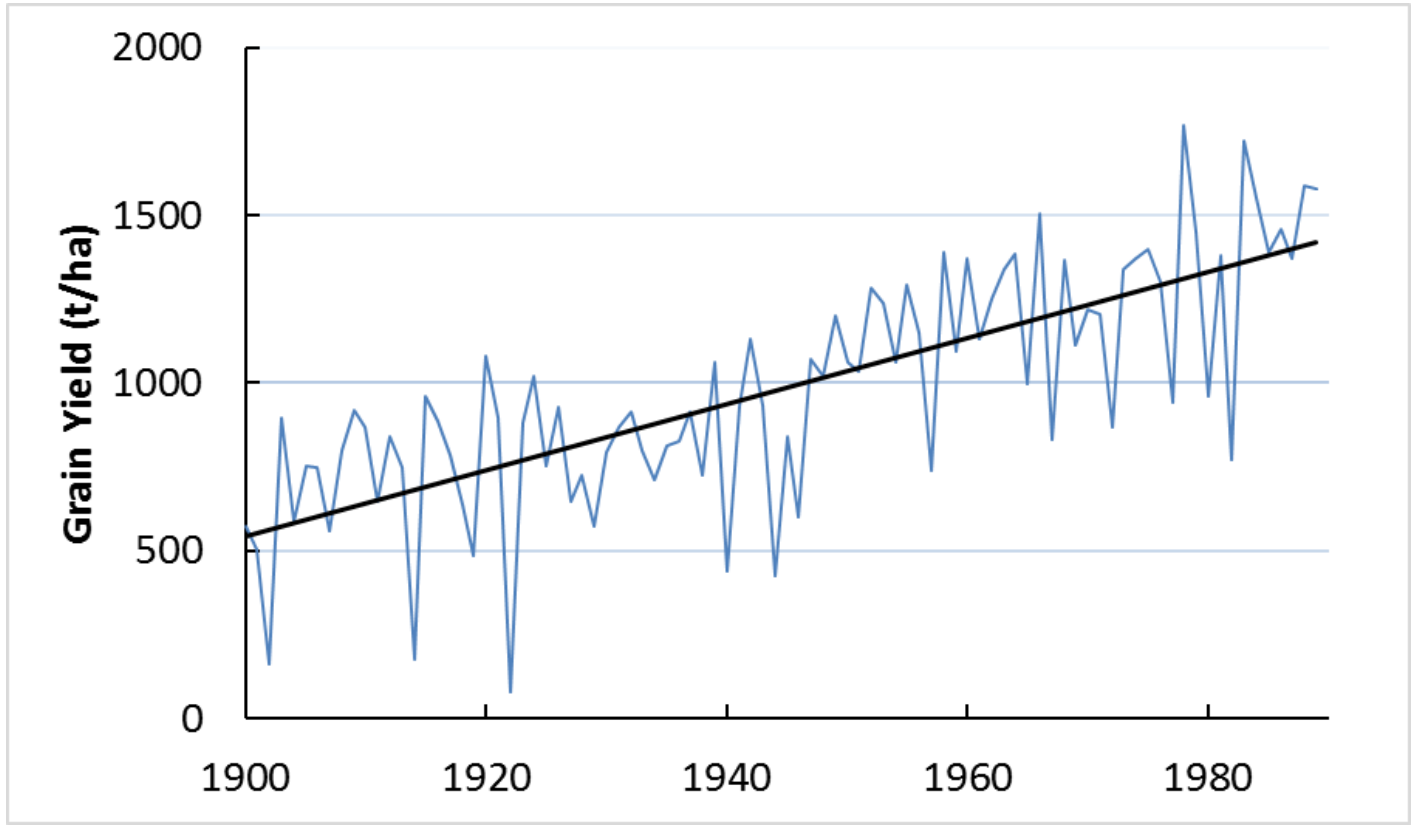
Climate trends and stalled wheat yields:
what are the links and what adaptations are feasible?

Zvi Hochman

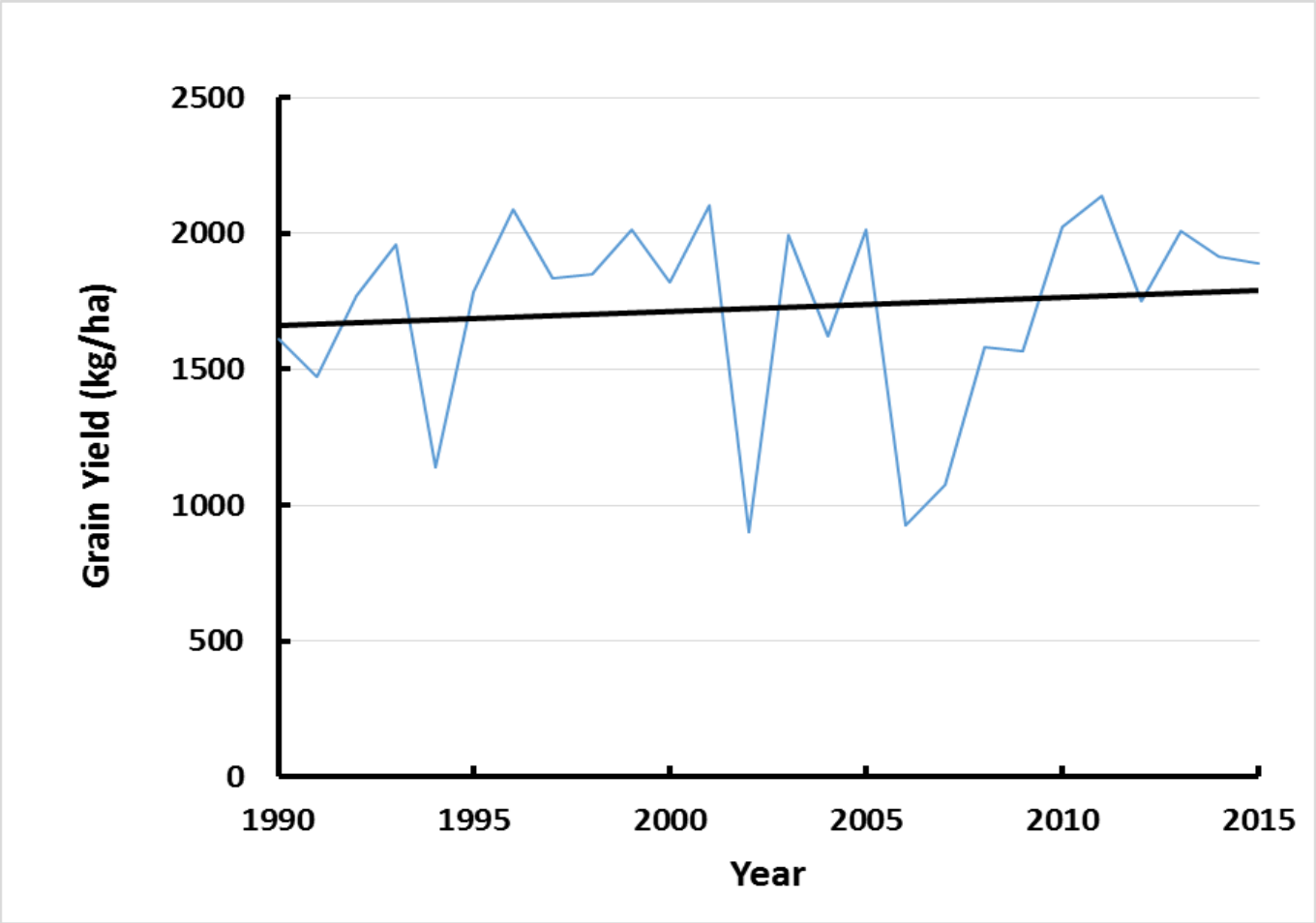
From 1900 to 1990 Australia's wheat yields tripled by increasing at an average rate of 10 kg/ha/year



Recent contributors to grain farm productivity increases.

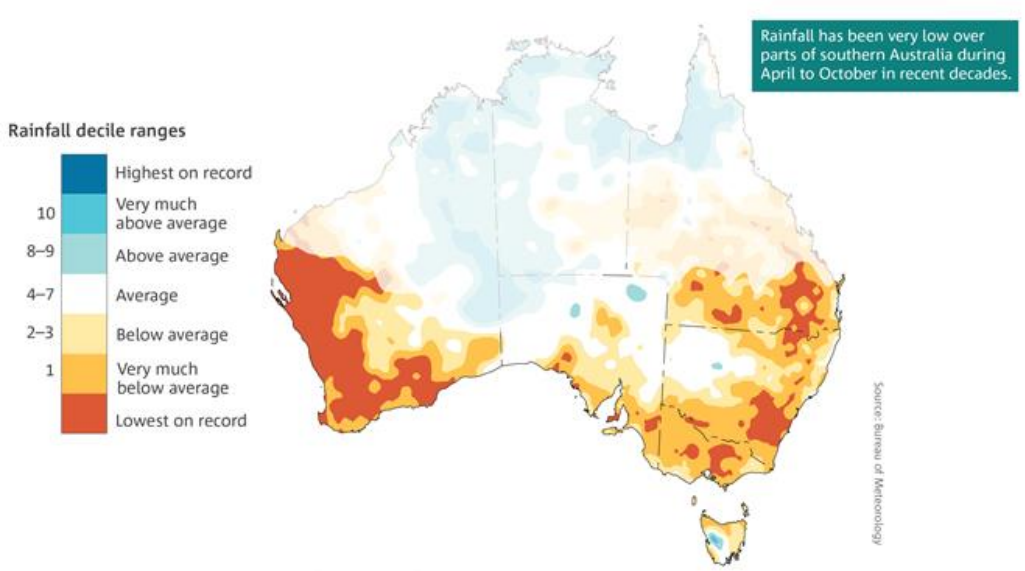
Robertson *et al.* 2016

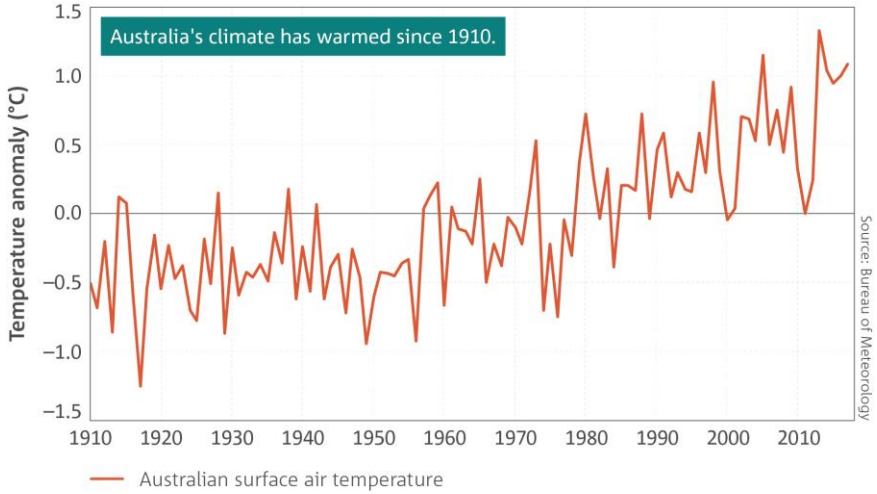
However, this rising trend has not been evident since 1990.



Can climate trends account for stagnant yields?

- Reduced rainfall in SW and SE Australia and rising air surface temperatures have been observed since the 1970s (The State of the Climate Report. 2018)





Australia’s surface air temperature has warmed by around 1°C since 1910

- Atmospheric CO2 increased, between 1990 and 2015, from 345.4 to 400.8 micromol/mol (NOAA, 2016)

Climate trends in the cropping zone: 1990-2015

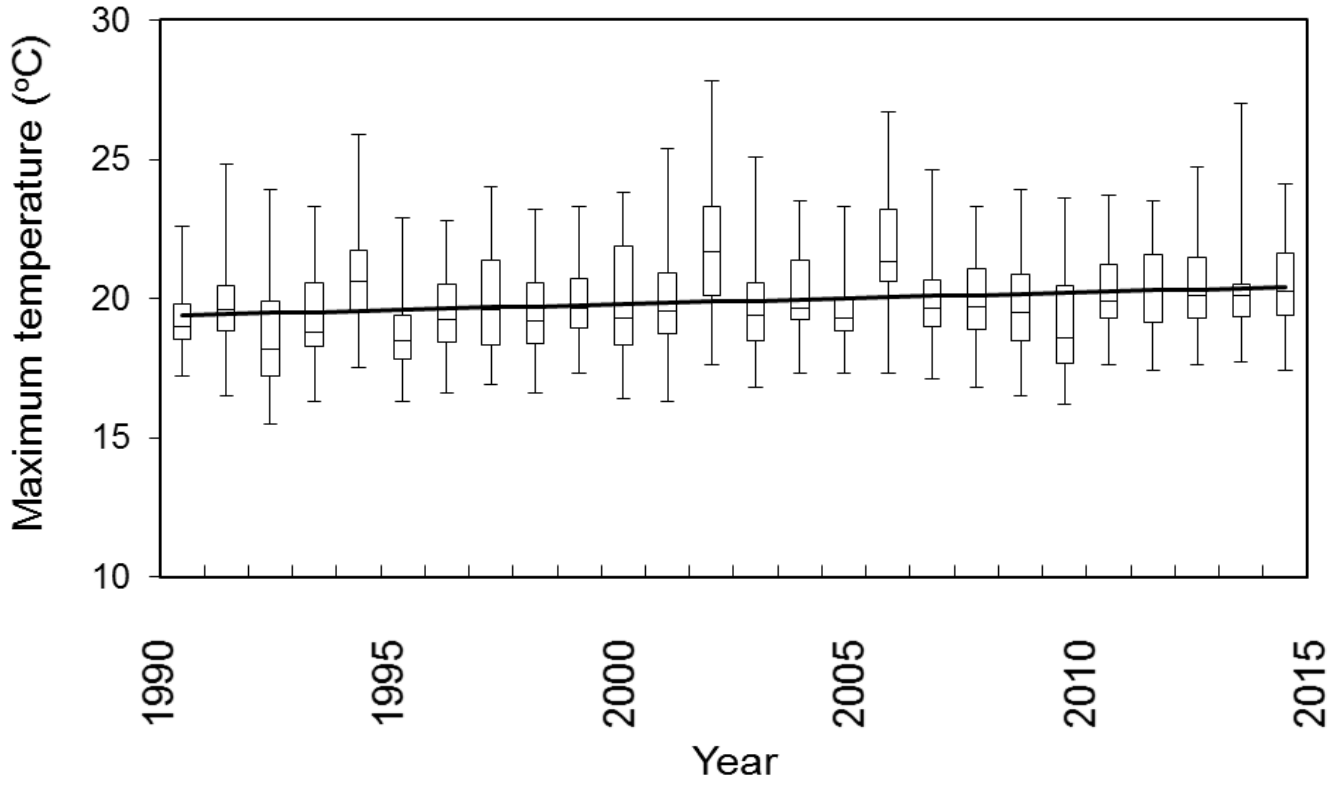
We selected 50 sites based on:

- > 90% complete daily record of rainfall and max and min temperatures (1972-2015)
- > 2,500 ha of winter cereal land use within 20 km radius of site
- Proportionately representative of 11 agro-ecological zones (these zones represent >90% coverage of Australia's cropping zone)
- Selecting the dominant cropping soil type within the 20 km radius to ensure a representative selection of the major soil types in Australia's cropping zone.

Zvi Hochman, David L. Gobbett, Heidi Horan, 2017. Climate trends account for stalled wheat Yields in Australia since 1990. Global change Biology, 23, 2071-2081.

Observed climatic trend (1990-2015) over the 50 sites:

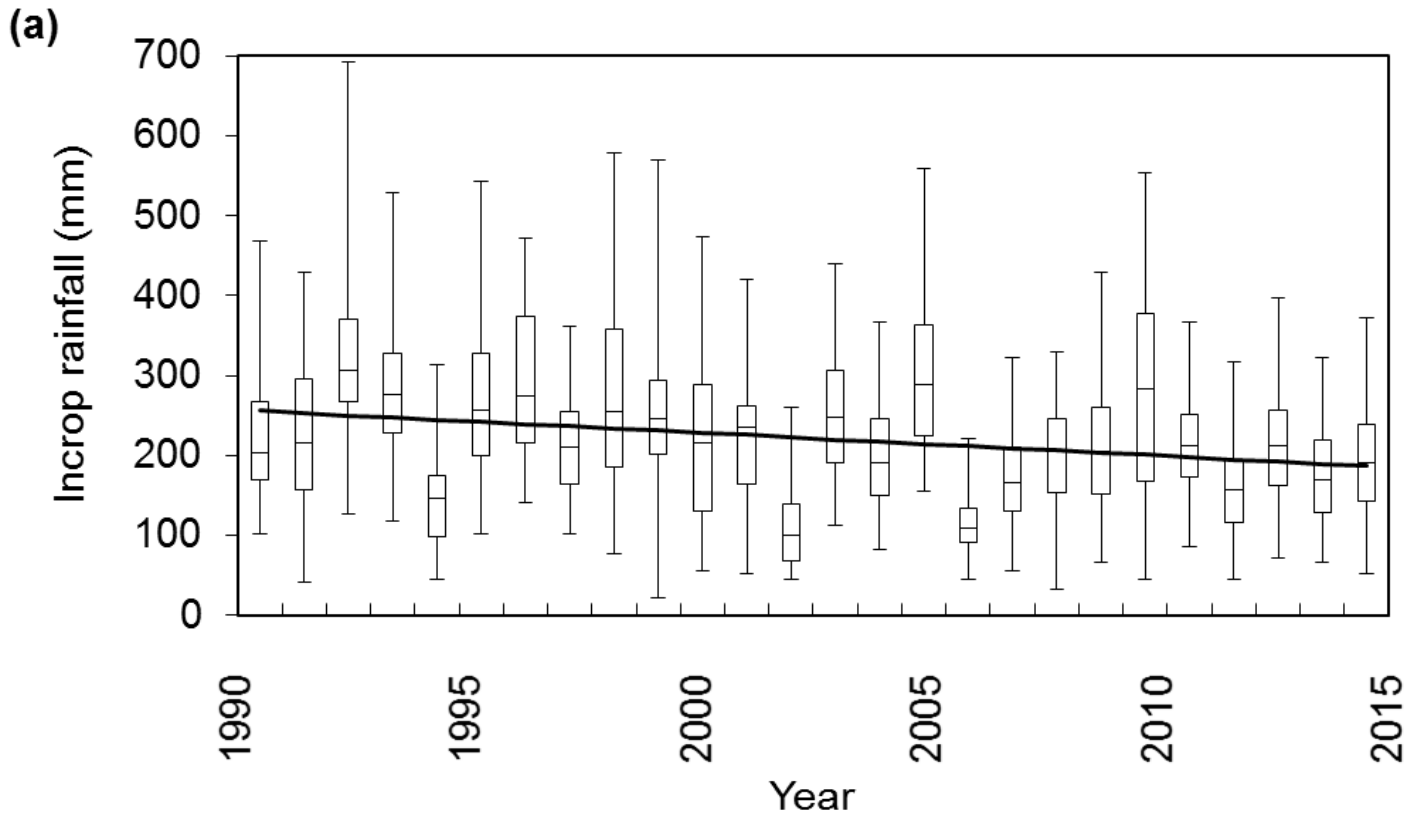
- Maximum Daily Temperatures during crop growth period



Max temp increased by 1.05 degrees over 26 years

Observed climatic trend (1990-2015) over the 50 sites:

- Rainfall during crop growth period

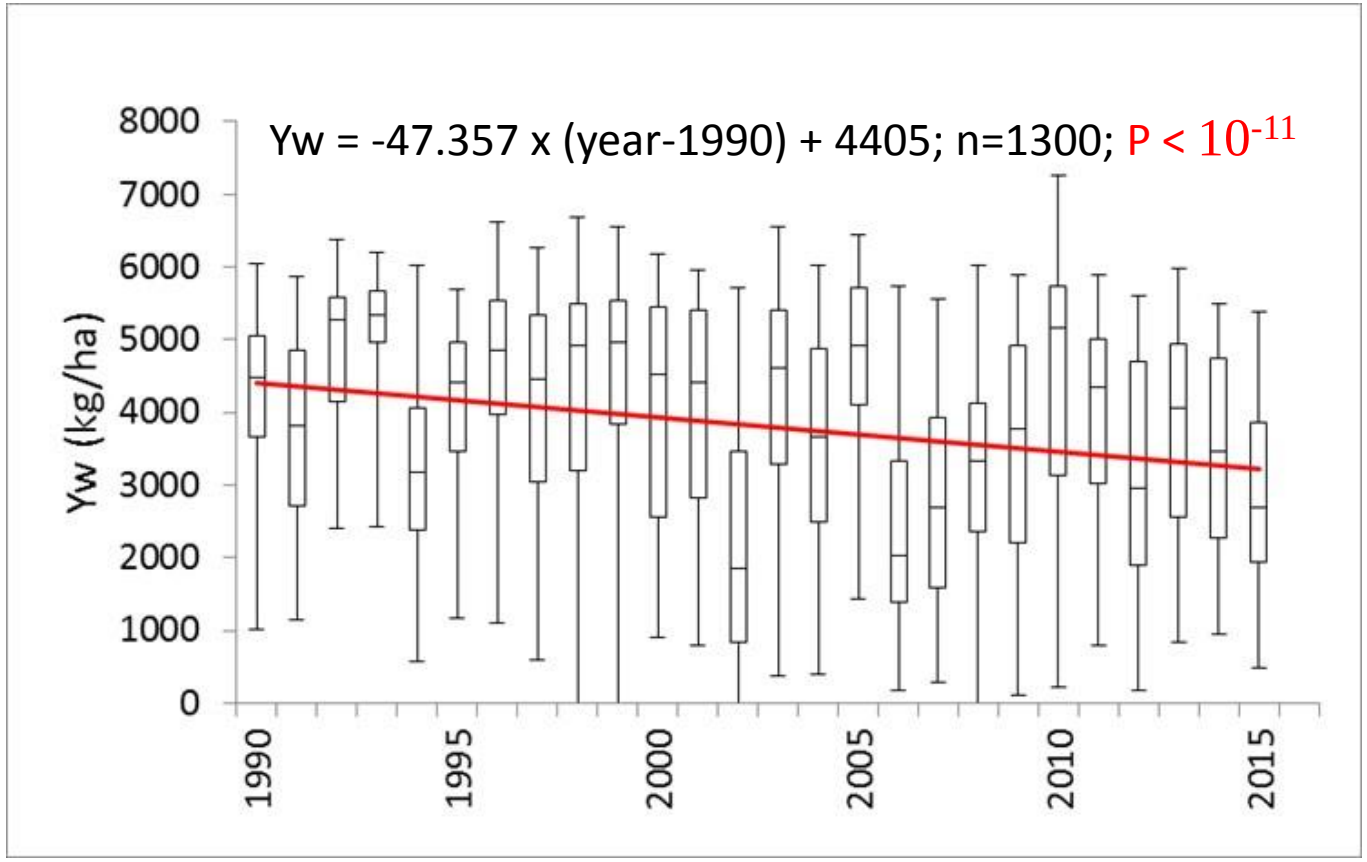


In-crop rainfall decreased by 71.8 mm over 26 years

We used the APSIM model to calculate how these climate trends impact on yield potential

- Rainfall amount and distribution
- Seasonal conditions (temperature, radiation, CO_2)
- Soil type
- Management based on best practice
  - Sowing rules – early sowing
  - Variety – best maturity type on average
  - N management – non-limiting
- Not limited by weeds, pests, or diseases
- Validated over 100's of wheat fields throughout Australia

Nationally, the yield potential of wheat (Yw) declined by 47 kg/ha/year; a 27% decline since 1990

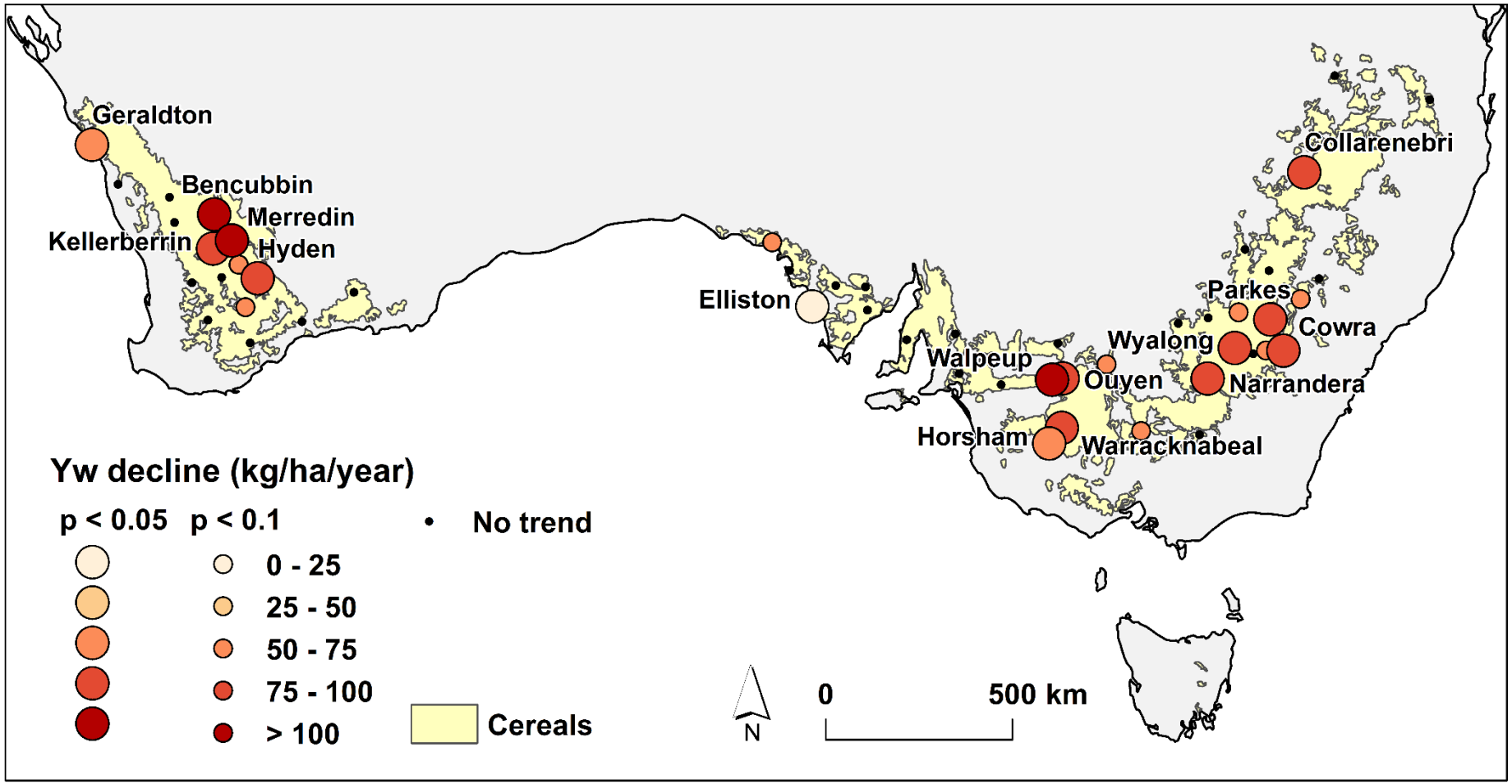


This decline is in contrast with the 1972-1990 period over which there was no significant change in yield potential (Yw)

47 kg/ha/year is a 1.2 t/ha reduction in yield potential from 1990 to 2015.

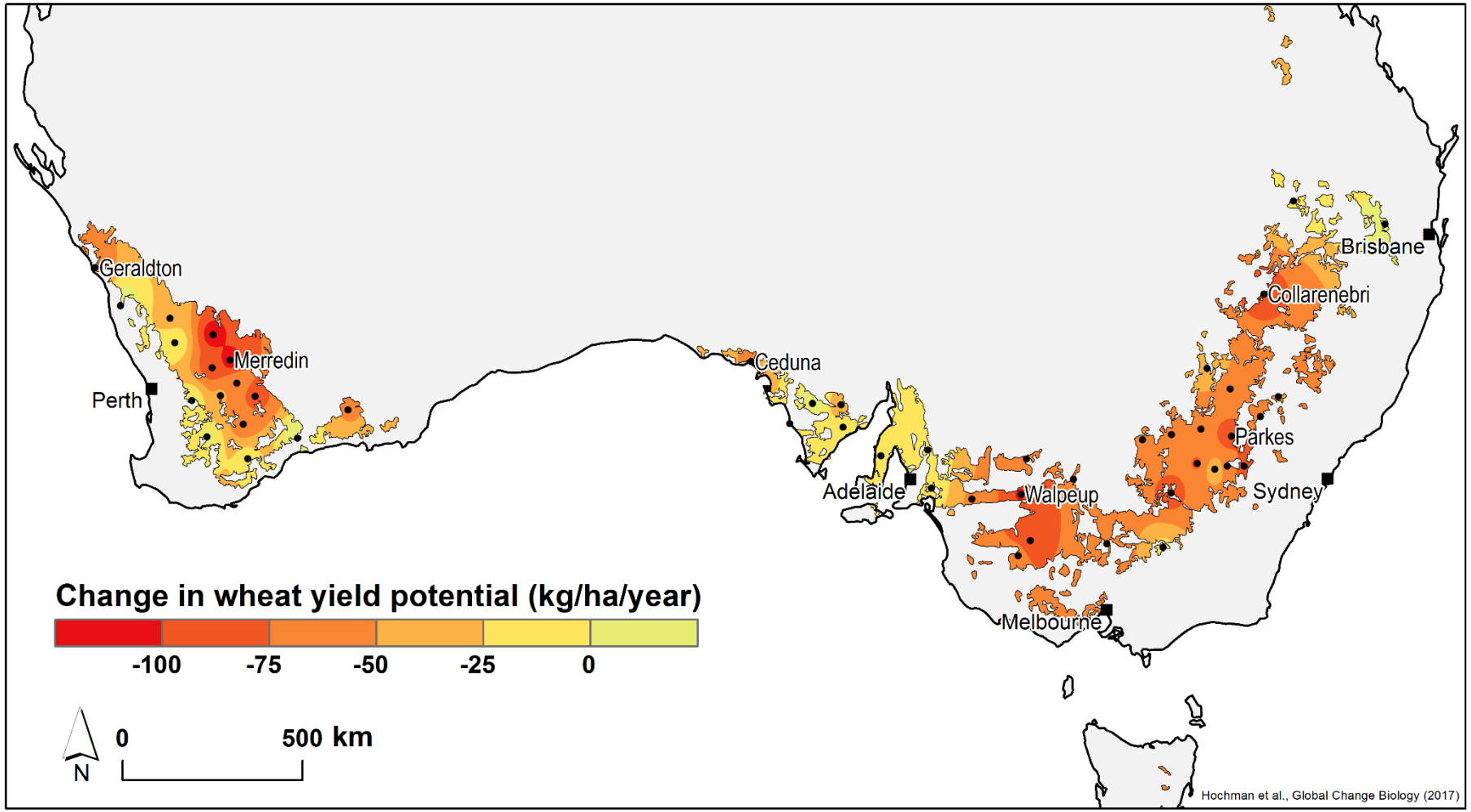
There is less than a one in one hundred billion chance that this trend is random !

Water limited wheat yield (Yw) trend (1990-2015) at 50 sites (black dots) in the Australian Grain Zone



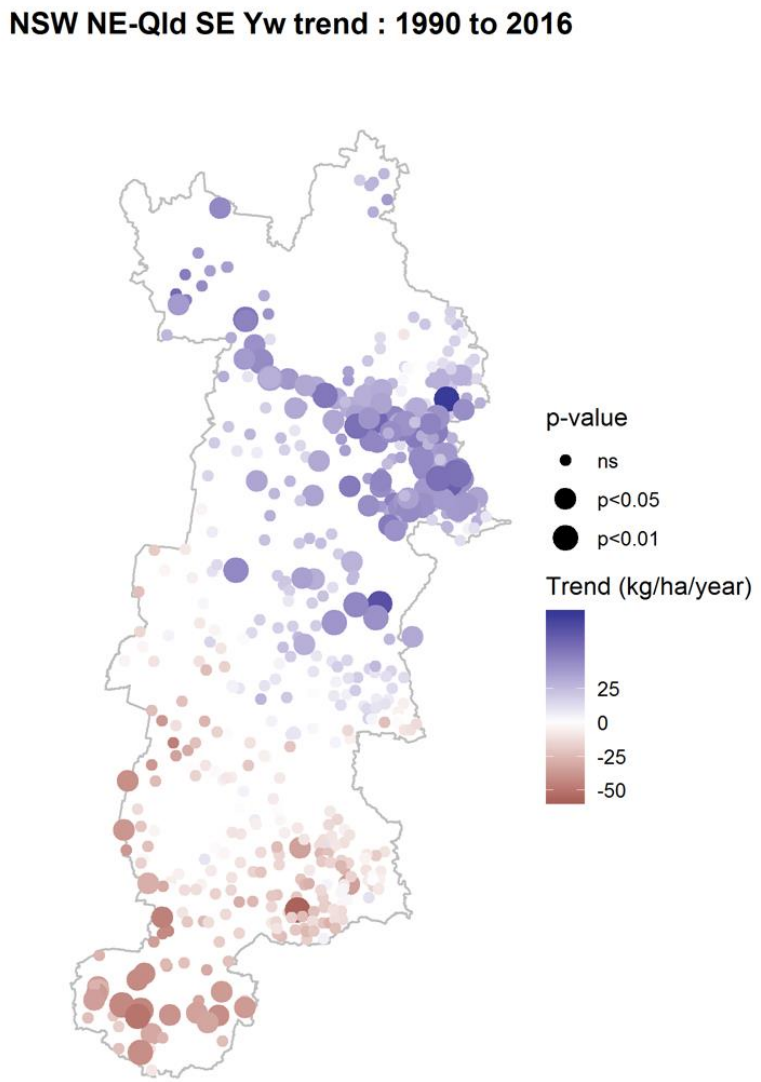
- The yield trend is not evenly distributed through the grain zone

Water limited wheat yield (Yw) trend (1990-2015) interpolated from 50 sites (black dots) in the Australian Grain Zone



- The yield trend is not evenly distributed through the grain zone

Taking a closer look: water-limited wheat yield trend in SE QLD



What is causing this decline in yield potential?

We conducted 2 virtual experiments:

1. We statistically “de-trended” temperature from 1990 to 2015 at all sites

   This resulted in a lower rate of yield decline over time:
   39 kg/ha/year or 8 kg/ha/year less than with rising temperatures

2. We kept CO_2 constant at the 1990 value of 354.4 micromole/mol at all sites

   This resulted in a higher rate of yield decline over time:
   54 kg/ha/year or 7 kg/ha/year more than with rising CO_2

CO_2 enrichment has helped but was cancelled out by the effect of rising temperatures. Reduced rainfall contributed 83% of the overall trend.

Given that Yw has declined why have yields not fallen?

- On average, Australian farmers achieved actual yields (Ya) that were about 50% of their yield potential (Yw). We therefor expect that as Yw declines, only half of that decline (47.4/2 = 23.7 kg/ha/year) would be expressed as a decline in Ya
- Our analysis showed that the actual annual national yield (Ya) was highly correlated with the annual 50 sites' average potential yield (Yw)
- This relationship was further strengthened (R^2=0.86) when the variable 'year-1990' was added to the analysis:

$$Ya = (0.50 * Yw) + (25.2 * (Year-1990)) - 517$$

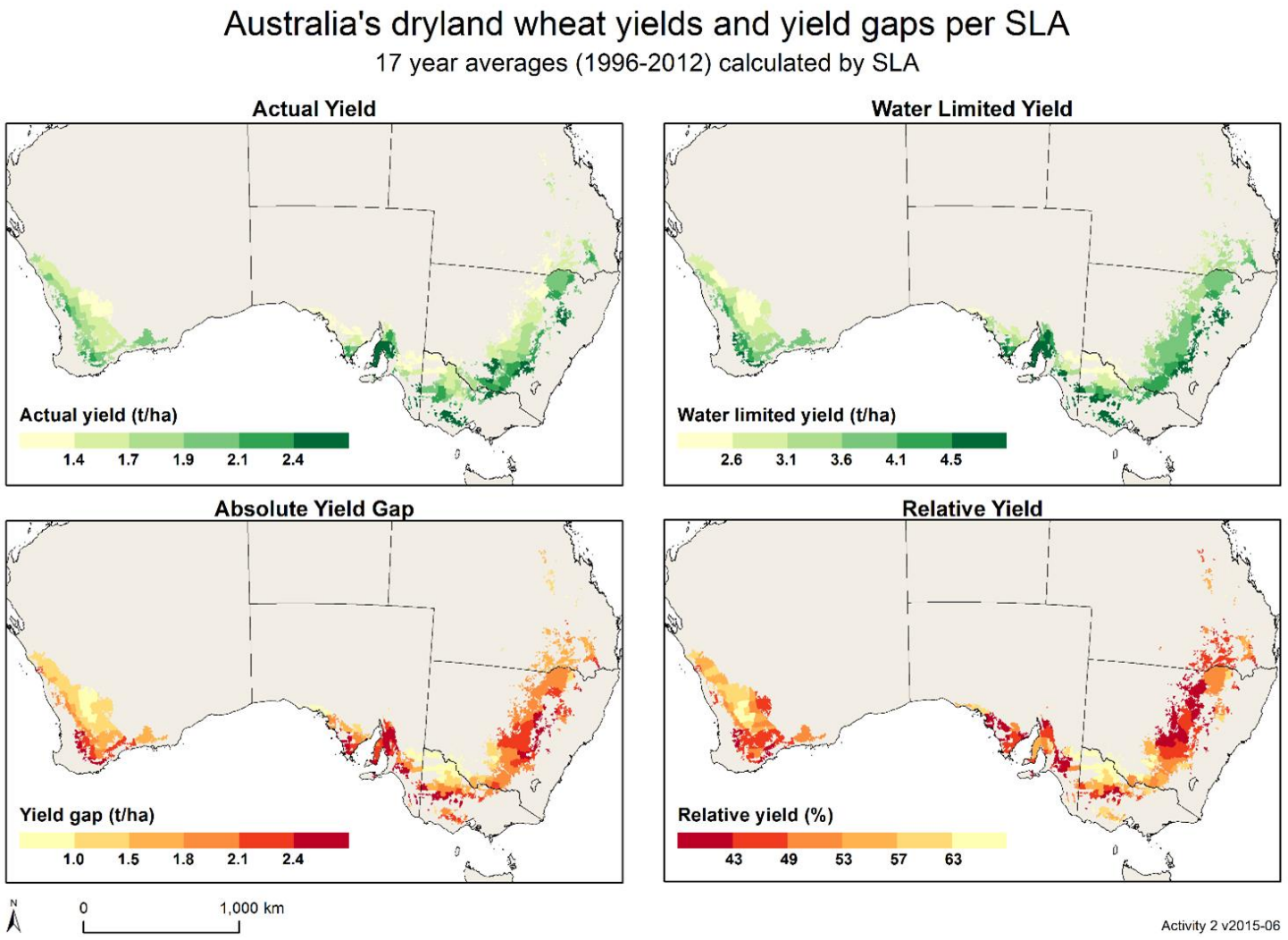
- *Closing of the yield gap by 25.2 kg/ha/year cancels out the expected 23.7 kg/ha/year decline in yield due to declining yield potential*

How can we adapt to this decline in yield potential?

1. Mitigation
   – Reduce GHG emissions to avoid “business as usual scenario” (requires a global effort)

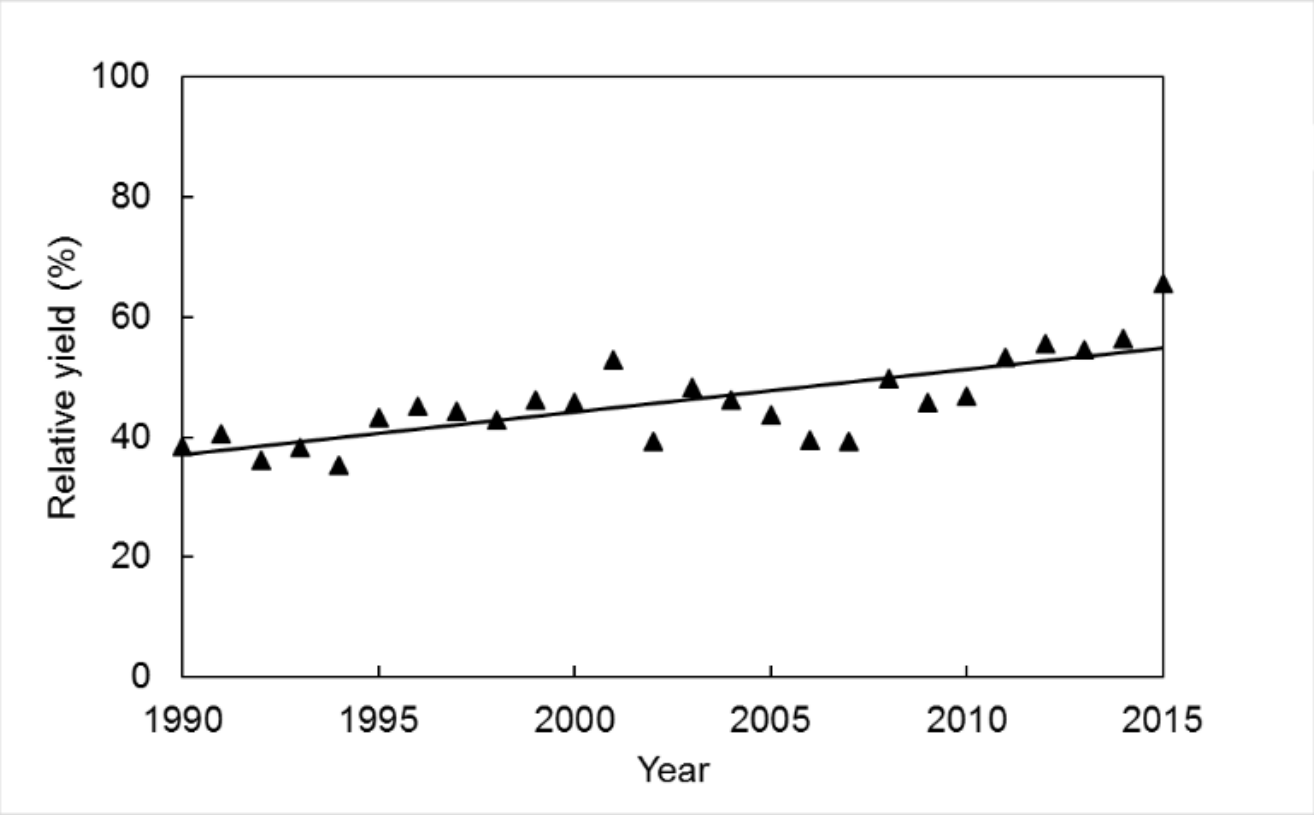
2. Adaptation to locked in climate change
   - Close the exploitable yield gap
   - Raise the production frontier

Adaptation 1. Close Yield Gaps: Australian Wheat Growers harvest about half their Water Limited Yield



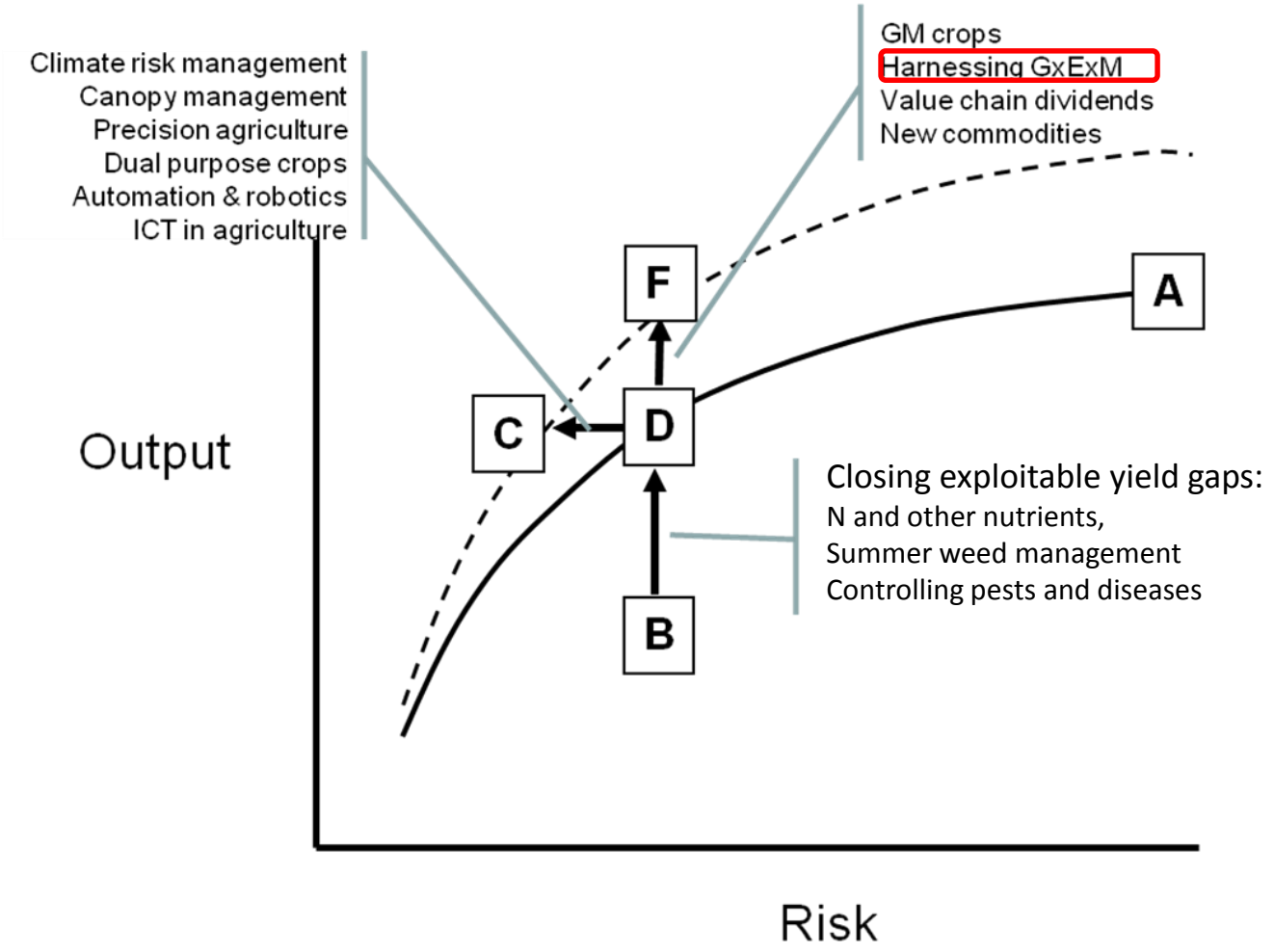
This leaves plenty of scope for increased productivity using current technology

This is already happening!
Faced with declining yield potential farmers have narrowed the gap between Yw and Ya.

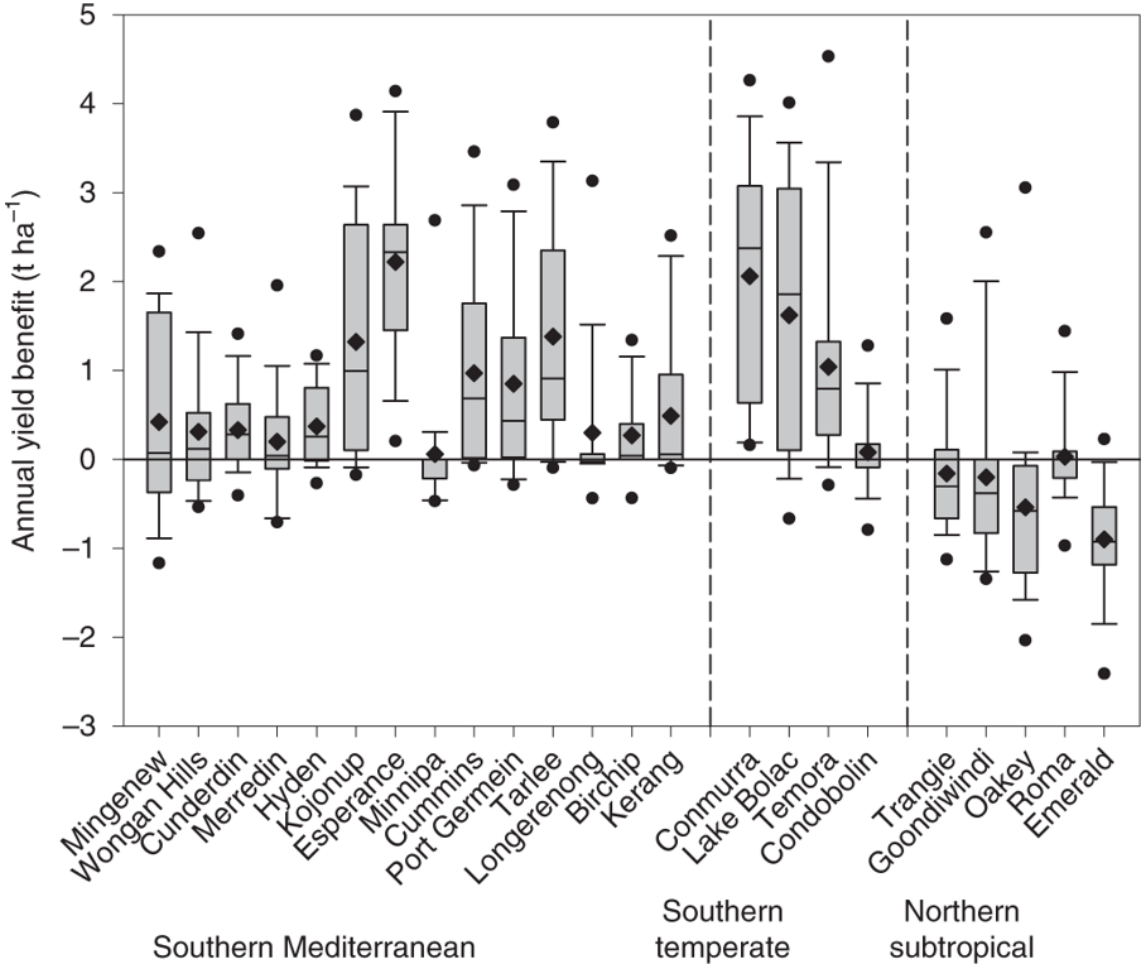


Relative yield (Y% = 100*Ya/Yw) has increased from 39% to 55%

Adaptation 2. Raise the production frontier



Yield benefits achieved by sowing wheat earlier using a slower-developing cultivar.



The proposed early sowing system can increase national yields by 0.54 t/ha representing an additional 7.1 Mt annually under reduced rainfall and increasing temperature regimes.

Hunt et al. 2019. Early sowing systems can boost Australian wheat yields despite recent climate change. *Nature Climate Change.* 9, 244-247.

Conclusions

- Stagnant yields in Australia's wheat crop in the last 26 years fully accounted for by a -47 kg/ha/yr trend in Yw
- Yield declines are explained by crop water stress and warmer seasonal conditions over the grain zone
- Increased atmospheric CO_2 has *slightly* moderated the decline in Yw
- Technology development and adoption is keeping actual yields from falling. *i.e.* farmers, advisers and scientists are working hard just to stay in the same place!
- Technologies to raise the production frontier, such as early sowing with slower maturing varieties, are required to keep yields from falling behind, especially for growers who have already closed the exploitable yield gap.

Thank you

Zvi Hochman
Senior Principal Research Scientist
Team Leader, Integrated Agricultural Systems
Zvi.Hochman@csiro.au