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Estimated effects of climate change on grassland production and legume content across southern Australia

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Introduction

Climate changes caused by anthropogenic increases in greenhouse gases such as CO₂ will affect southern Australia along with the rest of the globe. Dryland pastures supporting extensive beef, sheepmeat and wool production occupy a third of southern Australia's farming zone. These livestock production systems are highly sensitive to climatic variation, because they depend almost entirely on pasture as their source of feed. Given the diversity of current climates, soils and pastures that are found across southern Australia, and the spatial variation in projected climate changes (CSIRO 2007), it can also be expected that the impacts of changing climates on pasture production will differ across space. Annual and perennial forage legumes are an important part of the feedbase across most of southern Australia; experimental research suggests that legumes are likely to be favoured by increasing atmospheric CO₂ concentrations (*e.g.* Clark *et al.* 1997) and it is therefore possible that higher legume content in grasslands might be one positive effect of global climate change. In this study, therefore, we have modelled grassland and livestock production to examine the changes in amount, seasonal distribution and legume content of grass-based pastures at locations across southern Australia under climates projected for 2030, 2050 and 2070.

Methods

The GRAZPLAN grassland simulation models (Donnelly *et al.* 2002) were used to model the responses to changed climate and atmospheric CO₂ concentration of temperate pastures at 25 representative locations across southern Australia (Moore and Ghahramani 2013; Fig. 1). At each

location, one or more representative soils and grassland types were modelled as being grazed by each of 5 livestock enterprises; results in this paper, however, focus on a self-replacing Merino ewe enterprise. Pastures in all representative grazing systems contained at least 1 legume species. Climate projections for 2030, 2050 and 2070 were derived from 4 of the CMIP3 global climate models (CCSM3, ECHAM5/MPI-OM, GFDL-CM2.1 and UKMO-HadGEM1) and were then downscaled to daily weather sequences and used as input to simulations. Each grazing system was therefore simulated under historical climate (1970-99, 350 ppm CO₂) and under the 12 projected climates (451, 532 and 635 ppm CO₂ at 2030, 2050 and 2070). For each location x livestock enterprise x climate combination, stocking rates were varied and an "optimal sustainable" stocking rate was identified that maximised operating profit while keeping the frequency of days with ground cover < 0.7 below location-specific thresholds that were designed to keep erosion risk at acceptable levels.

Results

When averaged over the 25 locations and the 4 GCMs, total ANPP declined from its historical level by 6% at 2030, 3% at 2050 and 9% at 2070 (Table 1). There were, however, substantial differences in modelled ANPP between the climates projected by different GCMs, *e.g.* from a 12% decrease to a 7% increase at 2050. The small recovery in overall ANPP between 2030 and 2050 can be attributed to increasing atmospheric CO₂. Modelled pasture growth increased somewhat in winter but decreased in autumn and spring (Table 1), mostly as a result of a reduction in length of the growing season.

Table 1. Modelled seasonal ANPP (t DM/ha, as a weighted spatial average) and contribution of legumes to total ANPP of southern Australian grasslands under historical (1970-99) climate; projected climates at 2030, 2050 and 2070 (average of 4 GCMs); and under climates projected for 2050 by each of 4 GCMs.

Seasons	1970-99	2030	2050	2070	2050	2050	2050	2050
		Average	Average	Average	CCSM3	ECHAM5	GFDL2.1	HadGEM1
Autumn (Mar-May)	1.0	1.0	1.0	0.9	1.1	1.0	1.0	1.0
Winter (Jun-Aug)	1.9	2.0	2.1	2.1	2.4	2.1	1.9	2.1
Spring (Sep-Nov)	3.3	2.9	3.0	2.8	3.3	2.9	2.6	3.1
Summer (Dec-Feb)	0.6	0.5	0.5	0.5	0.6	0.5	0.6	0.4
Total	6.8	6.4	6.6	6.2	7.3	6.5	6.0	6.6
Legume proportion	0.25	0.39	0.56	0.59	0.58	0.53	0.54	0.59



Figure 1. Spatial variation in climate change impacts projected at 2050 for Merino ewe enterprises at each of 25 locations: (a) relative change in total ANPP; (b) change in the proportion of total ANPP contributed by legumes. Values are averages across 4 GCMs and 30-year simulation runs.

Despite a shift in projected rainfall toward the summer months, overall summer ANPP declined in most projected climates (Table 1). Figure 1(a) shows a strong gradient from the drier, inland locations where ANPP decreased sharply to the wetter locations (especially in south-eastern Australia) where total ANPP at 2050 was projected to increase. Figure 1(b) shows that the proportion of ANPP attributable to legumes increased at most locations, but that the increases were greater at the wetter locations; the increase in legume content was also greater where legume content in the historical simulations was smaller and hence the scope for compositional shift was greater.

Conclusion

Over much of southern Australia, climate change is likely to result in grasslands where shorter growing seasons are partly compensated for by increased livestock production per head due to higher legume content. The balance of risk is toward lower pasture

production. Livestock producers at the dry margin are most vulnerable to climate change.

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