Impact of climate change on wheat production and profitability in Queensland

Andrew F. Zull[1], Dhananjay K. Singh, Richard A. Routley, and Scott Geddes

[1]Crop and Food Science, Department of Agriculture, Fisheries and Forestry Queensland, Toowoomba 4350, www.deedi.qld.gov.au
Email andrew.zull@dpi.qld.gov.au

Abstract
The key driver of climate change is an increasing concentration of atmospheric CO_2, which is linked to rising temperatures and changes in rainfall patterns. Many studies have highlighted the effect of rising temperature on agricultural production, but fewer studies have reported of the combined impacts of increasing CO_2 concentration, increasing temperature, and changes in rainfall. This study, while using APSIM (a crop production model with inbuilt 'climate change' module for wheat), compares simulations of wheat production under current (1950-2010), and future climate scenarios, in five key regional cropping centres in southern Queensland (Emerald, Dalby, Roma, St George, and Goondiwindi). The atmospheric CO_2 concentration for the current climate was set at 350 ppm (the average value for the period 1950-2010) along with the current levels of rainfall, and minimum and maximum temperatures. The future climate scenarios included atmospheric CO_2 at 550 ppm, and 2 and 3 °C respective increases in the maximum and minimum temperatures compared with the current levels. Due to uncertainty of changes in future rainfall, three levels (current, -10% or +10%) of rainfall for future scenarios were used. Future climate scenarios tended to increase wheat production and gross margins. In St George (Qld), for example, with increased CO_2 and temperatures the average crop yield increased by 8%, crop frequency increased by 4% and average annual gross margins improved by almost 50%, holding all prices constant. Even with a 10% decrease in rainfall, crop production and economic returns tended to be better than the current climatic conditions. This indicates significant impacts of CO_2 fertilisation on wheat production in Queensland. Results from other regional centres are also compared and discussed.

Key Words
Bioeconomic, wheat, climate change, risk, nitrification

Introduction
Growing a winter wheat crop in summer-dominant rainfall regions of Queensland has always been challenging due to unpredictable in-crop rainfall, frosts, and dry finish. Developing risk management strategies under existing climate variability has been further challenged by looming and eminent "climate change" scenarios. In particular, predictions of increased temperature and drought frequency are concerning to the growers.

There is a need to get a better understanding of the biophysical impacts and economic implications of climate change for dryland crop production systems in southern Queensland. This is important to better understand and develop adaptation strategies to future climatic environments. As in-crop rainfall is often unpredictable, it is a primary driver of risk to dryland agricultural production systems (CSIRO, 2007). To help mitigate some of this climatic risk requires the capturing of soil water during fallow periods. Fallow management such as reduced tillage, controlled traffic farming, and chemical weed control are vital in these regions to increase soil moisture, and soil nitrification to improve dryland crop productivity and profitability (Thomas et al., 2007).

To estimate the risk of cropping systems with respect to climatic conditions we used simulation models based on past and possible future climatic conditions of various key cropping regions in southern Queensland. Model outputs included predicted wheat yields and variability (risk), as well as subsequent economic returns. The primary difference in measuring yield and economic returns is that the former does not explicitly consider the value of time. Often crop yields are measured as the quantity of grain produced per ha per crop, i.e. 2.2 t/ha. However, it may require a long fallow (two or more years) to achieve the crop, but this is not captured in the standard measure of crop yield. From an economic perspective, most returns are measured with respect to time. The cost of a long fallow is not only the cost of fallow management, but more importantly it includes the opportunity cost of not utilising a resource. Therefore, if it takes two years to produce a 2.2 t/ha then income should be based on 1.1 t/ha/year. Moreover, considering only crop yield in one year does not necessarily reflect production profitability, as a farmer with a lower crop yields but higher cropping frequency may be more profitable over time.

Methods

The focus of this study was to evaluate the effects of climate, both now and in the future, and the economic feasibility of wheat production in five key southern Queensland regions: Emerald, Dalby, Roma, St George, and Goondiwindi (Figure 1). The APSIM (v7.3) cropping system simulation model (Keating et al., 2003) was used to generate current and future wheat crop yields for the five key regional centres. These different regions not only have different climatic condition, but also tend to have different soil types and plant-available water capacities (PAWC).

Figure 1. Location of sites, which represents the five key regional cropping centres in southern Queensland

The atmospheric CO_2 concentration for the current climate was set at 350 ppm (the average value for the period 1950-2010) along with the current levels of rainfall, and minimum and maximum temperatures. The future climate scenarios included a CO_2 concentration of 550 ppm, and 2 and 3 °C increases in maximum and minimum temperatures, respectively, than the current levels (as widely projected for 2050-2070 from various Global Climate Models). Due to an uncertainty of future rainfall, three levels of rainfall (current, -10% or +10%) were used. These changes in temperature and rainfall were made to the current met files (downloaded from SILO, Longpaddock) on a daily basis for each regional centre. However, the future changes in temperature and rainfall in 2050 have also been generated from various Global Climate Models, also presented in this conference (Singh and Routley, 2012). Simulation for each scenario for wheat production was run from 1950-2010. Sowing window was between 1 May and 10 July for Dalby, Roma, St George and Goondiwindi, whereas for Emerald it was 1 May to 30 June. Minimum allowable soil water for planting was 100 mm for all centres, except for Roma with 70 mm due to less deep soil profile. Rule for planting was a minimum of 20 mm of rain over 5 days. ‘Hartog’ wheat cultivar was used with a planting density of100 plants/m^2, a row spacing of 250 mm, and sowing depth of 30 mm. Fertiliser was applied at each sowing. Parameterisations of CO_2, soil type, PAWC and N fertiliser are given in the Table 1.

Table 1. Parameterisation of CO_2, soil type, PAWC and N fertiliser for 5 regional centres in Queensland.

Region - scenario	Code	ApSoil (soil type)	Soil PAWC (mm)	N kg/ha/crop
Emerald – CO_2 350 ppm	E350	Black vertosol (Banana 046)	150	75
Emerald – CO_2 550 ppm	E550	Black vertosol (Banana 046)	150	75
Dalby – CO_2 350 ppm	D350	Black vertosol (Dalby 027)	250	120
Dalby – CO_2 550 ppm	D550	Black vertosol (Dalby 027)	250	120
Roma – CO_2 350 ppm	R350	Grey vertosol (Roma 851)	90	60
Roma – CO_2 550 ppm	R550	Grey vertosol (Roma 851)	90	60
St George – CO_2 350 ppm	SG350	Grey vertosol (Nindigully 040)	190	100
St George – CO_2 550 ppm	SG550	Grey vertosol (Nindigully 040)	190	100
Goondiwindi – CO_2 350 ppm	G350	Grey vertosol (Goondi. 219)	175	75
Goondiwindi – CO_2 550 ppm	G550	Grey vertosol (Goondi. 219)	175	75

Crop production costs

All costs and wheat prices were set at current market values to allow for a comparison of production systems independent of inflation and other market forces. Short and long fallow operating costs, such as chemical weed control, were set at $110/ha and $178/ha, respectively. Planting (including seed costs), in-crop operations, and harvesting costs were set at $264/ha. Price for fertiliser (N) was $1.05/kg. Wheat quality/grade was assumed to be homogenous, with a market price of $258/tonne.

Results

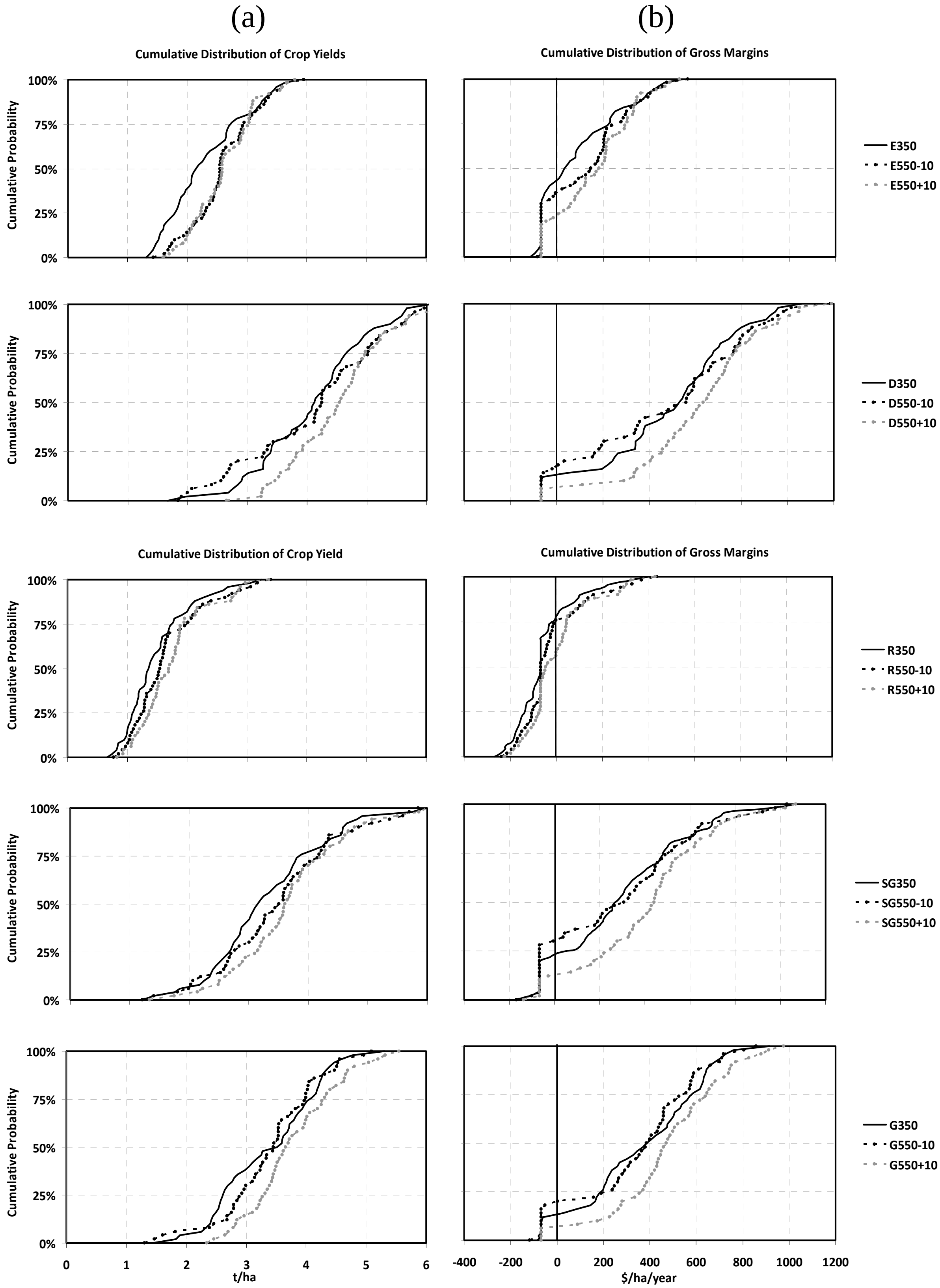

Figure 2. The cumulative distributions of (a) yields (t/ha) and (b) gross margins ($/ha/year) for wheat production for current (CO_2 at 350 ppm) climatic conditions and future scenarios (for 2050-70 of CO_2 = 550 ppm) with 2 and 3 °C increases in maximum and minimum temperatures, respectively, and +/- 10% changes in rainfall for Emerald (E), Dalby (D), Roma (R), St George (SG), and Goondiwindi (G).

The predicted yields and gross margins of wheat production in southern Queensland tended to increase with increased levels of CO_2 (**Error! Reference source not found.**). For readability purposes, future production results with CO_2 of 550 ppm are given with +/- 10% rainfall; "no change in rainfall" will lie between these results. For the expected (deterministic) results of average yield, cropping frequency (percentage of years a hectare is cropped), total yield production, average and expected gross margins see Table 2.

Table 2. Economic effects of increased CO_2, minimum and maximum temperatures (rainfall was kept at the current level) on wheat crop production in southern Queensland regions.

Region /scenario	Average yield t/ha	Cropping rate	Total yield t/ha (60 years)	Total income (60 years)	Total variable cost (60 years)	Average GM/year	Expected GM/year (median)
E350	2.31	75%	104	$26,810	$21,431	$90	$31
E550	2.60	75%	117	$30,180	$21,431	$146	$160
D350	4.07	88%	216	$55,605	$27,033	$476	$531
D550	4.41	88%	234	$60,258	$27,033	$554	$608
R350	1.50	80%	72	$18,612	$21,837	-$54	-$67
R550	1.71	82%	84	$21,652	$22,208	-$9	-$55
SG350	3.32	82%	162	$41,889	$24,266	$294	$267
SG550	3.59	85%	183	$47,200	$25,093	$368	$393
G350	3.39	88%	180	$46,396	$24,529	$364	$386
G550	3.64	88%	193	$49,782	$24,529	$421	$443

Conclusion

Increasing atmospheric CO_2 from 350 to 550 ppm, and 2 and 3 °C increases in maximum and minimum temperatures respectively (to represent 2050-2070 predicted climatic environments) increased the average yield per crop in all regions (Table 2). Yield increases were also observed with 10% less rainfall (Fig. 2), which appears to be due to a significant CO_2 fertilisation effect on wheat (Rawson 1995). There was also an increase of crop frequency in Roma and St George. As a result the expected (median) gross margins in all regions also improved, however cropping in Roma based on current cost of production tended to be unviable in most years (**Error! Reference source not found.** and Table 2). In all regions there would be years with negative gross margins, for example in Goondiwindi there was a 13% probability of having negative returns. With increased levels of CO_2, temperature, and +10% rainfalls, the probability of negative gross margins decreased to 7%, for this region. Under similar CO_2 levels and temperatures, but -10% rainfalls, there is a 20% probability of a negative gross margin. In **Error! Reference source not found.**(b) the vertical responses at -$178 represents the years with no crop production. Changes in climate will undoubtedly affect farm management practices and decisions; however there may be opportunities to exploit these changes for economic benefits.

References

BoM (2012) SILO Data Drill System. *B*ureau of Meteorology Australia, (http://www.longpaddock.qld.gov.au/silo/).

CSIRO (2007) Climate Change in Australia, technical report.

Keating, B. A., Carberry, P. S., Hammer, G. L., Probert, M. E., Robertson, M. J., Holzworth, D., Huth, N. I., Hargreaves, J. N. G., Meinke, H., Hochman, Z., McLean, G., Verburg, K., Snow, V., Dimes, J. P., Silburn, M., Wang, E., Brown, S., Bristow, K. L., Asseng, S., Chapman, S., McCown, R. L., Freebairn, D. M. & Smith, C. J. (2003) An overview of APSIM, a model designed for farming systems simulation. European Journal of Agronomy, 18, 267-288.

Rawson, H.M. (1995) Yield responses of two wheat genotypes to carbon dioxide and temperature in field studies using temperature gradient tunnels. Australian Journal of Plant Physiology 22, 23–32.

Singh, D. & Routley, R. (2012) Scenarious of Future Climate at the Sub-Regional Scale in Queensland's Mixed Farming Zones. Proceedings of 16th Australian Agronomy Conference. University of New England, NSW, Australia.

Thomas, G. A., Titmarsh, G. W., Freebairn, D. M. & Radford, B. J. (2007) No-tillage and conservation farming practices in grain growing areas of Queensland - a review of 40 years of development. *A*ustralian Journal of Experimental Agriculture, 47, 887-898.