Exploring profitable, sustainable livestock businesses in an increasingly variable climate

Cullen, BR[1]; Harrison, MT[2], Mayberry, D[3], Cobon, D[4], Reichelt, N[1], Sinnet, A[1], Christie, KM[2], Bilotto, F[2], An-Vo, D-A[4], Stokes, C[3], Perry, L[5], Davison, T[6]
[1] University of Melbourne; [2] University of Tasmania; [3] CSIRO; [4] University of Southern Queensland; [5]Queensland Department of Agriculture and Fisheries; [6] University of New England

Key words: climate change, adaptation, greenhouse gas emissions, mitigation

Abstract
Livestock production systems will need to change in many regions of the world to meet the dual challenges of adaptation to a changing climate and reducing net greenhouse gas (GHG) emissions. The 'Nexus project' is exploring these options using seven case studies in eastern Australia spanning a range of production systems from semi-arid beef production in northern Australia to mixed beef and sheep production in cool temperate climates of southern Australia. Regional reference groups, made up of 4-6 local farmers and advisers, identified a series of farm systems changes that could be made to meet these challenges. Options were categorised under four themes: feedbase, animal genetics and management, management and technology, and transformational options. More options for adaptation were identified compared to options to mitigate greenhouse gas emission of sequestered carbon. Adaptation options focussed on maximising pasture production in variable climates, and having efficient and flexible animal production systems. A focus on infrastructure for water and feed storage and use was also observed. Options to reduce GHG emissions focussed on reducing feed demand and sequestering carbon in soils and trees, and limited possibilities for feed additives were noted in these pasture-based systems. Further work will explore how combinations of these options will impact production, profit and greenhouse gas emissions from these production systems in current and future climate scenarios.

Introduction
Pasture-based livestock production systems around the world are facing the challenges of adapting to the changing climate and reducing net GHG emissions. In Australia there are emerging pressures from government, industry and the supply chain to reduce net GHGs (Mayberry et al. 2019). Climate change projections indicate warmer temperatures across Australia and changes to rainfall patterns (CSIRO and Bureau of Meteorology 2015). Projections for future rainfall vary regionally, with no consistent trend projected in northern Australia but a reduction in winter and spring season rainfall expected in southern Australia. An increase in the frequency and intensity of extreme climate events (such as heatwaves, drought and extreme rainfall) is also predicted. Meeting these dual challenges will require changes to farm systems, but there is a lack of knowledge about the options available to achieve these aims and how they will impact production and profit of farm businesses.

Options for reducing net GHG emissions include removing unproductive animals from farms, breeding for lower methane, feeding pastures with plant secondary compounds that reduce methane and increase efficiency of production (Eckard et al. 2010), and emerging technologies such as feed additives for example 3-Nitrooxyproponal and *Asparagopsis* (Reisinger et al. 2021). Opportunities for carbon sequestration exist in soils and trees. Adaptation options vary regionally, but include increasing shade and shelter and/or feed additives to deal with this stress, changing the pasture base (e.g. deep rooted or summer-active species), and altering stocking rates and stocking policies (Ghahramani and Moore 2015). The 'Nexus project' in eastern Australia is exploring the opportunities and costs of adaptation, GHG mitigation and carbon sequestration in livestock business in an increasingly variable climate. This paper details initial findings from consultation with producer reference groups on options for adaptation and greenhouse gas mitigation or carbon sequestration in their regions.

Methods
The project established seven case study farms in diverse production regions across eastern Australia ranging from Tasmania to north Queensland (Table 1). The case-studies spanned a climate zone from semi-arid, tropical climates in north Queensland to cool temperate climates in Tasmania and southern Victoria.

A regional reference group made up of 4-6 farmers/consultants/extension staff, has been established around each of the case study farms. These groups have identified a set of priority options that are considered useful in the region. Adaptation and mitigation options were classified under themes of feedbase (improving pasture/forage production), animal genetics and management, management and technology, and options to diversify and grow (encompassing an expansion of the current business and use of alternative markets).

Table 1. Summary of the seven Nexus project case study farms in eastern Australia.

Region	Climate description	Mean (range) annual rainfall (2000-2019, mm)	Production system and livestock enterprise
Julia Creek, North Queensland	Semi-arid to arid, summer dominant rainfall with high variability, extreme temperatures.	474 (224-858)	Extensive grazing of native pastures. Self-replacing *Bos indicus* cross herd, 2,000 adult equivalent (AE)
Moura, Central Queensland	Humid sub-tropical, warm season dominant rainfall	630 (200-1130)	Extensive grazing of native pastures. Self-replacing beef herd, 3,300 AE
Cassilis, northern New South Wales	Temperate, even rainfall distribution, hot summer	600 (322-1050)	Intensive grazing of sown and native pastures. 350 cow self-replacing Angus herd, 3000 self-replacing Merino ewe flock
Violet Town, northern Victoria	Temperate, winter dominant rainfall, hot summer	560 (240-1020)	Intensive grazing of sown pastures. 300 cow self-replacing Angus herd, 3,700 self-replacing composite ewes flock
Tambo Crossing, East Gippsland, Victoria	Temperate, winter dominant rainfall, warm summer	670 (470-880)	Intensive grazing of sown and native pastures. 300 cow self-replacing Angus herd, 1,200 self-replacing composite ewe flock
Stanley, North west Tasmania	Cool temperate, winter dominant rainfall, mild summer	780 (530-1110)	Intensive grazing of sown pastures. 350 cow self-replacing Angus herd, 115 weaners purchased and 155 purchased yearlings/agisted heifers
Campbell Town, Midlands Tasmania	Cool temperate, winter dominant rainfall, mild summer	510 (350-710)	Intensive grazing of sown pastures. 24,750 sheep with self-replacing prime lamb, Merino and super-fine Merino ram flocks

Results and Discussion

The adaptation and GHG mitigation options identified by the regional reference groups are summarised in Table 2. The feedbase adaptation options had a focus on pastures that could grow whenever soil moisture was available in a more variable climate, including increasing soil fertility and greater use of summer active and tropical pastures in regions with appropriate climate. Previous research has indicated these are effective adaptation option in both southern and northern Australia (Cullen et al. 2009; Ghahramani and Moore 2013, 2015; Bell et al. 2013; Ash et al. 2015). Adaptation of animal genetics and management focussed on increasing production (liveweight gain and reproduction) to increase flexibility to respond to variable seasonal conditions, as well as adjusting stock rates (Ghahramani and Moore 2015) and policies (Harrison et al. 2017) to changing pasture growth patterns in southern Australia. For adaptation there was also a focus on infrastructure to store feed to buffer seasonal conditions and to use water efficiently. The dairy industry has previously reported greater feed storage as a response to increased climate variability (Cullen et al. 2021).

The options to reduce net GHG emissions focussed on carbon sequestration from improved pastures or as tree planting either on the existing farm or a separate area (Table 2). Limited options to reduce methane production were identified in pasture-based systems.

Table 2. Summary of the Nexus project regional reference group adaptation, mitigation and sequestration options identified, and mapped to the future farm systems. The region where the option was identified is indicated by: NV (northern Victoria), NSW (northern NSW), EG (East Gippsland), MT (Midlands Tasmania), NWT (northwest Tasmania), CQ (central Queensland) and NQ (north Queensland).

Theme	Options to Adapt to changing climate	Options to reduce net GHG emissions
Feedbase	o Improved soil fertility to grow more pasture and have better drought recovery (NV, EG, MT, NWT) o Use of tropical grasses and legumes (in combination with winter species) (NSW) o Productive and persistent species in changing climate – but lack of options (NV, EG, MT, NWT) o Practices to reduce waterlogging (NWT) o Oversowing legumes (NQ) o Sowing forage crops (CQ) o Managing encroachment of woody weeds (NQ)	o Improved fertiliser, grazing management to increase soil carbon (NSW, EG, NV, MT, NWT) o Sowing legumes to increase LWG & reduce enteric methane (MT, NWT, NQ)
Animal genetics and management	o Stock policies – match lambing time/selling time with changing pasture growth patterns (NV, MT, NWT, EG) o Short term feedlotting (confinement and production) (NSW, EG) o Increased growth rate for earlier turnoff (NV, EG, CQ) o Increased feed conversion efficiency (NV, MT, NWT) o Heat tolerance (NSW, NQ) o High fecundity/reduced lamb & calf wastage/increased weaning rates (NV, EG, NSW, MT, CQ, NQ) o Livestock trading – flexibility of stocking rate and markets (NSW, NV, EG, NQ)	o First mating of heifers as yearlings (NQ) o Reduced mature size of livestock (All) o Feed supplements, additives or vaccines to reduce methane – if it can be delivered to animals grazing pastures (NV, EG, NSW, MT, NWT, NQ)
Management and technology	o Infrastructure – water storage, reticulated systems, hay/silage storage, confinement feeding (NV, EG, NSW) o Remote monitoring and control of feedbase, water points and livestock (NV, NSW, MT, NQ)	o Solar or wind electricity generation (NQ, NV and NSW)
Diversify and grow	o Increased scale, planning for succession (All) o Markets for ecosystems services/natural capital (eg providing clean water) (NSW, MT, NWT) o Increased scale in different climatic regions (NV, NSW)	o Trees on farm (NV, MT, NSW) o Soil carbon markets (NV, NSW, MT, NWT) o Buy a separate block of land just for trees and carbon (NWT)

Some of the options identified in Table 2 may have both adaptation and mitigation benefits. For example, increasing soil carbon levels will sequester carbon but it also improves the water holding capacity and nutrient cycling of soils leading to adaptation benefits (Meyer et al. 2015). Trees on farm can sequester carbon, and also provide shade and shelter for extreme climatic conditions. However, it is important to highlight that these options are not suitable for all production systems and regions, with year-to-year variability in temperature and soil moisture coupled with increased frequency of extreme events limiting the capacity of systems to sequester carbon.

The 'diversify and grow' options (Table 2) focussed on the farm getting larger and sometime expanding into regions with different climate patterns to reduce the climate risk. Exploring alternative markets for soil and tree carbon sequestration, and emerging markets for other ecosystems services was also noted as ways to diversify income away from livestock production.

Conclusions

In general, there were more options to 'adapt' to make better use of changing seasonal conditions and manage variability than there were to reduce net GHG emissions. Many of the adaptation options could be considered as the implementation of current best management practices (e.g. soil fertility, animal genetic gain), but other may require further research and development to be implemented on farm (e.g. oversowing legumes in north Queensland, remote sensing pastures, strategies for managing climate risk). There were limited options for reducing net GHG emissions identified. This reflects the lack of options available, and also uncertainty about how the options could be implemented (e.g. feed additives to reduce methane in pasture-based production systems) and their effectiveness (e.g. strategies to increase soil carbon). Further work will determine the production, profitability and greenhouse gas emissions of livestock farm systems implementing combinations of these options in current and future climate scenarios.

Acknowledgements

Funding for this research was provided by The University of Melbourne, University of Tasmania, CSIRO and Meat & Livestock Australia.

References

Ash A, Hunt L, McDonald C, Scanlan J, Bell L, Cowley R, Watson I, McIvor J, MacLeod N (2015) Boosting the productivity and profitability of northern Australian beef enterprises: Exploring innovation options using simulation modelling and systems analysis. *Agric. Sys.* 139: 50-65.

Bell, M.J., Eckard, R.J., Harrison, M.T., Neal, J.S., Cullen, B.R. 2013. Effect of warming on the productivity of perennial ryegrass and kikuyu pastures in south-eastern Australia. *Crop Past. Sci.* 64: 61-70.

CSIRO and Bureau of Meteorology. 2015. *Climate Change in Australia Information for Australia's Natural Resource Management Regions: Technical Report.* CSIRO and Bureau of Meteorology, Australia.

Cullen, B.R., Johnson, I.R., Eckard, R.J., Lodge, G.M., Walker, R.G., Rawnsley, R.P., McCaskill, M.R. 2009. Climate change effects on pasture systems in south-eastern Australia. *Crop Past. Sci.* 60: 933-942.

Cullen, B.R., Ayre, M., Reichelt, N., Nettle, R.A., Hayman, G., Armstrong, D.P., Beilin, R., Harrison, M.T. 2021. Climate change adaptation for livestock production in southern Australia: transdisciplinary approaches for integrated solutions. *Anim. Front.* 11: 30-39. doi:10.1093/af/vfab046

Eckard, R.J., Grainger, C., de Klein, C.A.M. 2010. Options for the abatement of methane and nitrous oxide from ruminant production: a review. *Livest. Sci.* 130: 47-56.

Ghahramani, A., Moore, A.D. 2013. Climate change and broadacre livestock production across southern Australia. 2. Adaptation options via grassland management. *Crop Past. Sci.* 64: 615–630.

Ghahramani, A, Moore, A.D. 2015. Systemic adaptations to climate change in southern Australian grasslands and livestock: Production, profitability, methane emission and ecosystem function. *Agric. Sys.* 133: 158-166.

Harrison, M.T., Cullen, B.R., Armstrong, D.P. 2017. Management options for Australian dairy farms under climate change: Effects of intensification, adaptation and simplification on pastures, milk production and profitability. *Agric. Sys.* 155, 19-32.

Mayberry, D., Bartlett, H., Moss, J., Davison, T., Herrero, M. 2019. Pathways to carbon neutrality for the Australian red-meat sector. *Agric. Sys.* 175: 13-21.

Meyer, R., Cullen, B.R., Johnson, I.R., Eckard, R.J. 2015. Process based modelling to assess the sequestration and productivity benefits of soil carbon for pasture. *Agric., Eco. Env.* 213: 272-280.

Reisinger, A., Clark, H., Cowie, A.L., Emmet-Booth, J., Gonzalez Fischer, C., Herrero, M., Howden, M., Leahy, S. 2021. How necessary and feasible are reductions of methane emissions from livestock to support stringent temperature goals?. Phil. Trans. R. Soc. A 379: 20200452. https://doi.org/10.1098/rsta.2020.0452