Shire scale impacts and adaptation options for Australian cereal crops affected by climate change

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Abstract

The sustainability of rural industries is threatened by temperature and rainfall changes associated with anthropogenic and natural climate change (CC). Recent research indicates that most parts of Australia are likely to become warmer and drier. Although there are considerable uncertainties about the magnitude of the changes, there is less uncertainty about their direction. Thus information on likely crop responses to potential future CC scenarios becomes essential to understand regional sensitivities and increase the preparedness of our major primary industries. Using a shire scale modelling approach, we investigated the likely impact of climate change on wheat production across the main winter crop producing shires of Australia. Specifically, we determined the spatial impact of CC on shire scale wheat production for 2020 and 2050 for both “low” and ‘high” emission scenarios in the absence of any adaptive measures. Results suggested an overall slight decrease in median crop yield by 2020, although some regions (e.g. southern parts of NSW) showed limited impact on simulated yield. Yields are expected to decline further by 2050 and show a similar spatial pattern to 2020 effects across Australia. We discuss the possible offsetting effects of CO2 fertilisation and potential effects of adaptations in crop maturity and planting time for the grains industry. A regional approach like that outlined here will be essential to develop the capacity that industry and policy makers require to better and pro-actively respond to the environmental, social and economic dimensions of climate change.

Key Words

Climate change, agro-climatic model, simulated shire scale yield, maturity, adaptation

Introduction

Australia is exposed to some of the world’s most variable climates with consequent impacts on the sustainability of most agro-ecosystems. For example, the 2002 El Ni?o related drought alone decreased the gross domestic product (GDP) by 0.75 percentage points. Climate change is expected to further increase the exposure of rural industries to drought and extreme climatic conditions, e.g. recent research has suggested that El Ni?o like events may increase in magnitude and frequency (IPCC 2007). Furthermore, an increasing number of Global Circulation Models (GCM) indicated that Australia, and in particular eastern Australia, is likely to get hotter and drier as climate changes in response to increased atmospheric CO_2 (IPCC 2001; IPCC 2007). Although there are considerable uncertainties about the magnitude of the changes, information on potential scenarios of how climate change might affect crop yields is essential for the grain industry and government prepare for change.

The aim of this study was to determine the shire scale impacts and potential adaptation options for Australian wheat producing shires as affected by likely climate change scenarios. In our work we identified Australian wheat regions (e.g. shires) that are most vulnerable to present climate trends and expected climate change. Possible adaptation options are discussed.

Methodology

Crop modelling

The modelling approach was based on a regional commodity forecasting system (Potgieter, Hammer et al. 2002; Potgieter, Everingham et al. 2003) that incorporates a shire-based simulation capability for wheat. The modelling was applied to wheat yield production for the 245 cropping shires across Australia. The model uses daily rainfall and temperature from the beginning of the fallow prior to the crop through to crop maturity. A simple, soil water balance is maintained and the degree of water stress experienced by the crop calculated and used to predict shire scale wheat yield. Benchmark yield distributions were derived from simulations using historical climate data (1901-2007). Yield distributions were then simulated (using the 107 year time series) with adjustments to the climate data to account for low and high CO_2 emission CC scenarios for 2020 and 2050 climates, relative to a reference climate period i.e. 1961 to 1990.

Climate data

Monthly patterns of rainfall and temperature change for CC scenarios were obtained from the CSIRO Cubic Conformal model (CCAM) and used in conjunction with global warming estimates for the years 2020 and 2050 derived for two different emission levels i.e. A1T (high) and B1 (low) (Figure 1). The resulting changes in monthly temperature and rainfall were then used to modify historical daily climate data applying a scaling procedure (Whetton, Katzfey et al. 2001). Potential evapotranspiration for the projected CC scenarios was calculated based on Hamon’s equation (Xu and Singh 2001).

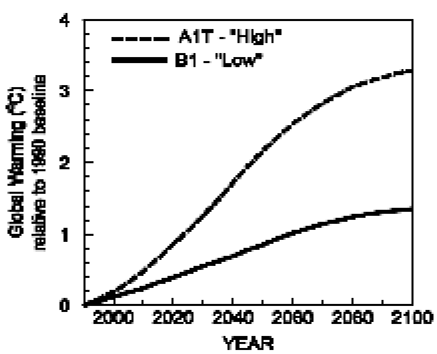

Figure 1: Annual global warming values expressed relative to the 1990 baseline for the ‘high’ and ‘low’ emission scenarios (after IPCC 2001).

Results and discussion

In general, wheat yields were only slightly reduced by the evaluated scenarios, i.e. high and low emissions, year 2020 and 2050. The median percentage yield change ranged from -1% to 0% and -5% to 0% for 2020 and 2050, respectively (Table 1). This suggested that the impact projected rainfall and temperature changes for 2020 will be small, while the impact is likely to be slightly more severe for 2050 particularly in North Eastern Australia (Figure 2). Large parts of NSW (southern) and WA (southern) showed less sensitivity in median yield to future climate projections i.e. median percentage yield changes of -2% and -1% for the 2050 high emission rate, respectively. There is however spatial heterogeneity in the degree of the responses that diminishes when the values are aggregated to state level (Table 1).

The lower effect on yield than on rainfall was likely related to the slightly enhanced development rate associated with the expected increase in temperature, i.e. crops reached flowering and maturity earlier in the growing season probably escaping some of the effects of terminal water shortages. Flowering was reached between 3% to 7% and 7% to 15% quicker for 2020 and 2050, respectively, across all states and emission rates (Table 1). The impact on fallow rainfall was less severe than the impact on in-crop rainfall, which concurs with the average Australian projection that CC will impact more severely on winter and spring rather than summer rainfall (IPCC 2007). The timing of rainfall and the amount of rainfall are the two important factors that determine final wheat yields. This further contributed in variability of CC impact footprint (Figure 2).

Through simple adaptive management options (e.g. planting dates and cultivar maturity) this level of impact footprint of CC on wheat can most likely be alleviated. Previous studies (Woodruff and Tonks 1983; Hammer 1987; Howden, Meinke et al. 2003; Meinke, Howden et al. 2006) have shown that combinations of planting date and crop maturity can be chosen to minimise chance of frost at flowering while making most effective use of available water. The diminishing extent of the frost window associated with increasing

Table 1: Simulated median % change in days to flowering (DTF), fallow rainfall, in-crop rainfall and yield, for 2020 and 2050 CC scenarios.

NSW	2020 Low	2020 High	2050 Low	2050 High
DTF	-3	-6	-6	-15
FallowRain	-1	-3	-3	-8
InCropRain	-2	-6	-6	-14
Yield	0	0	0	-2
QLD				
DTF	-3	-6	-6	-14
FallowRain	-2	-4	-4	-10
InCropRain	-3	-8	-8	-15
Yield	0	-1	-1	-5
SA				
DTF	-3	-6	-6	-14
FallowRain	-1	-2	-2	-5
InCropRain	-3	-6	-6	-11
Yield	0	0	0	-3
VIC				
DTF	-3	-6	-6	-14
FallowRain	-1	-2	-2	-5
InCropRain	-3	-5	-5	-15
Yield	0	-1	-1	-2
WA				
DTF	-3	-7	-7	-15
FallowRain	0	-1	-1	-3
InCropRain	-2	-6	-6	-12
Yield	0	0	0	-1

Percentages greater than 5% are indicated in bold.

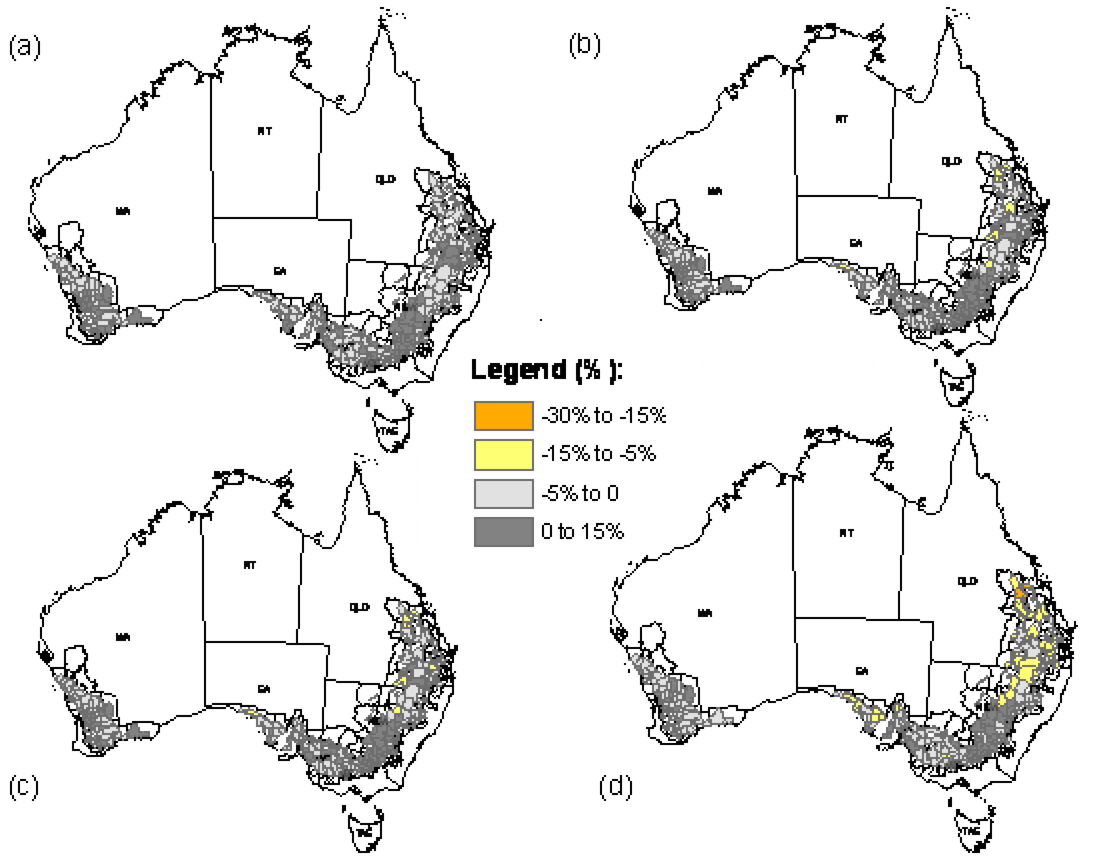

Figure 21: Percentage shire yield change for low and high CO_2 emission rates for 2020 (a – low, b – high) and 2050 (c – low, d – high).

temperature (Stone, Hammer et al. 1996) provides opportunities for yield gain as flowering can be timed earlier. Though, a more detailed analysis would be needed to determine optimal adaptation practices (planting date, cultivar choice, and crop choice) at paddock and farm levels. In addition, no CO_2 fertilisation effects were considered in this study. An increase in CO_2 levels will have a generally positive effect particularly in Australian water limited environments.

Although this analysis is preliminary, the knowledge of the impact of likely CC on the grains industry at temporal as well as spatial scales will not only assist industry in their long-term decision-making processes but is also likely to stimulate debate on future adaptation options and assist in the adoption of such strategies across disciplines and industries. This approach can furthermore effectively contribute in addressing some of the barriers (e.g. scales, markets, risks) (Howden, Soussana et al. 2007) that prevent the establishment of effective adaptation policies. Further research is required to link this regional approach and outputs to bio-economic models (Kokic, Nelson et al. 2007), which will assist in determining the economic and social vulnerability and/or resilience of industry under likely future climate change scenarios such as 2020 and 2050.

Conclusion

In the absence of adaptation or consideration of CO_2 fertilisation effects, impacts of climate change on winter crop yields are likely to be small by 2020 and slightly more severe by 2050. The challenge for industry is to anticipate these impacts and develop regional adaptation strategies to minimise effects or to capture potential advantages. More detailed simulation studies are needed to investigate most suitable adaptation options in each of the regions.

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