Modelling adaptation and mitigation strategies for southern livestock industries of Australia

Richard Eckard [AC], *Richard Rawnsley* [B], *Brendan Cullen* [A], *Matthew Bell* [A] *and Karen Christie* [B]

[A] The University of Melbourne, Parkville, VIC 2010 Australia
[B] Tasmanian Institute of Agriculture, University of Tasmania, PO Box 3523, Burnie, TAS 7320, Australia.
[C] Primary industries Climate Challenges Centre, 221 Bouverie St, Parkville, VIC 3010 Australia
Contact email: richard.eckard@unimelb.edu.au

Keywords: DairyMod, SGS, methane, nitrous oxide, climate change.

Introduction

Climate change will impact on the Australian grazing industries both through mitigation policies and the impact of warmer temperatures, increased atmospheric CO_2 and changed rainfall patterns (Cullen *et al.* 2009; Eckard *et al.* 2010). Mechanistic models are useful tools to inform our understanding of the complex interactions between future climates and the soil, plant, animal and management in livestock production systems.

This paper summarises the results of a number of whole farm systems modelling studies investigating likely impacts of climate change, adaptation options and emissions implications for livestock production in southern Australia.

Methods

The results presented were extracted from a sequence of recently published modelling studies by the authors, which included a combination of biophysical modelling, using the DairyMod and SGS (Johnson *et al.* 2008) models, together with static inventory-based models to estimate emissions of methane (CH_4) and nitrous oxide (N_2O) (Eckard *et al.* 2002). Downscaled future climate libraries for 2030 and 2070 were constructed by the methods of Cullen *et al.* (2009) or scaled as per Cullen *et al.* (2012), using either the IPCC A1B or A1FI emsision scenarios, compared with 2000 as a baseline year. These scenarios did not include predictions of extreme events. The sites simulated were located across the medium-high rainfall regions (550+ mm annual average rainfall) of Australia, spanning a climatic range from cool temperate to subtropical.

Results

Climate change impacts on pasture growth

This study modelled the effects of climate change scenarios and elevated CO_2 in 2030 and 2070 on pasture growth and species composition in climates ranging from cool temperate to subtropical (Cullen *at al.* 2009). Mean annual pasture production at 550 ppm CO_2 was predicted to be 24–29% higher than at 380 ppm CO_2 in C3 pastures in temperate southern Australia, with lower responses in a mixed C3/C4 pasture in a subhumid climate (17%) and in a C4 pasture in more sub-tropical climate (9%). In the subtropical and subhumid climates (temperature increase up to 4.4ºC by 2070 with little change in annual rainfall) the models predicted increased pasture production and a shift towards C4 dominance. In Mediterranean, temperate and cool temperate climates (temperature increase up to 3.3ºC with annual rainfall reduced by 28%) modelling predicted increased winter and early spring pasture growth rates but a shorter spring growing season. In Mediterranean and temperate climates annual pasture production was predicted to increase by 2030, but decline by up to 19% under an IPCC A1FI emission scenario by 2070. In a cool temperate environment annual production was higher than the historical baseline (1971 – 2000) in all future climate scenarios (A1B and A1FI for 2030 and 2070), but highest in the A1B medium scenario in 2070.

Resilience of pasture species

Downscaling climate projections for site specific modelling raises questions of compounding uncertainty. The reverse approach, using a sensitivity analysis was therefore used to test the resilience of pasture species by location to the incremental changes in climate (Cullen *et al.* 2012). Twenty-five future climate scenarios were developed by scaling the historical climate by increments of 0, 1, 2, 3 and 4ºC (with corresponding changes to atmospheric CO_2 concentrations and relative humidity) and rainfall by +10, 0, –10, –20 and –30%. Little change or higher annual pasture production was simulated at all sites with 1ºC warming. In a pasture containing a C4 native grass in a sub-humid climate annual pasture production increased with further warming, while production was stable or declined in pasture types based on C3 species in temperate environments. At all sites winter production was increased under all warming scenarios with summer and autumn growth being most negatively affected. The results indicate that annual pasture production is resistant to average climatic changes of up to 2ºC warming at the sites modelled. The approach used in this study modelling a resilience surface of a species can be used to test the sensitivity of plants to climatic changes and help identify strategies that may increase resilience of agricultural systems to climate change.

Plant traits for future climates

Biophysical models can also assist in identifying key plant traits and pasture species better adapted to anticipated warmer temperatures and lower rainfall. A further study assessed the effect of increasing root depth, heat tolerance and responsiveness to elevated CO_2 concentrations in perennial ryegrass (Cullen *et al.* 2013). Increased root depth was the most effective single trait influencing pasture growth in a high rainfall cool climate whilst increased heat tolerance was the most effective single trait in a medium and high rainfall temperate climate. When all three traits were increased at the same time the pasture production advantage was greater than the additive effects of changing single traits in all climates.

Greenhouse gas emissions in future climates

A subsequent study was conducted to model the net effect of future climate scenarios on greenhouse gas emissions from dairy and sheep pasture based systems in regions of south-eastern Australia (Eckard and Cullen 2011; Bell *et al.* 2012). While CH_4 emissions largely followed projected changes in stocking rate, as a function of pasture growth, N_2O emissions increased in the future projected climates at all sites (for example from 3.3 and 3.4 kg N_2O-N/ha/y in the baseline to 4.3 and 4.9 kg N_2O-N/ha/y in 2070 at two sites in coastal south eastern Australia). Warmer soil temperatures, coupled with wet but less saturated soils in winter, resulted in more conducive environment for N_2O production during these cooler months, while the potential for N_2O production during drier warmer months remained low. The likelihood of increased N_2O emissions from grazing systems with the progression of climate change emphasizes the need for targeted N_2O abatement options for sustainable livestock production in the future.

Conclusion

The simulations show that grazing systems in the medium-high rainfall zones of temperate and sub-tropical Australia, although moderately impacted by average predicted climate change, will still be viable in 2070. However, future extreme climate events, like drought, fire, flood and heat waves, are likely to have a larger impact on the viability of these pastoral systems. Plant breeding for deeper roots, heat tolerance and CO_2 response should be considered to adapt pastures to predicted changes. The simulations also indicate that a warmer, drier future may lead to higher N_2O losses, emphasizing the need for research on cost-effective mitigation options. Future modelling should focus on quantifying these impacts and explore options for pastoralists to manage both emissions and extreme climate events.

Acknowledgments

This research was supported by the Australian Government Department of Agriculture, Fisheries and Forestry Climate Change Research Program, Dairy Australia and Meat and Livestock Australia.

References

Bell MJ, Eckard RJ, Cullen BR (2012) The effect of future climate scenarios on the balance between productivity and greenhouse gas emissions from sheep grazing systems. *Livestock Science* **147**, 126-138.

Cullen BR, Eckard RJ, Rawnsley RP (2012) Resistance of pasture production to projected climate changes in south-eastern Australia. *Crop and Pasture Science* **63**, 77-86.

Cullen BR, Johnson IR, Eckard RJ, Lodge GM, Walker RG, Rawnsley RP, McCaskill MR (2009) Climate change effects on pasture systems in south-eastern Australia. *Crop and Pasture Science* **60**, 933-942.

Cullen BR, Rawnsley RP, Eckard RJ, Christie KM, Bell MJ (2013) Identifying perennial grass plant traits for future warmer and drier climates. *Crop and Pasture Science* **in review**,

Eckard RJ, Cullen BR (2011) Impacts of future climate scenarios on nitrous oxide emissions from pasture based dairy systems in south eastern Australia. *Animal Feed Science and Technology* **166-167**, 736-748.

Eckard RJ, Grainger CJ, de Klein CAM (2010) Options for the abatement of methane and nitrous oxide from ruminant production – a review. *Livestock Science* **130**, 47–56.

Eckard RJ, Hegarty R, Thomas G (2002) A decision support framework for greenhouse accounting on Australian Dairy farms. Dairy Research and Development Corporation Final Report No. UM10667 Available at http://www.greenhouse.unimelb.edu.au.

Johnson IR, Chapman DF, Snow VO, Eckard RJ, Parsons AJ, Lambert MG, Cullen BR (2008) DairyMod and EcoMod: Biophysical pastoral simulation models for Australia and New Zealand. *Australian Journal of Experimental Agriculture* **48**, 621-631.