Wheat yields have stalled since 1990 as technology and climate change battle it out

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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.

- New Technologies including improved genotypes
- Greater attention to management
- Bigger farms
- More mechanisation
- More specialisation
- New systems e.g. no-till, Integrated Weed Management
- Specialist advice

Robertson et al. 2016
However, this rising trend has not been evident since 1990.
Why? What could be causing yields to stagnate?

We can eliminate some of the usual suspects

- Government regulation
- Reduced investment in grains RD&E
- Declining soil fertility
- Expansion of wheat cropping into less suitable land
This leaves us with climate trends

- Reduced rainfall in SW and SE Australia and rising air surface temperatures have been observed since the 1970s (The State of the Climate Report; BOM and CSIRO 2014)

- Atmospheric CO2 increased from 345.4 micromol/mol in 1990 to 400.8 micromole/mol in 2015 (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.
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, CO₂)
- 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, diseases and extreme climate events
- 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.

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) interpolated from 50 sites (black dots) in the Australian Grain Zone

- The yield trend is not evenly distributed through the grain zone
- However, not a single site showed a positive trend
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\textsubscript{2} constant at 1990s values 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\textsubscript{2}

CO\textsubscript{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 therefore 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:

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

- Hence 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.
In the face of declining yield potential farmers have narrowed the gap between Yw and Ya at an unprecedented rate.

Relative yield (Y% = 100*Ya/Yw) has increased from 39% to 55%
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.
- A negative 26 year trend in Yw is highly unlikely to be explained by random climate variability alone.
- Yield declines are explained by crop water stress and warmer seasonal conditions over the grain zone.
- Increased atmospheric CO₂ 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!
About record yields in 2016
Observed climatic trend (1990-2016) over the 50 sites:

- Maximum Daily Temperatures during crop growth period

Max temp increased by 1.05 degrees over 26 years OR 0.67 degrees over 27 years
Observed climatic trend (1990-2016) over the 50 sites:

- Rainfall during crop growth period

In-crop rainfall decreased by 71.8 mm over 26 years OR 39.5 mm over 27 years
Nationally, the yield potential of wheat (Yw) declined by 36 kg/ha/year between 1990 and 2016.

2016 is still within the range of climate variability observed over the previous 26 years.

There is still less than a one in one hundred billion chance that this trend is random!
In the face of declining yield potential farmers have narrowed the gap between Yw and Ya at an unprecedented rate.

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

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Temperature de-trended Yw declined by 39 kg/ha/year (i.e. temperature trend accounts for 8 kg/ha/year)

83% of trend was due to rainfall, 17% due to temperature rise
Response of water-limited yield (Yw) of wheat to a. water use (plant available soil water at sowing plus in-crop rainfall); and b. average water stress index during pre and post anthesis growth stages
Response of water-limited yield ($Y_w$) of wheat to maximum temperatures during pre and post anthesis growth stages at 3 sites in the Australian grain zone