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Can animal genetics and flock management be used to reduce greenhouse gas emissions but also maintain productivity of wool-producing enterprises?

Douglas J. Alcock [a,1], Matthew T. Harrison [b,*], Richard P. Rawnsley [b,2], Richard J. Eckard [c]

[a] Graz Prophet Consulting, P.O. Box 1355, Cooma, NSW 2630, Australia
[b] Tasmanian Institute of Agriculture, P.O. Box 3523, Burnie, TAS 7320, Australia
[c] Melbourne School of Land and Environment, University of Melbourne, VIC 3010, Australia

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ABSTRACT

Farm intervention strategies that reduce greenhouse gas (GHG) emissions from the livestock industries may reduce global emissions associated with agriculture, though farmers are unlikely to adopt new practises unless they also improve farm profitability. Here our objective was to explore the effect of manipulating enterprise management or animal genotype on whole-farm production, profitability, enteric methane emissions and wool emissions intensities of sheep enterprises in southern Australia. Two enterprises that differed in lamb sale age were simulated using the model GrassGro; surplus animals were sold at either 18 weeks (weaner) or 12 months old (yearling). We examined the influence of lambing time (LT), joining maiden ewes at 7 months instead of 19 months of age (JA), increasing lamb weaning rates (WR), or superior genotypes with 10% improvement in fleece weight (FW), feed efficiency (FE) and/or methane yield (MY).

Annual wool production, methane emissions, wool emissions intensities and profitability averaged across the baseline enterprises were 55 kg clean wool/ha, 3.2 t CO_2-eq/ha, 31 kg CO_2-eq/kg clean wool and $569/ha. Relative to these values average profitability increased by up to 18%, 15%, 10%, 9%, 8% and 0% for the JA, WR, FW, FE, LT and MY strategies; associated changes in wool production were 0%, –3%, 11%, 0%, 2% and 0%, and wool emissions intensities changed by –4%, –8%, –5%, –7%, 0% and –10%, respectively.

Increasing weaning rate and introducing genotypes with lower methane yield afforded the greatest reductions in wool emissions intensities. Divergence between the relative effects of alternative strategies on farm economics, production and wool emissions intensities suggests that farm adaptations will depend on the goal of the individual farmer. If the goal is to increase profitability, flock management interventions are most beneficial; if the goal is to reduce emissions intensity, superior breeds containing improvements in several genetic traits have the greatest potential. We demonstrate that no intervention – to farm management, animal genotype or otherwise – is likely to achieve simultaneous improvements in all of production, profitability, net farm emissions and wool emissions intensity. Under current carbon prices, subsidies greater than $150/t CO_2-eq would be required if economic returns from GHG abatement were to equal those from increased productivity, suggesting there would be little incentive for wool producers to participate in the Carbon Farming Initiative under the intervention strategies modelled here.

1. Introduction

Growing international demand for livestock products and consequent increased production are projected to raise Australian livestock greenhouse gas (GHG) emissions to 72% of total national agricultural emissions by 2020 (DCCEE, 2013). On the other hand, global GHG emissions must fall if dangerous climate change is to be averted (Hansen et al., 2007; Wigley et al., 1996), demonstrating a need to sustainably intensify livestock production without increasing associated GHG emissions.

Emissions intensity is a metric often used to assess the amount of GHG produced per unit livestock production (Alcock and Hegarty, 2011; Browne et al., 2011; Hegarty, 2012; Hegarty et al., 2010). Strategies that alter farm management or animal production and that reduce emissions intensities may also improve production efficiency. For example,

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[*] Corresponding author. Tel.: +61 3 6430 4501.
E-mail address: doug@grazprophet.com.au (D.J. Alcock), Matthew.Harrison@utas.edu.au (M.T. Harrison).
[1] Tel.: +61 2 6453 3187.
[2] Tel.: +61 3 6430 4501.

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methane has an energetic value of ~55 MJ/kg (Eckard et al., 2010), so emissions from enteric fermentation represent significant energy losses from feed intake. It is possible that energy conserved from reduced enteric methane emissions could be used in other metabolic processes, such as liveweight gain. Emissions intensities of livestock products may be reduced by manipulating farm management or by improving animal production efficiency (Alcock and Hegarty, 2011; Cruickshank et al., 2008; Ferguson et al., 2007; Young et al., 2011). Prospective interventions to farm management include reducing ewe age at first mating (Harrison et al., 2014a), changing seasonal time of lambing (Cruickshank et al., 2008), selectively breeding genotypes with higher reproduction rates or ewe fecundity (Harrison et al., 2014b; Ho et al., 2014), manipulating seasonal feed-base supply and grazing utilisation (Harrison et al., 2014a), feedlot finishing (Bentley et al., 2008), diet composition (Hegarty et al., 2010) and age of lamb slaughter (Bentley et al., 2008).

Interventions to animal genotypic traits that reduce emissions intensities include selective breeding of animals with greater feed efficiency (lower than expected feed intake relative to the size and performance of the animal; FE) and/or with lower methane yield (MY) per unit dry matter intake. Differences in FE of individual animals represent a divergence between the efficiency of ingested feed used by the animal for maintenance and for production, primarily due to differences in digestion and metabolism (Waghorn and Hegarty, 2011). More efficient animals require less feed than average and produce less methane per unit product compared with the population average when expressed at a similar level of production. Ongoing research has stressed a need for productive individuals with high FE and low MY to reduce emissions intensities (Waghorn and Hegarty, 2011). The effect of interactions between such traits on liveweight gain at the paddock-scale remains to be determined.

Since emissions intensity represents both production and emissions, there are several mechanisms through which emissions intensity may be altered. Reducing maiden ewe joining age increases the proportion of the flock used for reproduction and may reduce emissions intensity by increasing animal production through greater lamb sales (Harrison et al., 2014a). Feed-lot finishing increases rates of liveweight gain and reduces the time required for animals to reach slaughter weight (Pinares-Patino et al., 2009), reducing emissions intensity by reducing total lifetime emissions. Similarly, animals expressing the low MY trait have lower methane emissions per unit dry matter consumed (Goopy et al., 2006), reducing emissions intensity by decreasing the rate of GHG production and thus cumulative emissions. Because these management or genetic interventions can influence either production or emissions, it is difficult to quantify how a given strategy will impact on emissions intensity until the strategy is examined in a whole of farm context.

It is also important to consider whether the goal of the decision-maker is to reduce net emissions, to reduce emissions intensity, to increase productivity or to increase profitability, since changes in the four rarely align. Industry goals are generally to increase productivity and profitability, which in some cases translates to reduced emissions intensity (Harrison et al., 2014a; Ho et al., 2014), but rarely aligns with reduced net farm emissions (Alcock and Hegarty, 2006, 2011; Waghorn and Hegarty, 2011). Pinares-Patino et al. (2009) discussed numerous methods for reducing net emissions but stipulated that few were profitable. Dynes et al. (2011) indicated that many changes to farm management had little impact on net emissions and exposed the business to greater economic risk due to market constraints and climate variability. Further, intensification strategies that improve animal production – such as increasing the proportion of grain in the animal's diet – do not necessarily improve farm profitability (Ho et al., 2014). Farmers are unlikely to participate in government schemes that reward them for mitigating emissions (such as those under the Emissions Reduction Fund or the Carbon Farming Initiative) unless such schemes either maintain or improve profitability. The polarisation between the effects of various interventions on the profitability, production, emissions and emissions intensity of livestock enterprises suggests there is a need to better explore the trade-offs between these variables.

The scale with which imposed strategies are assessed is important. Management strategies effective in reducing emissions at the individual animal level may be less effective in reducing emissions at the enterprise level if stocking rates are modified such that surplus feed is also consumed (Hegarty et al., 2010). For example, selecting animals with high FE may lower methane emissions per animal (Waghorn and Hegarty, 2011), but if more animals are retained on farm to eat the surplus feed, there may be no change or even an increase in net emissions (Harrison et al., 2014b). New GHG mitigation technologies should be evaluated in terms of their effects on whole-enterprise net emissions and emissions intensity, not just on their effects on individual animals. Whole-farm models represent an avenue for incorporating the interactions between plants and animals over longer time scales, including feedbacks due to changes in animal liveweight gain and dry matter intake with pasture regrowth (Harrison et al., 2011a, 2011b). Although several intervention strategies for mitigating emissions per unit product have shown promise at the animal scale, many of these strategies are yet to be assessed at the paddock scale. The aim of the present study was to identify enterprise-scale trade-offs between production, profitability, GHG (methane) emissions and emission intensity as influenced by manipulation of flock management and animal genotype of a representative sheep farm in southern Australia.

2. Materials and methods

2.1. Model simulations, pasture and soil data

The GrassGro model (Freer et al., 1997; Moore et al., 1997) was used to conduct all simulations. Herbage availability and dry matter intake are simulated in GrassGro as a function of pasture characteristics, and methane production is estimated using the equations of Blaxter and Clapperton (1965) as described by Freer et al. (1997). Simulations were conducted for a representative farm at Hamilton in south-west Victoria (37°50′S, 142°04′E), a prominent region of Australian wool and prime lamb production (DEPI, 2013; LFMP, 2011). GrassGro has been extensively parameterised and simulations validated for pasture and animal data on sites throughout south-western Victoria in previous work (Cayley et al., 1998; Clark et al., 2003; Harrison et al., 2014b; Mokany et al., 2010), with validations demonstrating credible capacity to simulate biophysical data for sites in this region (Moore and Harrison, 2011). Hamilton has an average annual rainfall of 649 mm and a winter dominant rainfall pattern with cold winters and warm summers (Supplementary Fig. 1). All simulations were conducted for the period 1978–2012 using the GrassGro default weather set constructed from Bureau of Meteorology data. The 35-year simulation period was chosen to provide a sufficient time frame to capture the impacts of climate variably while being sufficiently recent to be of relevance to the experience of the current farming community. Pasture and soil parameters in GrassGro simulations were set to those typical of south-western Victoria (for further information on soil data see Harrison et al., 2014a). Botanical compositions included perennial and annual ryegrass (*Lolium* spp.) and subterranean clover (*Trifolium subterraneum* cv. Leura), with root depths set to the default value for the soil type (780 mm, 250 mm and 250 mm, respectively). The soil A horizon was 250 mm deep and consisted of clay loam (bulk density 1.06 Mg/m^3, plant available water capacity 19% v/v), overlaying a B horizon consisting of clay (bulk density 1.33 Mg/m^3, plant available water capacity 15% v/v) to a total soil depth of 1000 mm.