Agricultural Systems 131 (2014) 94–104

Contents lists available at ScienceDirect

Agricultural Systems

journal homepage: www.elsevier.com/locate/agsy

Varying pasture growth and commodity prices change the value of traits in sheep breeding objectives

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ARTICLE INFO

Article history:
Received 5 January 2014
Received in revised form 4 August 2014
Accepted 15 August 2014
Available online 15 September 2014

Keywords:
Uncertainty
Management
Breeding
Economic values

ABSTRACT

Breeding programs for livestock require economic weights for traits that reflect the most profitable animal in a given production system. Economic weights are commonly based on average conditions. In pasture based livestock production systems the cost of feed is an important profit driver, but availability of feed from pasture can vary greatly within and between years. Additionally, the price of supplementary feed during periods of feed shortage and the prices for meat and wool vary between years. Varying prices and pasture growth can change the optimal management of the flock affecting profitability. This paper investigates how variation in commodity prices and pasture growth affect the economic values of traits in the breeding objective. We modelled a sheep farm with a self-replacing Merino flock bred for wool and meat in a Mediterranean environment. We optimised management decisions across 5 years using dynamic recursive analysis to maximise profit when commodity prices and pasture growth varied annually. Actual pasture growth and wool, meat, and grain prices from 2005 to 2009 were used. Management could adapt to varying pasture growth and commodity prices by changing sheep numbers, age structure of the flock and amount of grain fed to sheep. The economic value of seven traits in the breeding objective were compared for a scenario with average pasture growth and commodity prices over years and a scenario with varying pasture growth and commodity prices over years. Variation in pasture growth and commodity prices decreased average profit and increased the economic value of all breeding goal traits compared to the average scenario. The order of importance of traits stayed the same between varying and average scenarios but the relative importance of traits changed. The economic values that increased the most were for traits that had increased profit with the smallest impact on energy requirements such as yearling live weight, longevity and fibre diameter. Our results showed that it is important to account for variation in feed availability and commodity prices when determining the expected profit and economic values for traits. The results also suggest that whereas variation in pasture growth and commodity prices between years makes the farming operations less profitable, these changing conditions increase the genetic variation in profitability of sheep. Therefore, genetic improvement has more value relative to scenarios where pasture feed supply and prices are constant.

1. Introduction

Breeding programs for livestock require clearly defined breeding objectives that select the animals that are most profitable in a given production system. To calculate the economic value of changing traits in animals, changes in optimal management need to be accounted for before calculating the change in profit (Amer, 1994; Groen, 1989). Economic weights used to optimise selection on multiple traits can be derived from profit models of such systems and those models are usually based on average conditions (Byrne et al., 2010; Conington et al., 2004; Wolfova et al., 2009). However, many livestock production systems have high levels of variability in pasture growth and commodity prices across years. For example, periods of drought in summer and autumn in Mediterranean climates require farmers to feed grain, which is more expensive than feeding pasture (Purser, 1981, p. 181). Additionally, the length and severity of these drought periods varies between years (Kingwell, 2002; Kopke et al., 2008; Thompson et al.,

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http://dx.doi.org/10.1016/j.agsy.2014.08.007
0308-521X/© 2014 Published by Elsevier Ltd.

1994). Farmers manage variation in pasture growth by altering the grain feeding and the number of sheep managed from year to year (Saul and Kearney, 2002; Young et al., 2011). Despite the influence on varying prices and pasture growth, little attention has been paid to how variation across years affects the importance of traits within breeding objectives.

Changes in management depend largely on the energy requirements of the flock, and since the energy requirements of sheep change when most traits in the breeding objective are altered, uncertainty in pasture growth and prices may also affect the economic value of traits in the breeding objective. These changes in energy are not always at the same time of the year. For example, energy requirements for reproduction peak around lambing time, whereas the energy requirements for wool growth are distributed evenly across the whole year and changing the diameter of wool fibres has no impact on energy requirements Therefore, the economic values of traits may respond differently to varying pasture growth and commodity prices across years.

The effect of variation in commodity prices and pasture growth on breeding objectives can be simulated in bio-economic models that optimise management to adapt to such changes. Recursive dynamic models can be used to optimise farmer decisions in response to variation in commodity prices and pasture growth between years where the management of the current year depends on the optimal management of previous years (Mosnier et al., 2009). Many models have investigated the impact of pasture (Olson and Mikesell, 1988; Kingwell et al., 1993; Jacquet and Pluvinage, 1997; Kobayashi et al., 2007) and price (Lambert, 1989; Barbier and Bergeron, 1999; Lien and Hardaker, 2001; Ridier and Jacquet, 2002; Mosnier et al., 2009, 2012) uncertainty, providing insights into optimal management of farming systems under uncertainty. There are limited studies, however, into how variability in pasture growth and commodity prices across years affects the relative economic value of changing breeding goal traits.

In this study, we tested the hypothesis that accounting for the variation in pasture growth and meat, wool and grain prices across years changes the relative economic value of traits in the breeding goal. We also tested whether the change in profit due to variation across years was affected by how much energy requirements change when traits are changed.

2. Outline of materials and methods

Testing the hypotheses that economic values of breeding goal traits are affected by variation in prices and pasture growth across years required three steps:

1. Model (described in part 3) – model a sheep farm that can optimise farm profit across years for the purpose of calculating economic values for sheep.
2. Scenarios (described in part 4) – define scenarios for different pasture growth and prices across years.
3. Economic values (described in part 5) – calculate the economic values for each pasture growth and price scenario for individual years and across years. We calculated economic values for seven breeding goal traits: weaning weight, yearling weight, fleece weight, fibre diameter, longevity, and number of lambs weaned.

3. Model description

We modelled monthly production decisions for a sheep farm in an environment, which experiences significant variation in pasture growth and wool, meat, and grain prices between years. The modelled 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 with one lambing per year in July and lambs weaned at 3 months old. There was no allowance for buying and selling of livestock additional to those bred on the farm. We based pasture growth on the Katanning region (33°41′S, 117°35′E, elevation 310 m). Katanning is located 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, typically extending from November to May each year.

Profit from wool and sheep sales was maximised for the sheep farm per hectare (ha) by optimising sheep sales and grain feeding based on pasture availability and prices of grain, wool and meat. We maximised profit per ha because pasture growth (pgr) per ha affects how many sheep can be managed on the farm and the number of sheep managed mostly determines farm profit (Warn et al., 2006; Young et al., 2011). Therefore, we optimised management of sheep sales and grain feeding per ha using the General Algebraic Modelling System with the linear programming solver BDMLP (Brooke, Drud, and Meeraus linear program) Brooke et al. (2013).

The optimisation included five groups of equations, profit (objective function), flock structure, pasture, energy requirements and intake. Profit depended on the number of sheep (via wool sales and variable costs), sheep sold and grain intake. The amount of pasture available affected how much pasture could be eaten by sheep which also affected how much was available in the next period. 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, whilst pasture and grain eaten had to match the energy requirements of the sheep. Fig. 1 shows that all the relevant interactions between price, pasture growth, flock structure, energy requirements and intake were in the model, and how the variables and parameters interacted in the optimisation of profit.

The model optimised profit for 5 years using dynamic recursive programming to simulate the sequential decision-making of farmers based on changes in prices and pasture growth from year to year. The first year had the current prices and pasture growth whilst years 2–5 used average prices and pasture growth. This simulates a farm where decisions have to be made in the current year without knowledge of pasture growth or prices in the following years. Average pasture growth and prices are used as the best source of information to make decision in the current year, considering the long term profit of the farm. The profit from the first year was recorded and the optimised values from the first year used as the starting point for the next analysis, with new prices or pasture growth values for the first year of analysis. We used prices and pasture growth from years 2005 to 2009. The starting points for variables in the first optimisation step for 2005 were taken from the equilibrium from average prices and pasture growth. The optimised variables from the first analysis of 2005 was used as starting values for the first month of the first year to optimise management for 2006, again assuming the following 4 years had average prices and pasture growth. This was done until all years up until 2009 were optimised. Predictions for each year were optimal for the 5 year planning horizon and different to optimising years 2005–2009 together. This is because the modelled farmer could adjust management based on anticipated sudden changes in prices and pasture growth across the 5 years.

It was assumed that ewes were kept up to an age of 78 months and litter size varied between 0 and 2 lambs. This resulted in 79 categories for age-months ($a = \{0, 1, 2, 3, \ldots, 78\}$), 3 categories for litter size at birth ($b = \{0, 1, 2\}$), and litter size at weaning ($r = \{0, 1, 2\}$), and two categories for sex (s = {wether (castrated male) or ewe (female)}). Ewes were first mated at 20 months old. There were 6 categories for litter size at birth and litter size at