Proceedings, 10th World Congress of Genetics Applied to Livestock Production

Optimal breeding strategies for sheep should consider variation in feed availability

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ABSTRACT: Large pasture growth variation across years requires changes in optimal management between years, making breeding objectives difficult to calculate. We modeled a farm with Merino sheep bred for wool and meat in a Mediterranean environment where feed availability and prices vary widely between years. We calculated profit and economic values for 6 traits by optimizing management across 5 years using dynamic recursive analysis, comparing varying to average pasture growth and prices. Profit decreased for the varying scenario but economic values increased. Economic values for yearling live weight and fibre diameter increased most and were least sensitive to uncertain pasture growth, having least effect on energy requirements. These changes shifted selection response from wool towards meat and reproduction, mostly because reproduction had a higher genetic correlation with yearling weight than wool traits. Therefore, variation in pasture growth should be considered when developing sheep breeding programs.

Keywords: pasture growth uncertainty; price uncertainty; sheep; breeding objectives

Introduction

Breeding programs for livestock require clearly defined breeding objectives that select the most profitable animals for a given production system. Economic weights used to optimize selection on multiple traits are derived from profit models that are usually based on average conditions (Byrne et al. (2010); Wolfova et al, (2009)). Many livestock production systems, however, have a high variability in pasture growth and commodity prices across years. For example, Mediterranean climates have periods of drought in summer and autumn, requiring farmers to feed grain, which is expensive (Purser (1981)). Additionally, the length and severity of these drought periods varies between years (Thompson et al. (1994)), making sheep difficult to manage. Despite the influence of varying prices and pasture growth, little attention has been paid to how variation across years affects breeding objectives. To optimize breeding objectives for uncertain environments, optimal management of sheep must be considered.

Optimal management when pasture growth and prices vary can be derived using dynamic recursive programming (Mosnier et al. (2009)). Many models have investigated the impact of pasture and price uncertainty (Kingwell et al. (1993); Ridier and Jacquet, (2002)), but these models have not connected uncertainty to breeding objectives.

The optimal management of livestock in uncertain environments is mostly driven by the distribution of energy requirements of the animals across the year and the availability of feed resources. Since the energy requirements of sheep depend on many breeding goal traits, uncertainty in pasture growth and prices may also affect the economic value of breeding goal traits. Different breeding goal traits change energy requirements at different times of the year. For example, energy required for growth and reproduction peaks at lambing time, while wool traits require a more stable energy intake all year. Therefore, economic values of traits may respond differently to varying pasture growth and prices between years.

Therefore, we tested the hypothesis that accounting for variation in pasture and meat, wool and grain prices, both within and across years, changes trait economic values, and therefore, the breeding objectives for sheep breeding. These changes will cause subsequent changes in selection responses.

Materials and Methods

Model. We modeled monthly production decisions for a sheep farm in an environment with variation in pasture growth and in wool, meat, and grain prices. The farm had a self-replacing Merino sheep flock, bred for wool and meat. The parameters of the farm and sheep represent a typical sheep enterprise in South Western Australia. We based pasture growth on the Katanning region in a Mediterranean climatic region with hot dry summers and mild wet winters. This combination of temperature and rainfall means that there is a period of no pasture growth during summer and autumn.

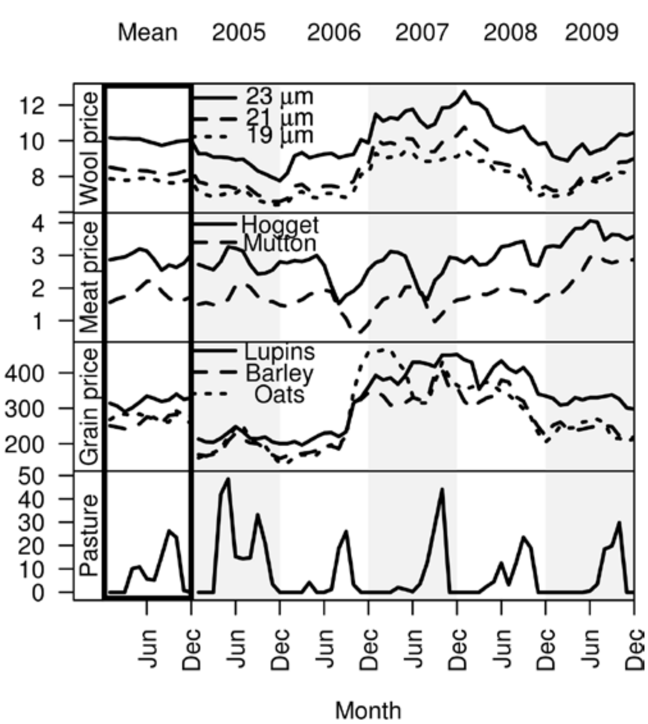
Profit from wool and sheep sales was maximized by optimizing flock structure, sheep sales and grain feeding based on pasture availability and prices of grain, wool and meat. We maximized profit per ha because pasture growth per ha affects how many sheep can be managed on the farm. The number of sheep managed per ha is a major driver of profit (Young et al. (2011)). Therefore, we optimized the stocking rate and management of flock structure, sheep sales and grain feeding per ha using the General Algebraic Modeling System with the linear programming solver Brooke, Drud, and Meeraus linear (Brooke et al. (2013).

The optimization included five groups of equations: profit (objective function), flock structure, pasture, energy, and intake. Profit depended on the number of sheep managed, sheep sold and grain intake. The amount of pasture available affected how much pasture could be eaten by sheep, which also affected how much pasture was available in the next month. The number of sheep depended on energy requirements, potential intake, and the number of sheep sold. The amount of pasture and grain eaten was constrained by the potential intake of the sheep, while pasture and grain eaten had to match the energy requirements of the sheep.

Profit was income from meat and wool sales minus variable and grain costs. Meat sales were the product of number of sheep sold, live weight, price per kg carcass and carcass percentage. Sheep sales were split into mutton (over 20 months old) and hoggets (less than 20 months old), with different prices for both classes. We assumed the minimum carcass weight at which sheep can be sold was 16 kg. Wool income was the product of the number of sheep in November (shearing month), wool weight, and wool price minus shearing costs. The profit equation therefore included all relevant incomes and costs to calculate the impact of varying prices and pasture growth on breeding objectives.

Scenarios. We optimized profit for two scenarios: Average pasture growth and average prices and varying pasture growth and varying prices. Parameters for pasture growth and prices were from 2005-2009 (Figure 1). We selected these years because they represented the high variation in pasture growth and prices experienced in harsh environments. For the varying scenario, we used dynamic recursive programming to optimize management in each year, based on the management of the previous years but expecting average pasture growth and prices in the following years. This dynamic modeling represents how farmers need to optimize management in the current year based on current pasture growth and prices, with no idea of what will happen in the following year.

Figure 1: Wool price ($AU/kg), meat price ($AU/kg carcass), grain price (AU$/t) and pasture growth (kgDM/kg per day) for the average scenario and in years 2005 to 2009.



Pasture growth data were remote sensing estimates from the Pastures from Space project (Hill et al. (1999)) recorded at Katanning. Wool prices were based on the Western region micron price guide from the Wool Desk, Department of Agriculture and Food WA (DAFWA (2009)). Meat prices were based on hogget and mutton prices from Meat and Livestock Australia's National Livestock Reporting Service (MLA (2009)). Grain prices were taken from Co-operative Bulk Handling (CBH (2009)). Using real pasture growth and prices ensured all the relationships between pasture growth, grain prices, wool prices, and meat prices were included.

Traits. For each scenario, we calculated the economic values for 6 traits: weaning live weight, yearling live weight, adult live weight, fleece weight, fibre diameter and number of lambs weaned. These traits are economically the most important traits in Merino breeding objectives. We then compared the expected selection responses using economic values from the two scenarios. Responses were predicted using truncation selection across age classes in SelAction (Rutten et al. (2002)).

We assumed first mating at 19 months age, with a ewe to ram ratio of 20 to 1. Each ewe gave birth to 0.8 lambs once per year, with 10% death and culling for ewes and 50% for rams. We used 7 age classes, each representing one year, with weaning weight for class 1, yearling weight for age 2, adult weight and number of lambs weaned for classes 3-7, and wool weight and fiber diameter for classes 2-7. Rams and ewes were selected based on own performance and from 15 half sibs from 19 dams for all traits, except for number of lambs weaned. For number of lambs weaned, ewes were selected based on own performance and 7 half sib sisters from 9 ewes. For number of lambs weaned, rams were selected based on the performance of 8 half sib sisters from 10 dams. For all traits at all ages, ewes and sires were selected based on BLUP-EBV, approximated with a pseudo-BLUP selection index (Rutten et al. (2002)). We used genetic parameters from the MERINOSELECT database (Brown et al. (2006)).

Results

Profit. Average profit decreased by 12% from $AU184 for the average scenario to $AU162 when pasture growth and prices varied. Profit decreased because of annual changes in management in reaction to changes in pasture growth and prices. These changes in management, in particular, changing the number of ewes mated, made the farm vulnerable to unfavorable changes in pasture growth and prices. Therefore, grain costs increased by 40% compared to the average scenario. Additionally, favorable prices and pasture growth in 2009 did not compensate the unfavorable prices and pasture growth in 2006 and 2008.

Economic values. The economic value for all traits increased when pasture and prices varied, compared to the average scenario (Table 1). The economic value for yearling weight increased the most (244%), followed by lambs weaned (85%) and fleece weight (66%) (Table 1). The economic value for weaning weight increased from a small negative to a small positive economic value, whereas adult weight became slightly more positive (Table 1). The economic value for fibre diameter decreased by 110% to more negative, because finer wool was more valuable (Table 1). These changes in economic values caused changes in the response to selection for each trait.

Table 1. Economic values ($AU/genetic standard deviation) and responses to selection (in genetic standard deviations) for average (mean) and varying pasture growth and prices (vary).

Traits	Economic value		Selection response	
	Mean	Vary	Mean	Vary
wean live weight	-0.06	0.63	0.19	0.31
yearling live weight	3.20	11.00	0.19	0.29
adult live weight	-1.80	-1.41	0.20	0.28
wool weight	13.00	21.70	0.15	0.12
fibre diameter	-10.00	-21.00	-0.13	-0.11
lambs weaned	14.00	25.90	0.09	0.11

Response to selection. Selection response of live weight and reproduction traits increased when pasture and prices varied, compared to the average scenario (Table 1). Weaning weight increased the most (64%), followed by yearling weight (52%), adult weight (42%) and number of lambs weaned (28%). Fleece weight decreased the most (-22%), followed by fibre diameter (-17%, decrease of negative response) (Table 1). Live weight and reproduction increased because the genetic correlations between these traits and yearling body weight were higher than for wool traits (Table 1). Therefore, varying pasture growth and prices caused a shift in trait responses towards meat oriented traits. Despite this shift, the responses from the two breeding programs had a correlation of 0.94.

Discussion

In this study, economic values and response to selection of traits changed when prices and pasture growth varied. Therefore, we confirmed our hypothesis that accounting for uncertainty in pasture and prices across years changes the economic value of breeding goal traits.

Changes in the value of breeding goal traits differed between traits because traits varied in relation to their energy requirements. The largest changes were found for traits that had the smallest impact on energy requirements.

Our model provides insight into how breeding goals should be adapted to a production system with uncertain pasture growth and prices. Our results suggest that farming systems become more vulnerable when pasture growth and prices vary across years because profit decreases. Additionally, although the farming system is more vulnerable, genetic improvement of sheep has more value when pasture growth and prices vary. The additional value of improving breeding goal traits is not the same for all traits. Despite the high correlation between responses, we found that emphasis shifted to traits that make the farming system less vulnerable to changes in pasture growth and prices.

Increasing yearling weight only increases energy requirements in a small proportion of the flock, whilst the extra income from heavier lambs and hoggets increases meat income a lot more than the higher energy costs. Fibre diameter does not change energy requirements, so decreasing fibre diameter increases the value of every kg of wool grown. Additionally, increasing the number of lambs weaned increases energy requirements mostly in winter and spring, when pasture growth is peaking. These traits were most profitable without a large increase in sheep per ha. Fleece weight was most optimal to manage at high stocking rates and was more vulnerable to sudden changes in pasture growth and prices.

Conclusions

Our study showed that varying prices and pasture growth increased the economic value of breeding goal traits compared to a scenario with no variation. Traits increased by different amounts, depending on how they affected energy requirements, changing the expected response in breeding goal traits and the optimal sheep type for the production system. Therefore, varying pasture growth and prices across years should be considered when estimating the economic value of breeding goal traits.

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