
Supplementary feed - 3.5 kgs grain/hd/week @ $280 /t					
	4555	ewes	$0.98 /week	4 weeks	$17,856.18
Grazing crops	0 ha	@	$360 /ha		$0.00
Supplementary fodder	0 t	@	$350 /t		$0.00
Pasture maintenance	200 ha	@	$50 /ha		$10,000.00
			B. Total Variable Costs:		**$200,658.63**
				incl. fodder costs	excl. fodder costs
	GROSS MARGIN (A-B)			**$291,409**	**$319,265**
	GROSS MARGIN /EWE			**$74.72**	**$81.86**
	GROSS MARGIN /DSE			**$36.45**	**$39.93**
	GROSS MARGIN /HA			**$364.49**	**$399.33**

Table A2. Business as Usual (BAU) farm enterprise budget (template sourced from P Graham 2014; figures derived from DPI Farm Enterprise Budget Series – Dec 2012 and adjusted to reflect 2012/2013 average prices and a representative property size of 800 ha for the Yass area)

Farm Enterprise Budget - Business as Usual (BAU) (-29%SR)					
Flock size:	**2769**	**ewes**			
Ewe body weight:	**50**	**kgs**			
DSE rating:	**2.1**	**dse's / ewe**			
INCOME					**Budget ($)**
Wool	**number**	**class**	**kg /hd**	**$/kg**	
Shear	3258	ewes	5.00	$7.96	$129,705.59
	55	rams	7.00	$7.96	$3,086.74
	1126	ewe lambs	3.00	$3.14	$10,597.55
Crutch	4991	mixed ages	0.30	$3.19	$4,780.62
Sheep Sales	**number**	**class**	**$ /hd**		
	489	CFA ewes	$100.00	(20.5 kg cwt)	$48,900.00
	11	CFA rams	$120.00		$1,329.12
	1149	weth weaners	$70.00	(6 months)	$80,430.00
	503	ewe hoggets	$140.00	(18 months)	$70,420.00
Fodder	**tonnes**	**type**	**value per tonne**		
Hay	0 t	lucerne hay @	$200 /t		$0.00
Fodder crop grain	0 t	oats @	$150 /t		$0.00
			A. Total Income:		**$349,249.62**
VARIABLE COSTS					
Replacements	**number**	**class**	**cost ($)**	**reps**	
	11	rams	$1,400.00		$15,400.00
Wool Harvesting & Selling Costs					
Shearing	4384	ewes/hoggets	$6.00	1	$26,303.47
	55	rams	$8.61	1	$473.74
Crutching	4935	ewes/hoggets	$0.85	1	$4,211.39
	55	rams	$1.71	1	$93.86
Wool tax			2.00%		$2,963.41
Commission, warehouse, testing charges			$42.99/ bale		$5,158.37
Wool - cartage	120	bales	$17.43		$2,091.60
- packs	120	packs	$11.14		$1,336.80
Sheep health					
Drenching following WormKill					
Broadspectrum	3865	adults/hoggets	$0.75	3	$8,695.78
	2381	lambs	$0.75	4	$7,143.00
Narrowspectrum	3865	adults/hoggets	$0.38	1	$1,468.62
	2381	lambs	$0.21	1	$500.01
Dipping	4439	adults/hoggets	$0.90	1	$3,995.36
Jetting	3865	adults/hoggets	$1.65	1	$6,376.91
	1149	ewe weaners	$1.38	1	$1,585.62
Vaccination- 6 in 1	3290	adults/hoggets	$0.32	1	$1,052.89
	2381	lambs	$0.32	1	$761.92
Mules + Mark	2381	lambs	$4.00	1	$9,524.00
Scanning	3258	ewes	$1.00	1	$3,257.91
Livestock Selling Costs					
Livestock cartage	2,152	sale sheep	$3.00		$6,456.23
Commission on sheep sales			5.00%		$10,053.96
Levies (Yard dues, MLA Transaction levy and RLPB rates)					$3,260.20
Fodder					
Supplementary feed - 3.5 kgs grain/hd/week @ $280 /t					
	3234	ewes	$0.98 /week	4 weeks	$12,677.89
Grazing crops	0 ha	@	$360 /ha		$0.00
Supplementary fodder	0 t	@	$350 /t		$0.00
Pasture maintenance	200 ha	@	$50 /ha		$10,000.00
			B. Total Variable Costs:		**$144,842.93**
				incl. fodder costs	excl. fodder costs
	GROSS MARGIN (A-B)			**$204,407**	**$227,085**
	GROSS MARGIN /EWE			**$73.82**	**$82.01**
	GROSS MARGIN /DSE			**$36.01**	**$40.00**
	GROSS MARGIN /HA			**$255.67**	**$284.03**

Farm Enterprise Budget Alternative Future (-29%SR; +1kg flcwt; -0.7um)					
Flock size:	**2769**	**ewes**			
Ewe body weigh	**50**	**kgs**			
DSE rating:	**2.1**	**dse's / ewe**			
INCOME					**Standard Budget ($)**
Wool	**number**	**class**	**kg /hd**	**$/kg**	
Shear	3258	ewes	6.00	$8.25	$161,225.09
	55	rams	8.00	$8.25	$3,654.14
	1126	ewe lambs	3.60	$3.25	$13,172.83
Crutch	4991	mixed ages	0.30	$3.31	$4,951.96
Sheep Sales	**number**	**class**	**$ /hd**		
	489	CFA ewes	$100.00	(20.5 kg cwt)	$48,900.00
	11	CFA rams	$120.00		$1,329.12
	1149	weth weaners	$70.00	(6 months)	$80,430.00
	503	ewe hoggets	$140.00	(18 months)	$70,420.00
Fodder	**tonnes**	**type**	**value per tonne**		
Hay	0 t	lucerne hay @	$200 /t		$0.00
Fodder crop grain	0 t	oats @	$150 /t		$0.00
			A. Total Income:		**$384,083.14**
VARIABLE COSTS					
Replacements	**number**	**class**	**cost ($)**	**reps**	
	11	rams	$1,400.00		$15,400.00
Wool Harvesting & Selling Costs					
Shearing	4384	ewes/hoggets	$6.00	1	$26,303.47
	55	rams	$8.61	1	$473.74
Crutching	4935	ewes/hoggets	$0.85	1	$4,211.39
	55	rams	$1.71	1	$93.86
Wool tax			2.00%		$3,660.08
Commission, warehouse, testing charges			$42.99/ bale		$6,104.08
Wool - cartage	142	bales	$17.43		$2,475.06
- packs	142	packs	$11.14		$1,581.88
Sheep health					
Drenching following WormKill					
Broadspectrum	3865	adults/hoggets	$0.75	3	$8,695.78
	2381	lambs	$0.75	4	$7,143.00
Narrowspectrum	3865	adults/hoggets	$0.38	1	$1,468.62
	2381	lambs	$0.21	1	$500.01
Dipping	4439	adults/hoggets	$0.90	1	$3,995.36
Jetting	3865	adults/hoggets	$1.65	1	$6,376.91
	1149	ewe weaners	$1.38	1	$1,585.62
Vaccination- 6 in 1	3290	adults/hoggets	$0.32	1	$1,052.89
	2381	lambs	$0.32	1	$761.92
Mules + Mark	2381	lambs	$4.00	1	$9,524.00
Scanning	3258	ewes	$1.00	1	$3,257.91
Livestock Selling Costs					
Livestock cartage	2,152	sale sheep	$3.00		$6,456.23
Commission on sheep sales			5.00%		$10,053.96
Levies (Yard dues, MLA Transaction levy and RLPB rates)					$3,260.20
Fodder					
Supplementary feed - 3.5 kgs grain/hd/week @ $280 /t					
	3234	ewes	$0.98 /week	4 weeks	$12,677.89
Grazing crops	0 ha	@	$360 /ha		$0.00
Supplementary fod	0 t	@	$350 /t		$0.00
Pasture maintenan	200 ha	@	$50 /ha		$10,000.00
			B. Total Variable Costs:		**$147,113.85**
				incl. fodder costs	excl. fodder costs
	GROSS MARGIN (A-B)			**$236,969**	**$259,647**
	GROSS MARGIN /EWE			**$85.58**	**$93.77**
	GROSS MARGIN /DSE			**$41.75**	**$45.74**
	GROSS MARGIN /HA			**$296.40**	**$324.76**

Table A3.

Alternative Future farm enterprise budget (template sourced from P Graham 2014; figures derived from DPI Farm Enterprise Budget Series – Dec 2012 and adjusted to reflect 2012/2013 average prices and a representative property size of 800 ha for the Yass area)

Table A4. Alternative Future greasy wool clip price points (17 & 18 µ sourced from AWI (2014b); linear incrementation advised by P Graham 2014)

Greasy clip price ($/kg) for micron 17-18 in 0.1 increments										
17	17.1	17.2	**17.3**	17.4	17.5	17.6	17.7	17.8	17.9	18.0
$8.37	$8.33	$8.29	**$8.25**	$8.21	$8.17	$8.13	$8.08	$8.04	$8.00	$7.96

Table A5. Flock structure for Baseline scenario (derived from DPI Farm Enterprise Budget Series – Dec 2012 and adjusted to reflect a representative property size of 800 ha for the Yass area)

Flock Structure – Base line

Sheep numbers are modified to reflect mortality throughout the year

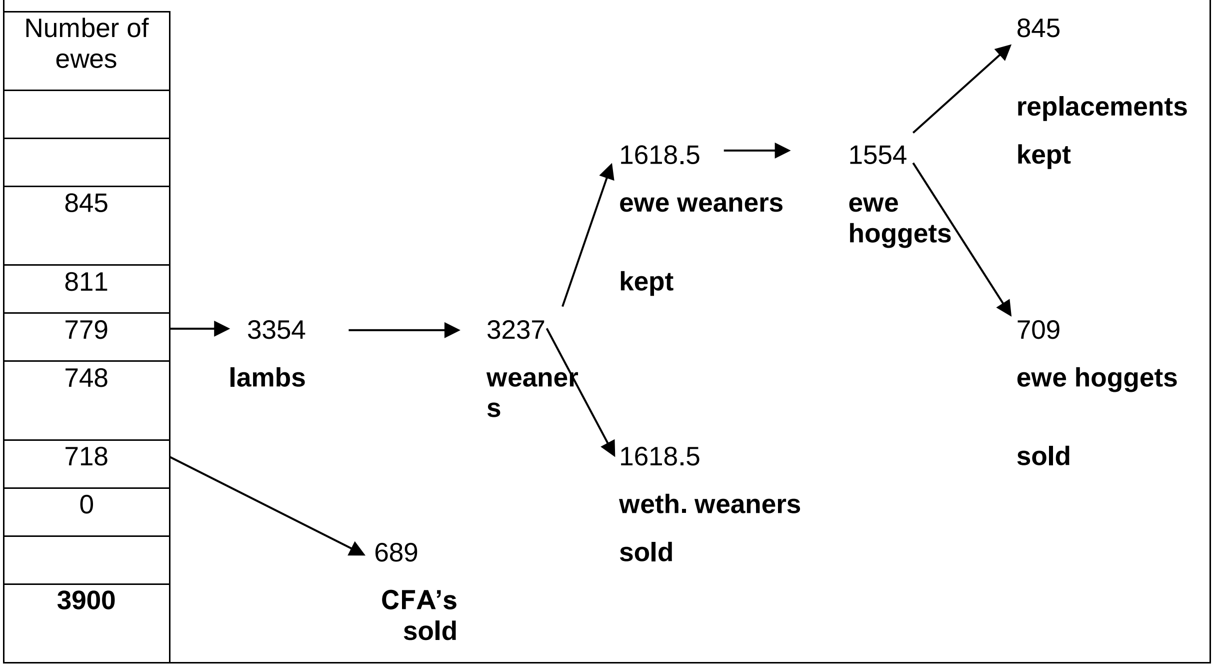

Table A6. Flock structure for BAU and Alternative Future scenario (derived from DPI Farm Enterprise Budget Series – Dec 2012 and adjusted to reflect a representative property size of 800 ha for the Yass area and SLA2030 projections of a 29% reduction in stocking rate)

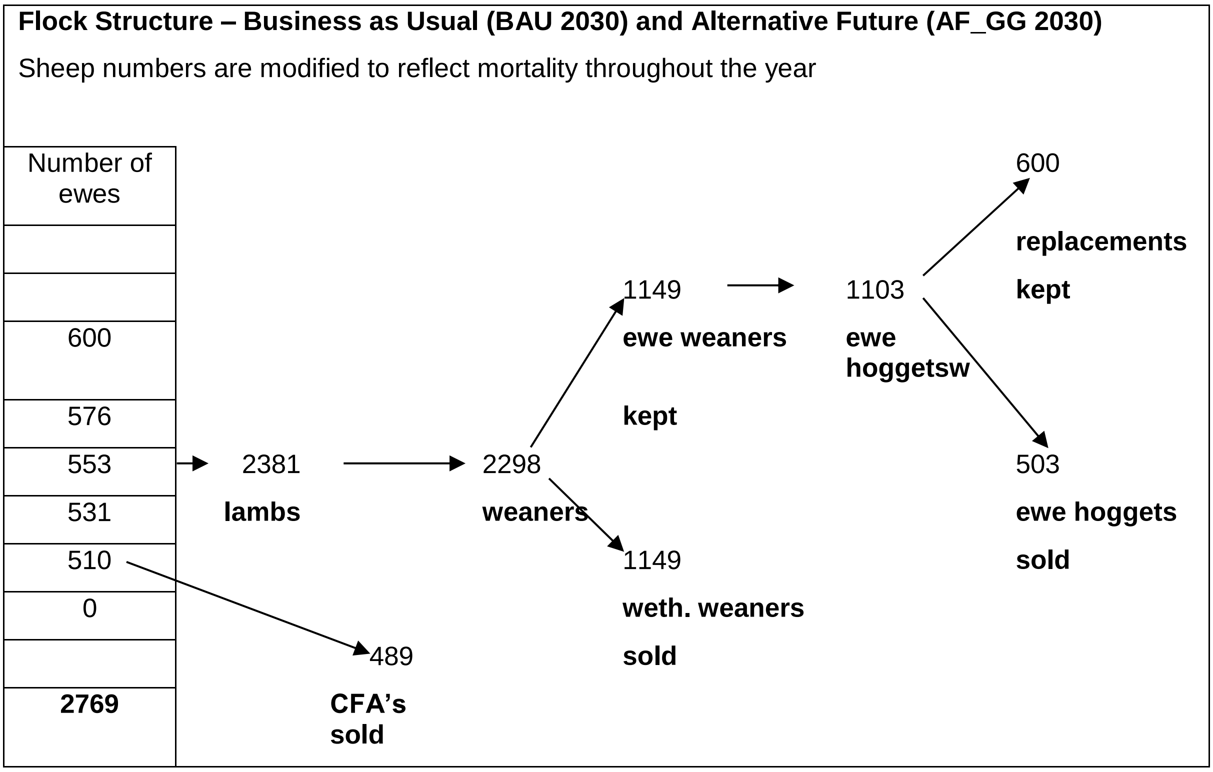

Table A7. Weekly clean fleece price for 17µ and 18µ for 12 month period 5 Jul 13 – 27 Jun 14 (AWI 2014b)

Weekly Clean Fleece Price 2013-2014			
Month	**Week**	**17µ**	**18µ**
05-Jul-13	W1	1290	1156
12-Jul-13	W2	1315	1167
	W3		
	W4		
	W5		
09-Aug-13	W6	1328	1205
16-Aug-14	W7	1323	1195
23-Aug-13	W8	1330	1204
30-Aug-13	W9	1418	1277
06-Sep-13	W10	1451	1338
13-Sep-13	W11	1377	1278
20-Sep-13	W12	1341	1268
27-Sep-13	W13	1332	1280
04-Oct-13	W14	1325	1281
11-Oct-13	W15	1357	1312
18-Oct-13	W16	1331	1299
25-Oct-13	W17	1305	1267
01-Nov-13	W18	1319	1276
08-Nov-13	W19	1325	1272
15-Nov-13	W20	1335	1294
22-Nov-13	W21	1340	1298
29-Nov-13	W22		
06-Dec-13	W23		
13-Dec-13	W24	1393	1355
20-Dec-13	W25		
27-Dec-13	W26		
4/01/2014	W27		
10-Jan-14	W28	1390	1346
17-Jan-14	W29	1351	1320
24-Jan-14	W30	1373	1335
31-Jan-14	W31	1389	1328
07-Feb-14	W32	1350	1302
14-Feb-14	W33	1320	1262
21-Feb-14	W34	1362	1268
28-Feb-14	W35	1316	1271
07-Mar-14	W36	1316	1263
14-Mar-14	W37	1294	1245
21-Mar-14	W38	1256	1211
28-Mar-14	W39	1224	1174
04-Apr-14	W40	1228	1167
11-Apr-14	W41	1276	1221
17-Apr-14	W42	1291	1247
24-Apr-14	W43		
02-May-14	W44	1300	1242
09-May-14	W45	1279	1223
16-May-14	W46	1239	1180
23-May-14	W47	1249	1199
30-May-14	W48	1248	1197
06-Jun-14	W49	1251	1202
13-Jun-14	W50	1233	1179
20-Jun-14	W51	1224	1169
27-Jun-14	W52	1221	1168
Average (c)		**1314**	**1250**

Table A8. Average clean fleece price points for microns 17 to 18 for periods 2009 to 2013, 2011 (High market) and 2013 (Low market); (linear incrementation advised by P Graham 2014) (ABARES 2014a, AWI 2014b)

Average Clean Fleece Price 2009 to 2013 (c/kg) for micron 17-18 in 0.1 increments										
17.0	17.1	17.2	17.3	17.4	17.5	17.6	17.7	17.8	17.9	18.0
$15.15	$15.00	$14.86	$14.71	$14.57	$14.42	$14.27	$14.13	$13.98	$13.84	$13.69
Average Clean Fleece Price 2011 – High Market (c/kg) for micron 17-18 in 0.1 increments										
17.0	17.1	17.2	17.3	17.4	17.5	17.6	17.7	17.8	17.9	18.0
$21.39	$21.10	$20.81	$20.52	$20.23	$19.95	$19.66	$19.37	$19.08	$18.79	$18.50
Average Clean Fleece Price 2013 – Low Market (c/kg) for micron 17-18 in 0.1 increments										
17.0	17.1	17.2	17.3	17.4	17.5	17.6	17.7	17.8	17.9	18.0
$13.48	$13.40	$13.31	$13.23	$13.15	$13.07	$12.98	$12.90	$12.82	$12.73	$12.65