Climate change impact on Western Australian mixed farm systems

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1 Introduction

Primary enterprises are expected to contend with more frequent climate crises, environmental degradation and even climate-related regulatory change (IPCC, 2014). These stressors occur against an existing backdrop of conventional drivers including economic, biophysical, institutional, cultural and political pressures (Marshall *et al.*, 2012). Australia's primary industries have historically operated in a highly variable climate and this has posed significant challenges to production, requiring sound and responsive risk management practices. Climate change, brings with it a number of new challenges not yet accounted for by Australian primary producers, and so understanding the scale of these impacts is of importance in undertsanding the changing nature of agricultural risk in the near future. Western Australia with about 4 million ha of wheat production is a major contributor to the Australian agrifood sector and economy. Like cereal production, pastures in WA play a major role in agricultural enterprises and contribute over $3 billion annually through animal production, improvements to crop rotations and conserved fodder (The Department of Agriculture and Food, 2014). Farming profitably in the Western Australia in recent years has been a challenge due in part to declines in annual rainfall as well as exposure to both heat and cold teperature extremes (McConnell & O'Hare, 2013), although lower production might be still profitable. Climate drives the productivity, profitability and environmental health of these systems as they often have to respond to low and variable rainfall. Here we identify the likely effect of climate change in 2030 on mixed farm systems of the Western Australia across a climate transect in terms of production, profit, and environmental impacts for projected climate scenarios in 2030 relative to the baseline of 1980-1999. This work will give insight for designing strategies to respond to changes in climate such as optimized shift towards more intensive livestock systems, dual-purpose cropping, etc.

2 Materials and Methods

Four (4) representative mixed farm systems were identified across a climate gradient of 369 to 241 mm of growing season rainfall (Apr-Oct). The rationale for using a transect approach was to capture the range of possible future impacts across a range of soil and climate regimes (Fig. 1a). These sites represent complex agro-ecosystems with different soil, farm, livestock management and input intensity regimes. Representative farming systems were developed across this transect through facilitated workshops with stakeholders, and modelled by linking the APSIM soil water, soil nutrient cycling, crop and surface residue simulation models (Holzworth *et al.*, 2014) to the GRAZPLAN pasture and ruminant simulation models (Moore *et al.*, 1997) via an AusFarm interface. Future climate conditions we established by using two greenhouse gas emission scenarios of A1FI and A2 in conjunction with six different global climate models (GCM): ECHAM 5, GFDL 2.1, HADCM3, HADGEM1, MIROC-H, and MRI-GCM232. This range of emission and climate models allowed us to sample across a wide range of possible future climate conditions at 2030 and compare against mean conditions for the period 1980 to 1999. A gross margin (GM) calculation was carried out for each financial year of each modelled farming system (ABARES, 2014). Atmospheric CO_2 concentrations of 449 ppm for 2030 under the A1FI and 444 ppm under A2 were assumed, and for the baseline, we used monthly observed atmospheric CO_2 concentration. C-N flow was made possible by coupling organic matter cycling amongst plants, soils, and animals. In addition to expert knowledge, simulated crop yields were validated through producer's workshops and with regional database of Co-operative Bulk Handling (unpublished) as the best proxy yield data available.

3 Results – Discussion

Averaged over 20 years and for all climate models, projected yields declined for most of the crops × sites combinations in a range between 1.6% (Canola) to 18.2% (Lupin). Wheat yield increased only at Katanning by 6.7% while barley increased by 4.2% in Katanning and 13.7% at Cunderdin when compared to the baseline (Fig. 1b). Simulated crop gross margins were also shown to decline between 4.5% and 21.4%, except for Katanning, where GMs were simulated to increase by 8.9%. Crop gross margins were highly variable over time with greatest variability at Merredin and smallest at Katanning (Fig. 1a). Changes in simulated livestock production were much more modest than for crop production with stock sale weights increasing by up to 1.7% (Fig. 1a). Wool production declined by 3.3% and 2.7% in Cunderdin and Merredin, while increased by 1.7% in Katanning. Changes in crop/livestock production and financial outputs of sites and years were non-linearly related to the changes in growing season (Apr-Oct) rainfall and temperature projected for 2030 (Fig. 1c). Relative changes in crop gross margins declined progressively with a warming in maximum and minimum temperatures and declines in rainfall greater than 11% (Fig. 1c). Some improvements in crop GM's were simulated for modest declines in rainfall (i.e. 1 to 10% declines) which is most likely related to reductions in water-logging and oxygen deficits in root systems on shallow duplex soils common in this area (Fig. 1c). Livestock production/profit tended to be less responsive to changes in climate (Fig. 1b).

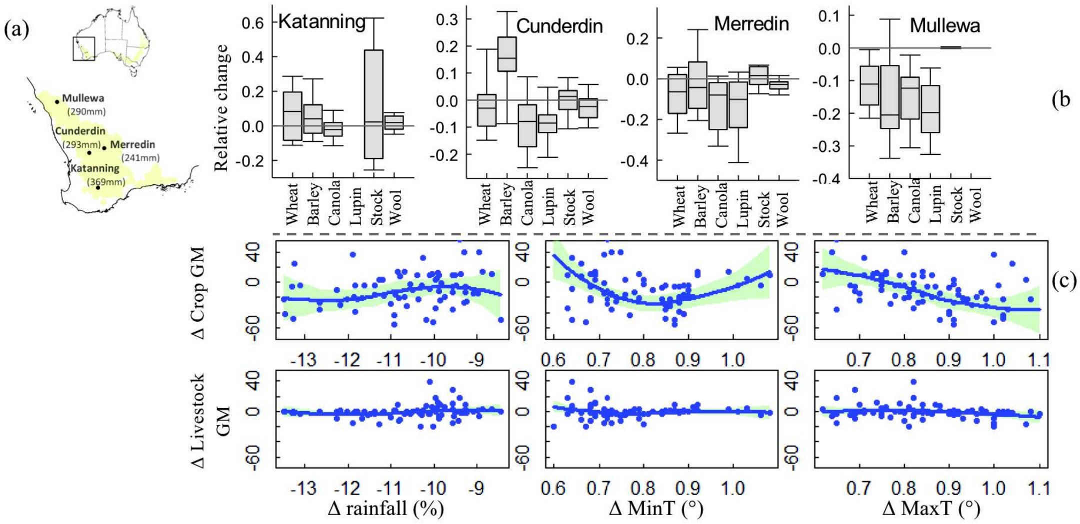

Fig. 1. (a) Location map, (b) Relative changes of production in 2030 compared to the baseline, (c) Relative change of crop and livestock production & gross margin (GM) in 2030 (averaged over all GCMs, sensitivities, and scenarios) compared to the baseline related to the changes in the local climate (Apr-Oct) at each simulated year - the fitted lines are non-parametric regressions; the shaded areas are the 95% confidence intervals.

The fertilization effect from elevated atmospheric CO_2 is one component of the climate change impacts in water-limited environments i.e. the great majority of Australian agriculture (Tubiello *et al.*, 2007). Here the positive effect of the elevated atmospheric CO_2 on crop yield and crop annual net primary productivity (ANPP) declined with climate gradient toward the drier eastern farming areas (Table 1) while the modelled pasture ANPP had less decline (Table 1). Changes in climate generally had less impact on livestock and pasture production (with current stocking rate) in comparison with cropping systems. A main characteristic of the climate change adaptation strategies in dryland mixed-farming system management would see shifts in enterprise mix options, and include shifts toward & away from livestock enterprises depending on how the climate drives the financial optimization of the whole farm system. Overall the livestock gross margin is more likely to be sustained in 2030 in comparison with those of crops (Fig. 1c).

Table 1. Relative changes in ANPP with (+CO_2) and without (-CO_2) fertilisation effect of elevated atmospheric CO_2

	Cunderdin		**Katanning**		**Merredin**		**Mullewa**	
ANPP	+CO_2	-CO_2	+CO_2	-CO_2	+CO_2	-CO_2	+CO_2	-CO_2
Total	-2.8%	-3.6%	+2.3%	-1.2%	-8.5%	-9.2%	-12.9%	-12.8%
Pasture	-2.3%	-16.6%	+2.7%	-4.8%	-8.6%	-16.4%	-	-
Crop	-7.1	-2.4%	+4.5%	+1.4%	-6.6%	-8.7%	-12.9%	-12.8%

4 Conclusions

The current production and profitability of whole mixed farm systems in Western Australia appears to be unsustainable around the drier margins in 2030. The cropping component of mixed-farm systems is more sensitive to climate change than the livestock component, and an increase in the proportion of livestock in the farming system in these regions may enhance current and future resilience to climate change.

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