## Impact of climate change on wheat yields in Western Australia. Will wheat production be more risky in the future?

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### Abstract

Future climate is likely to be warmer and drier in the wheatbelt of Western Australia. The aim of this paper was to quantify the impact of climate change on the wheat production in the wheatbelt of WA. Downscaled climate data from the CCAM Global Climate Model (GCM) was used as input into the APSIM-Wheat crop simulation model, in order to evaluate the wheat yields under future climate in a range of representative locations and soil types of the Western Australian wheatbelt. Simulations showed future yields lower than current yields in most locations and soil types. Yield reductions were greater on clay soils than on sandy or duplex soils. Future yields increased in some high rainfall locations due to reduction in the level of waterlogging. The results showed that climate change impacts, without allowing for adaptation strategies, would lead to an increase in the frequency of low yields and a decrease in the frequency of high yielding years for most of the Western Australian wheatbelt.

### Key Words

Climate model, APSIM-Wheat model, yield

### Introduction

Climate change projections for the mid 21st century for southern WA indicate an increase in temperatures, a decrease in rainfall and higher $CO_2$ concentrations from current conditions. These changes could have adverse impacts on some agricultural systems, but they may also offer new opportunities (i.e. in areas where the risk of waterlogging may be reduced). The aim of this paper is to quantify the impact of climate change on the risk of wheat production in the wheatbelt of WA. Downscaled climate data from a Global Climate Model (GCM) was used as input into a crop simulation model, in order to evaluate the wheat yields under future climate in a range of representative locations and soil types of the West Australian wheatbelt.

### Material and Methods

Downscaled climate data from the Cubic Conformic Atmospheric Model (CCAM), which is a higher-resolution version of the CSIRO Mk3 GCM, was used as an input into the crop simulation model APSIM-Wheat (v. 4.1) (Keating et al. 2003), which has been well validated for WA conditions. The APSIM-Wheat model was run with current and future daily climate data to simulate grain yield.

The APSIM-Wheat model simulates daily values of root growth, biomass and grain yield based on information on daily weather, soil type and crop management. It calculates the water-limited potential yield of the site, that is, the yield not limited by weeds, pests, and diseases, but limited only by temperature, solar radiation, water, and nitrogen supply at that site.

The wheat model was run with two sets of climate data for 30 year periods: 1) current simulated climate for the period 1975-2004 with current level of $CO_2$ (350 ppm) and 2) future simulated climate for the period 2035-2064 with expected $CO_2$ level in the mid 21st century (440 ppm). Simulations were run for 27 locations across the WA wheatbelt. Three representative soil types, a duplex (Plant-available water (PAW) = 86 mm), a clay (PAW=116 mm) and a sand (PAW = 55 mm) soils were used for the simulations. Waterlogging effects on crop growth and yield were accounted for on the duplex soil. Simulations were performed for periods of 30 years assuming the soil was dry at 1st January each year. Sowing time was controlled by a sowing rule. Every year sowing occurred in the first sowing opportunity between 25th April and 31st July. A long season cultivar was sown if sowing occurred before 20th May, a medium season cultivar was sown between 21st May and 9th June, and a short season cultivar was sown after that date.

These runs were devised to improve our understanding of the nature of the season by soil type by location responses to future climate. Simulations for both current and future periods were run assuming present technology, current varieties and current agronomy packages.

**Results**

The downscaled climate data used in this study showed annual rainfall reductions of 5 to 10% for the future period studied across all locations, with greatest rainfall decrease in the April-June period and a small increase in summer rainfall (Farre and Foster, 2007).

Simulation results showed future yield decline in most locations (Fig. 1). The yield decline was due to lower rainfall and higher temperatures, which caused shorter growth duration and more water deficit in most locations. The lower rainfall in autumn caused delayed sowing, which caused a reduction in growth duration and increased chance of a more severe water deficit during grain filling. In most locations, the positive effect of increased $CO_2$ levels was more than offset by the negative effect of lower rainfall, delayed sowing and increased temperatures. Among soil types, yield reductions were greater on the clay soil than on the sandy or duplex soils, because clay soils hold more water in the topsoil and therefore lose more water to evaporation than lighter soils. The yield increase in some high and medium rainfall locations was due to the positive effect of increased $CO_2$ levels and reduction of waterlogging effects.

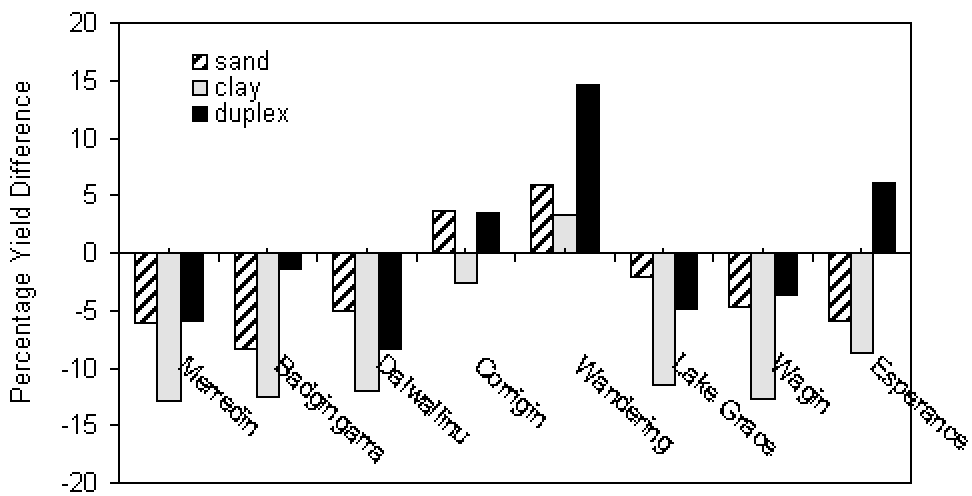


**Figure 2. Impact of future climate on yield expressed as percentage yield difference between future and current yields for 8 locations and 3 soil types. Simulated climate obtained from the CSIRO CCAM model. Simulated yields from APSIM-Wheat model.**

Simulation results showed future yield decline for most of the wheatbelt. Without taking into account the possible effect of changes in technology, varieties and other adaptation strategies, and assuming clay soil at all locations, simulated average yields were lower at most locations (Fig. 2). However, future yields could be higher in high rainfall regions and waterlogging prone soils, where the decrease in rainfall would mean a reduction in waterlogging.

Results showed differences between soil types, with heavier clay soils experiencing greater yield penalties in the future, compared with light textured soils. The largest yield decline, found in Mullewa, was 24 % on clay soil and 17% on lighter duplex soil. The largest yield increase, found in Wandering, was 14% on duplex soil and 7 % on clay.

Simulations results showed an effect of climate change on yield distribution. Most locations in the low and medium rainfall zones showed an increase in the frequency of years with low or very low yields and a decrease in the frequency of high yielding years, making cropping a more risky business than currently in those locations (Fig. 3). For example, in Merredin, in the low rainfall zone, and across soil types, we found an increase in the frequency of years with yield under 1 t/ha from 2 out of 10 years currently to 3 out of 10 years by mid 21[st] century. In Wandering, a high rainfall location, and on a waterlogging duplex soil, simulations showed a decrease in the frequency of low yielding years and an increase in the frequency of high yielding years.

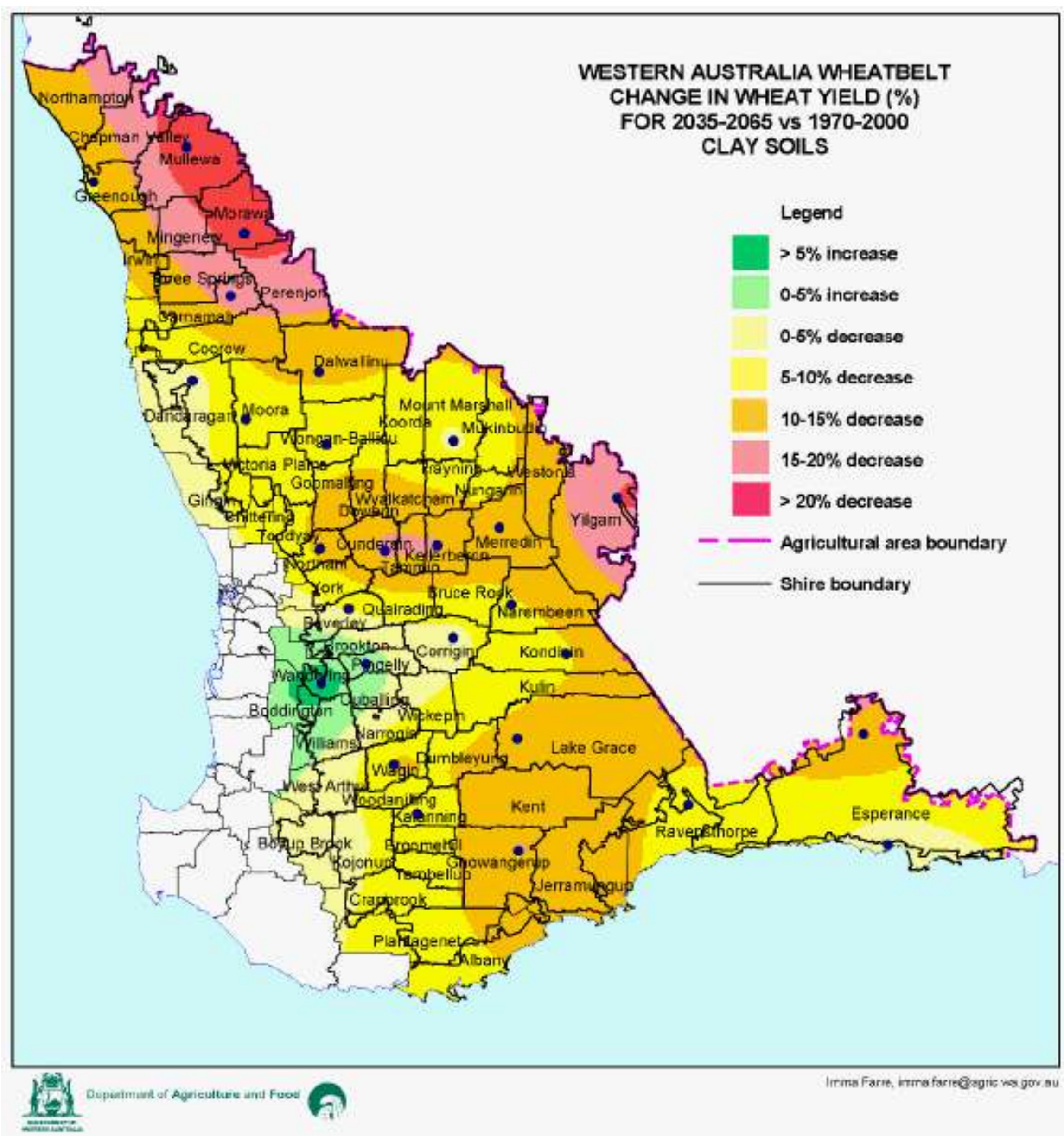

**Fig. 2. Change in simulated wheat yield (%) for the period 2035-2064 compared to the period 1975-2004 if we assume a clay soil in all 27 locations.**

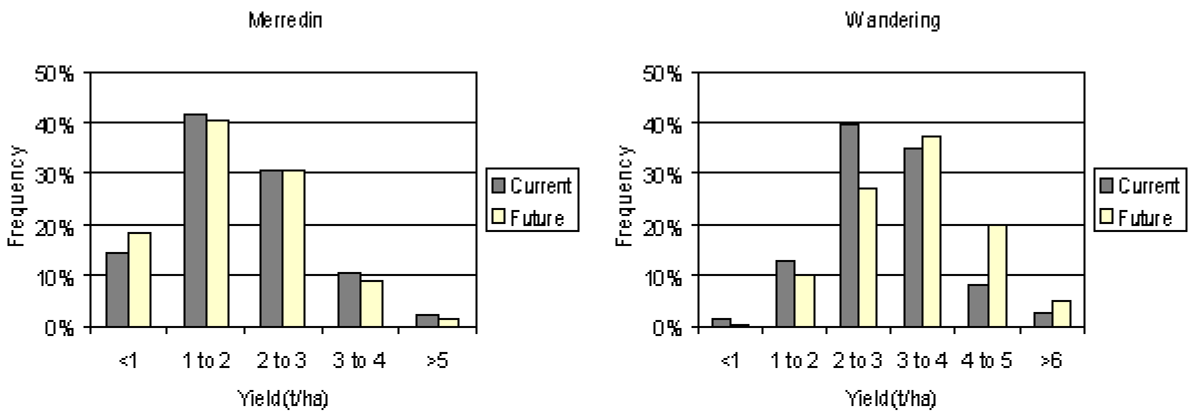


**Fig. 3. Frequency distribution of yields for the period 1975-2004 (current) (dark bar) and 2035-2064 (future) (light bar) for Merredin (low rainfall) and Wandering (high rainfall). Simulated yields for a duplex soil.**

There were complex interactions between climate change and cropping systems in the simulations. Effects of higher temperatures, elevated $CO_2$ and decreased rainfall differed between soil types and locations. Table 1 shows the probability of getting a low or a high yield for different soil types and two contrasting locations in the low and in the high rainfall zone. In both locations, the probability of a low yielding year is lower in the clay soil than in the duplex or sand soil. In Merredin, in all soil types, but to a different extent, the probability of low yielding years increases and the probability of high yielding years decreases in the future. In Wandering, the probability of high yielding years increases in the future.

**Table 1. Probability (%) of getting certain yield (t/ha) for the period 1975-2004 (current) and 2035-2064 (future) for a clay, duplex and sand soil in Merredin and Wandering.**

| | Yield (t/ha) | Clay | | Duplex | | Sand | |
|---|---|---|---|---|---|---|---|
| | | Current | Future | Current | Future | Current | Future |
| Merredin | <1 | 36 | 42 | 15 | 19 | 20 | 23 |
| | 1-2 | 39 | 39 | 44 | 41 | 62 | 59 |
| | >2 | 25 | 19 | 41 | 40 | 18 | 18 |
| Wandering | <2 | 2 | 1 | 14 | 11 | 54 | 29 |
| | 2-3 | 36 | 22 | 40 | 27 | 37 | 49 |

| | | | | | | |
|---|---|---|---|---|---|---|
| >3 | 62 | 77 | 46 | 62 | 9 | 22 |

## Conclusion

Future climate, without considering changes in technology, varieties and other adaptation strategies, would lead to a decline in wheat yields for most of the wheatbelt. However, future yields could be better in high rainfall locations and waterlogging-prone soils. Heavier soil types are more vulnerable to climate change than light textured soils. The frequency of low yielding years is likely to increase in low and medium rainfall locations. Wheat cropping on low rainfall locations and heavy soils would be more risky than under the current climate.

## References


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