Yield and Climate : A Statistician's Perspective

Presentation for Market Information Committee

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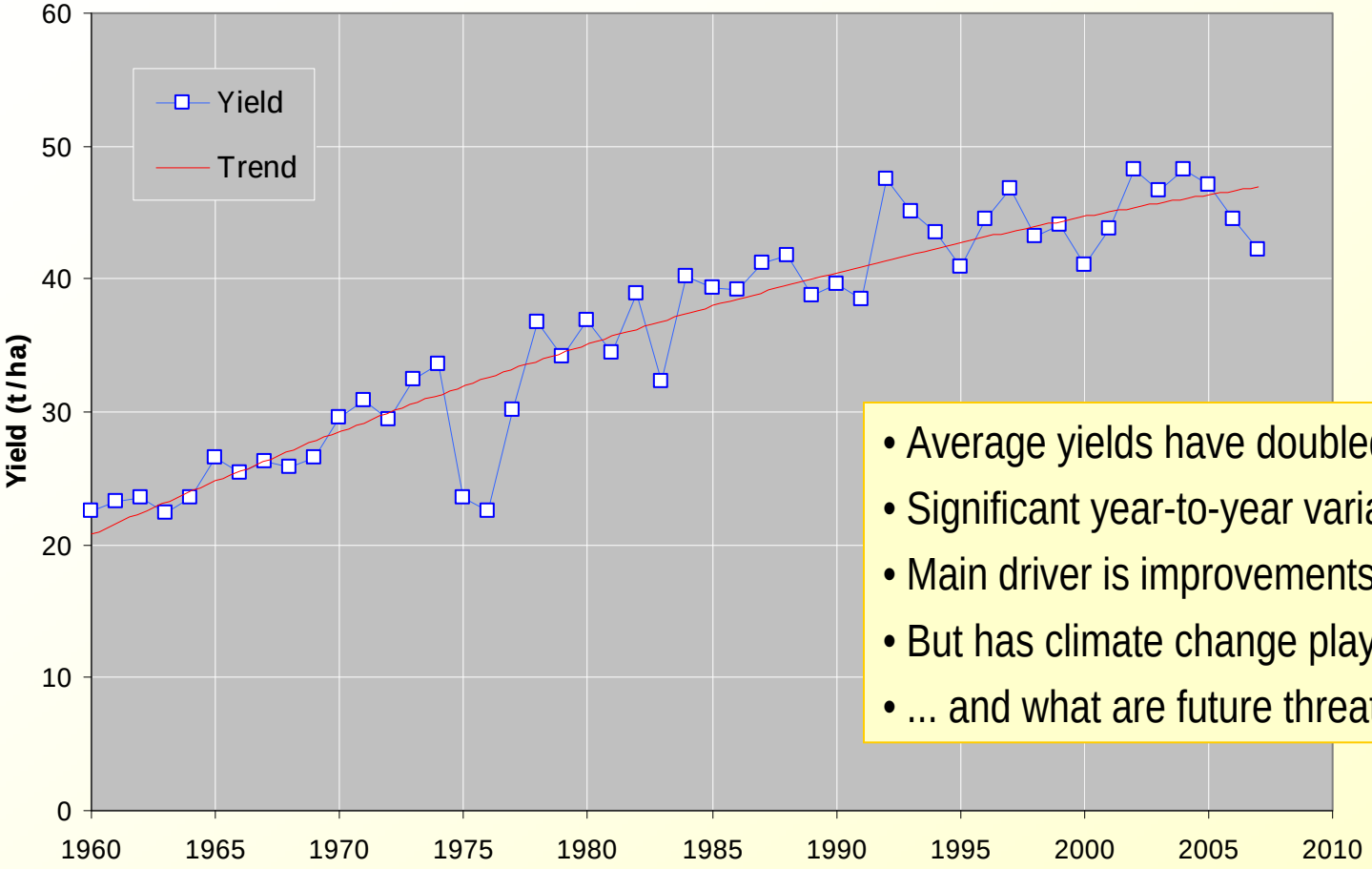
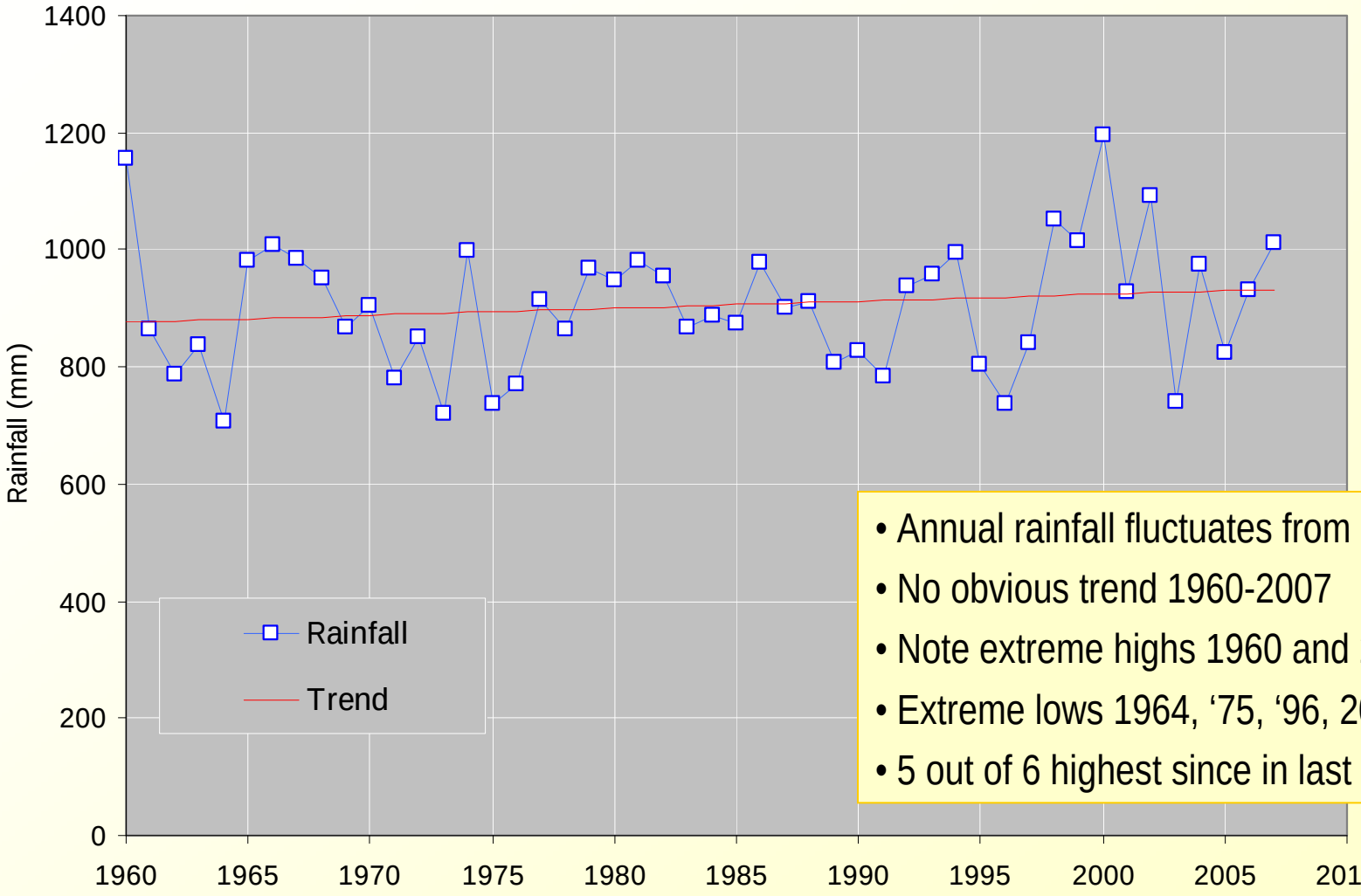
Yields 1960-2008



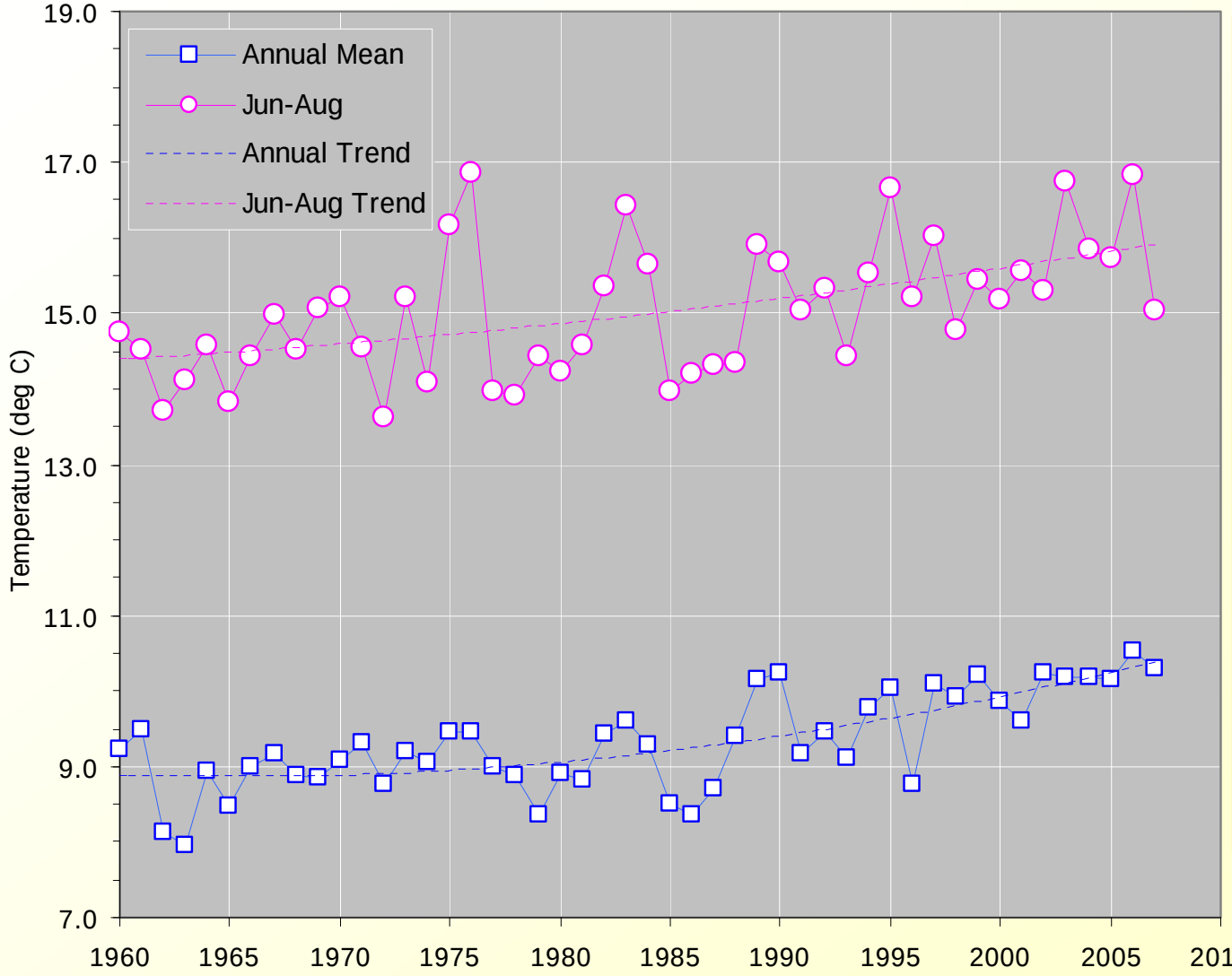
- Average yields have doubled since 1960
- Significant year-to-year variation due to weather
- Main driver is improvements in agronomy
- But has climate change played a role?
- ... and what are future threats and opportunities?

Rainfall



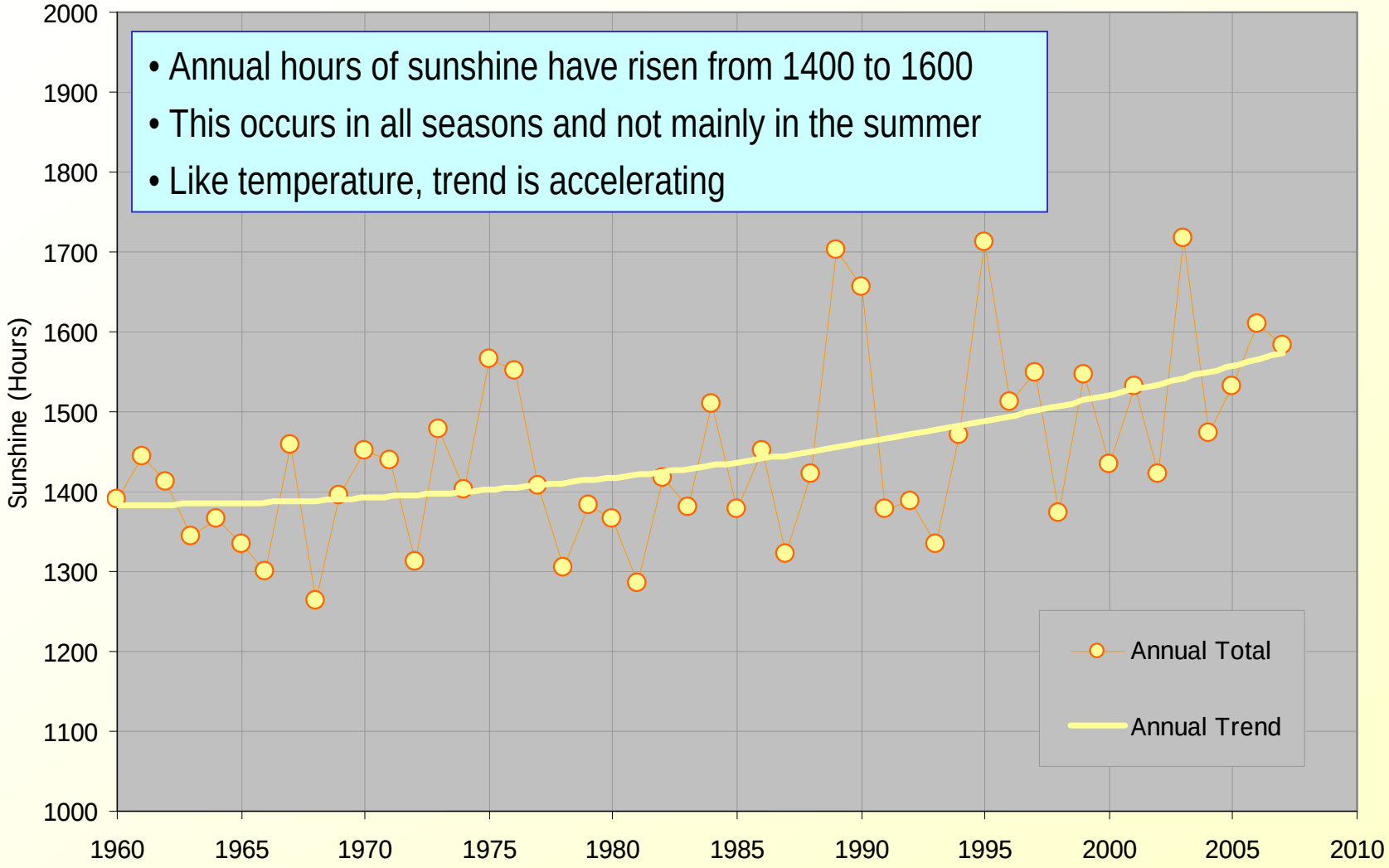
- Annual rainfall fluctuates from 700-1200 mm
- No obvious trend 1960-2007
- Note extreme highs 1960 and 2000
- Extreme lows 1964, ‘75, ‘96, 2003
- 5 out of 6 highest since in last decade

Temperature

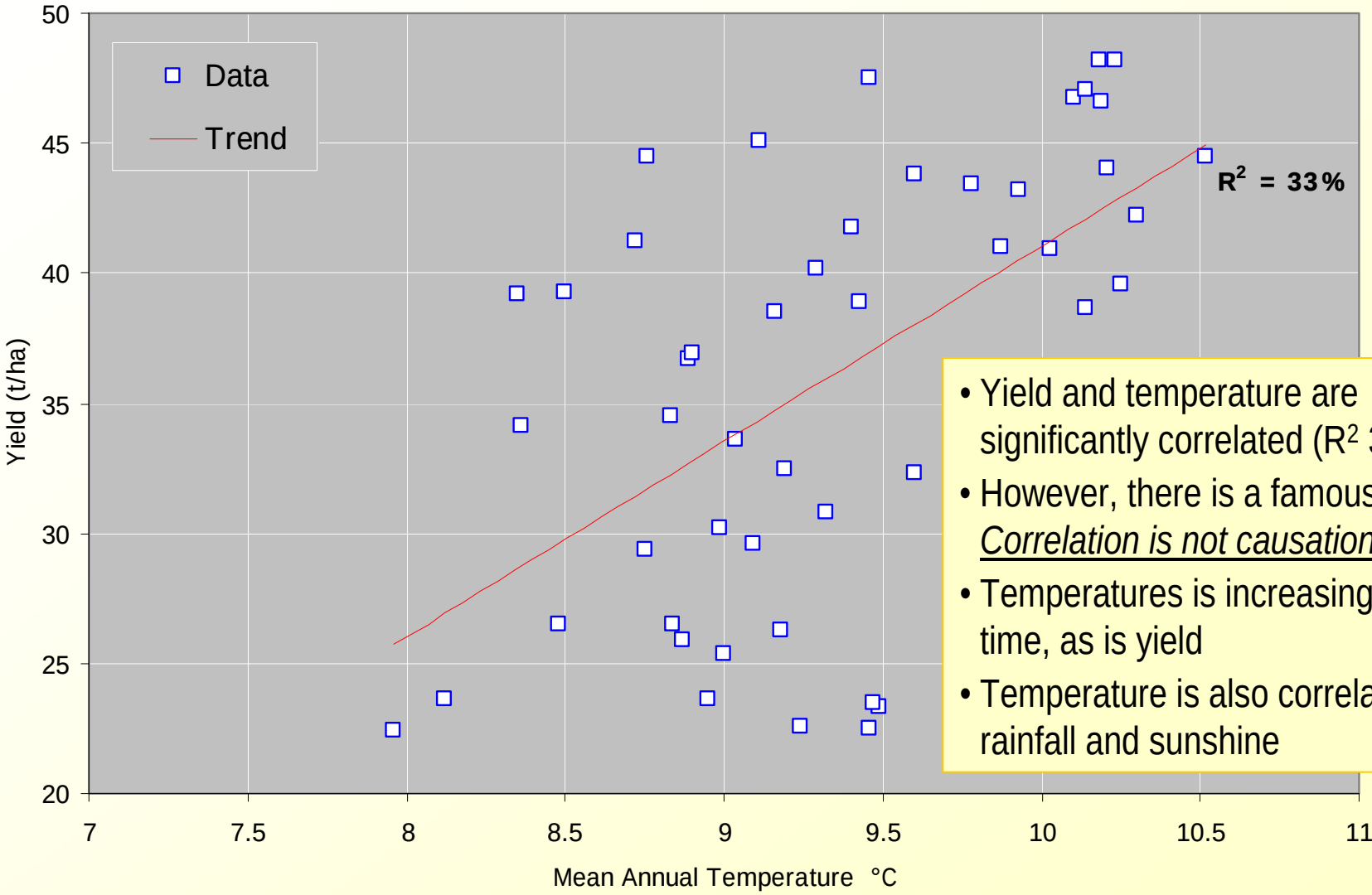


- Mean and summer temperatures increasing
- Jun-Aug mean has risen from 14.5ºC to 16 ºC
- Annual mean has risen from 9ºC to 10.5 ºC
- Note correlation of rising yield and temperature
- Chart shows accelerating rate of increase

Sunshine

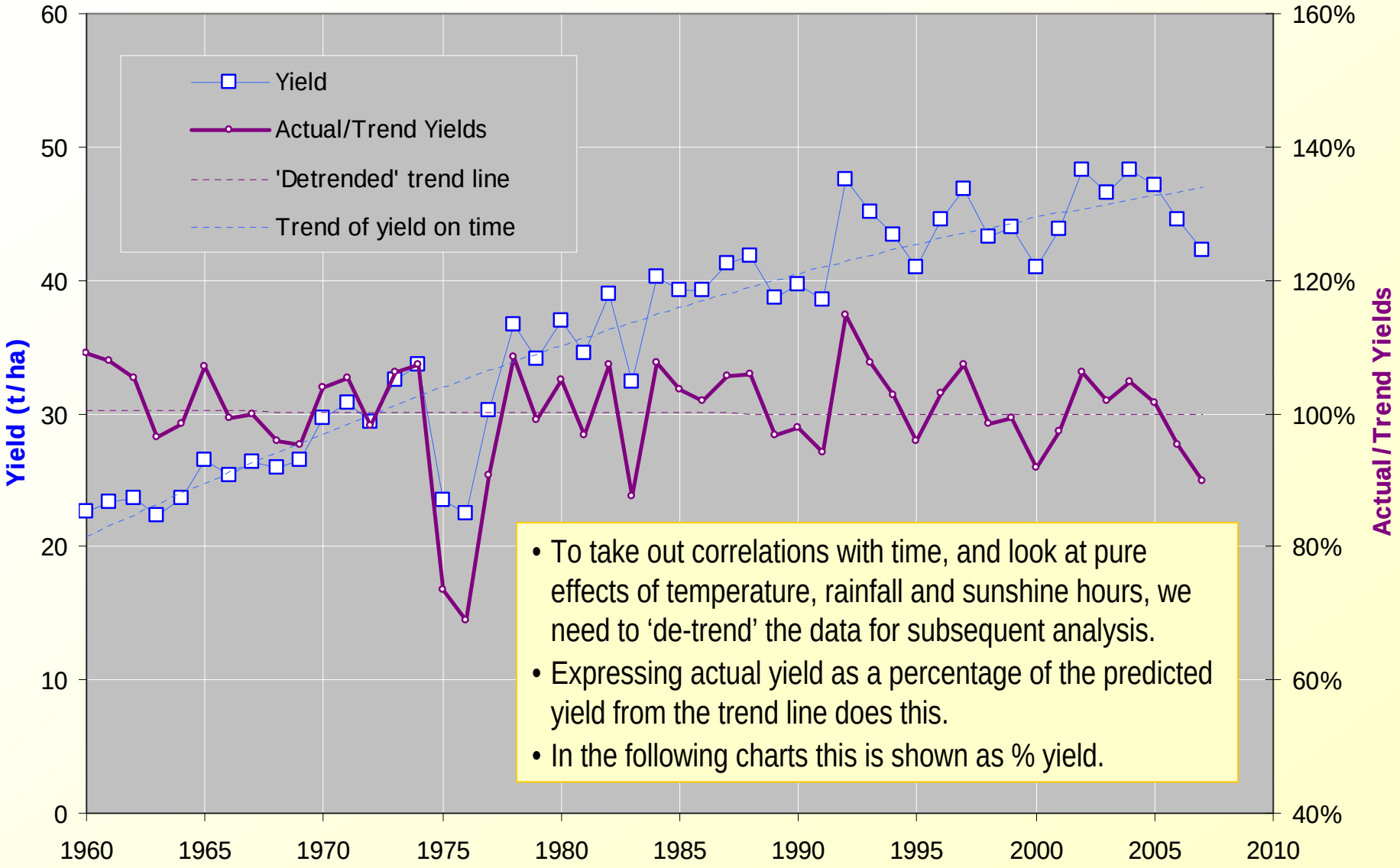

• Annual hours of sunshine have risen from 1400 to 1600
• This occurs in all seasons and not mainly in the summer
• Like temperature, trend is accelerating
Sunshine (Hours)
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Annual Total
Annual Trend

Temperature and Yield



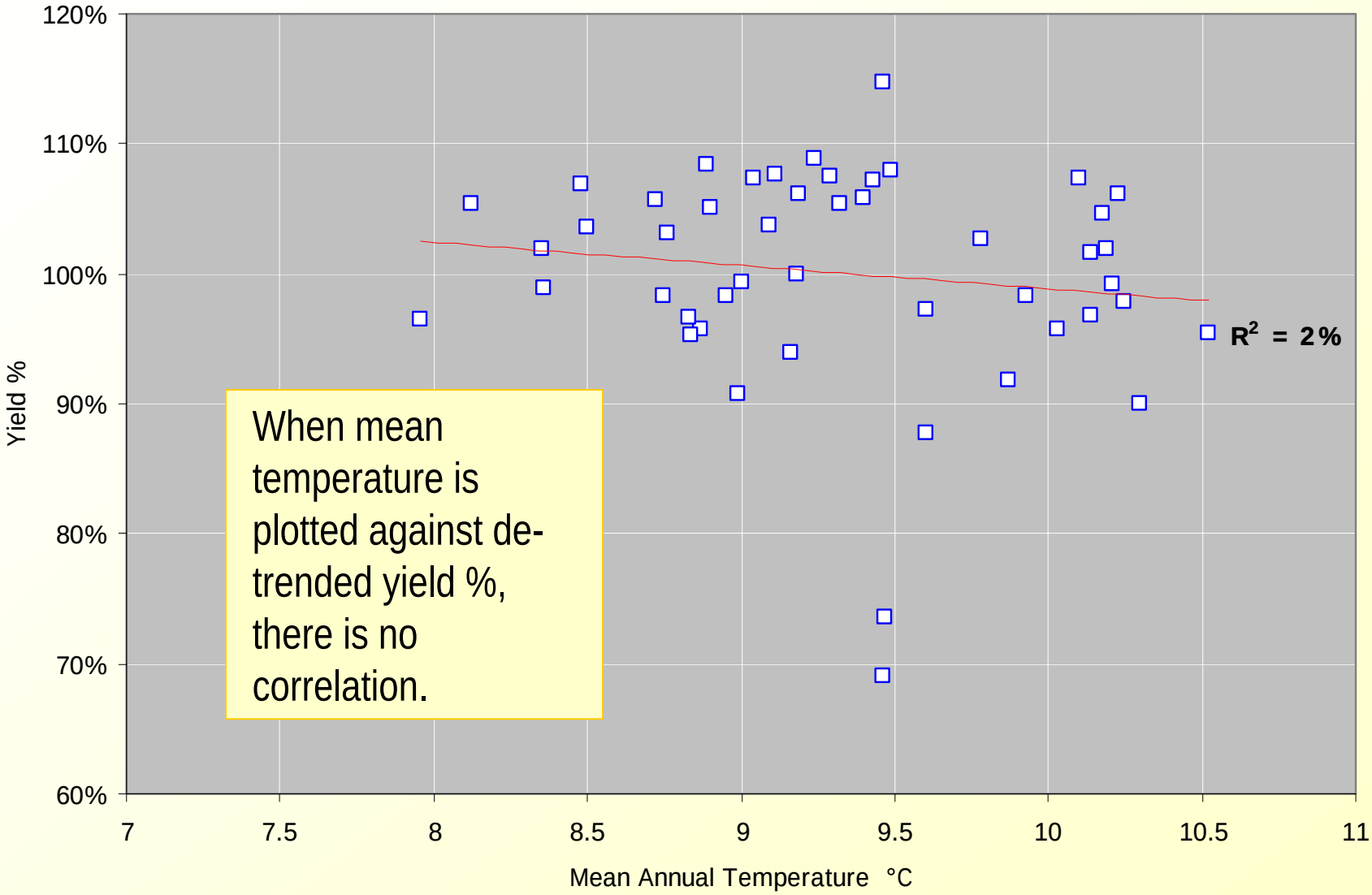
- Yield and temperature are significantly correlated (R^2 33%)
- However, there is a famous proverb: *Correlation is not causation*
- Temperatures is increasing over time, as is yield
- Temperature is also correlated with rainfall and sunshine

De-trending time series data

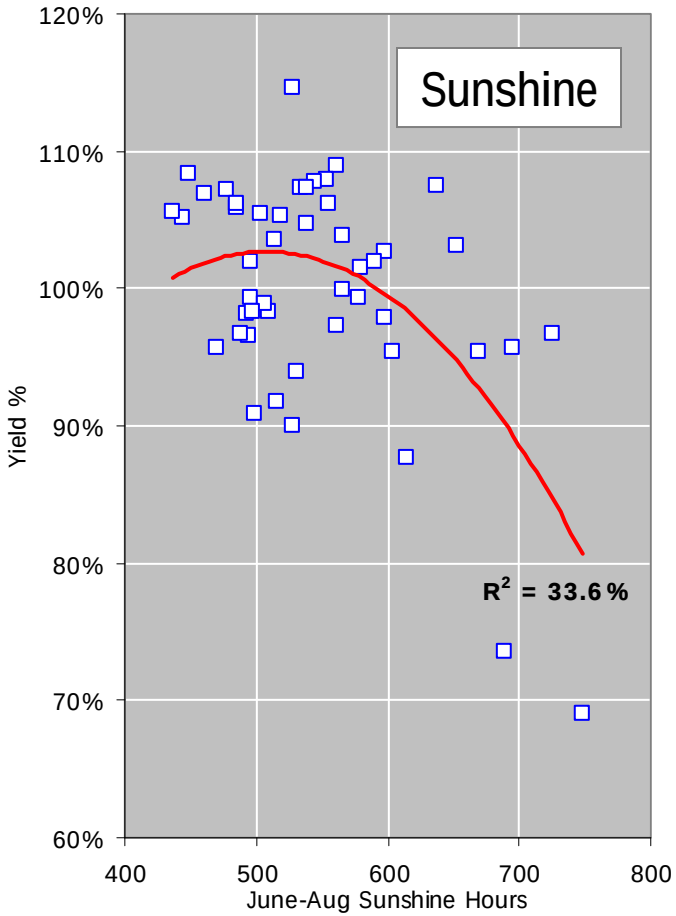


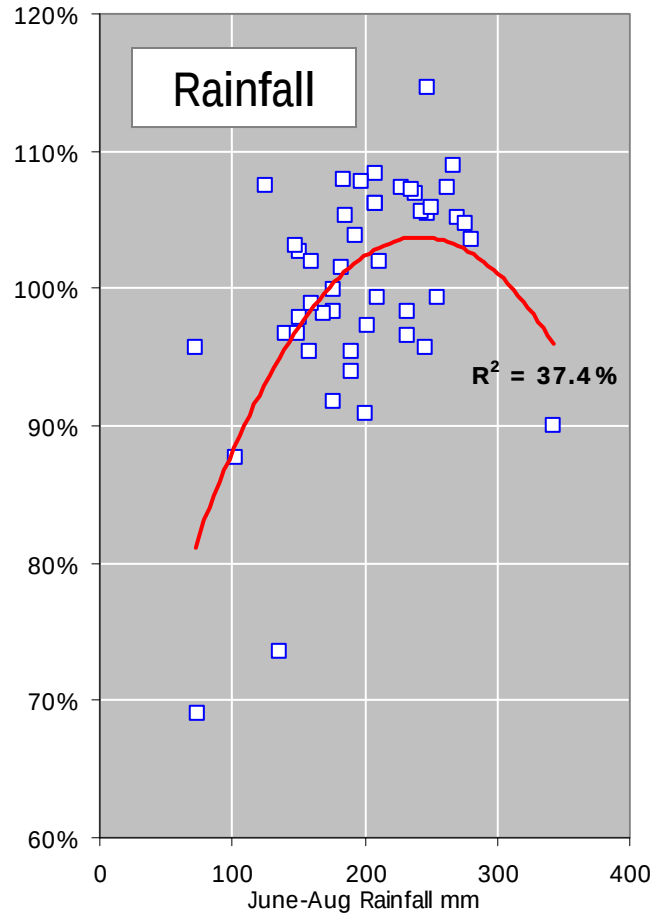
- To take out correlations with time, and look at pure effects of temperature, rainfall and sunshine hours, we need to 'de-trend' the data for subsequent analysis.
- Expressing actual yield as a percentage of the predicted yield from the trend line does this.
- In the following charts this is shown as % yield.

Temperature and de-trended yield



Strongest weather effects



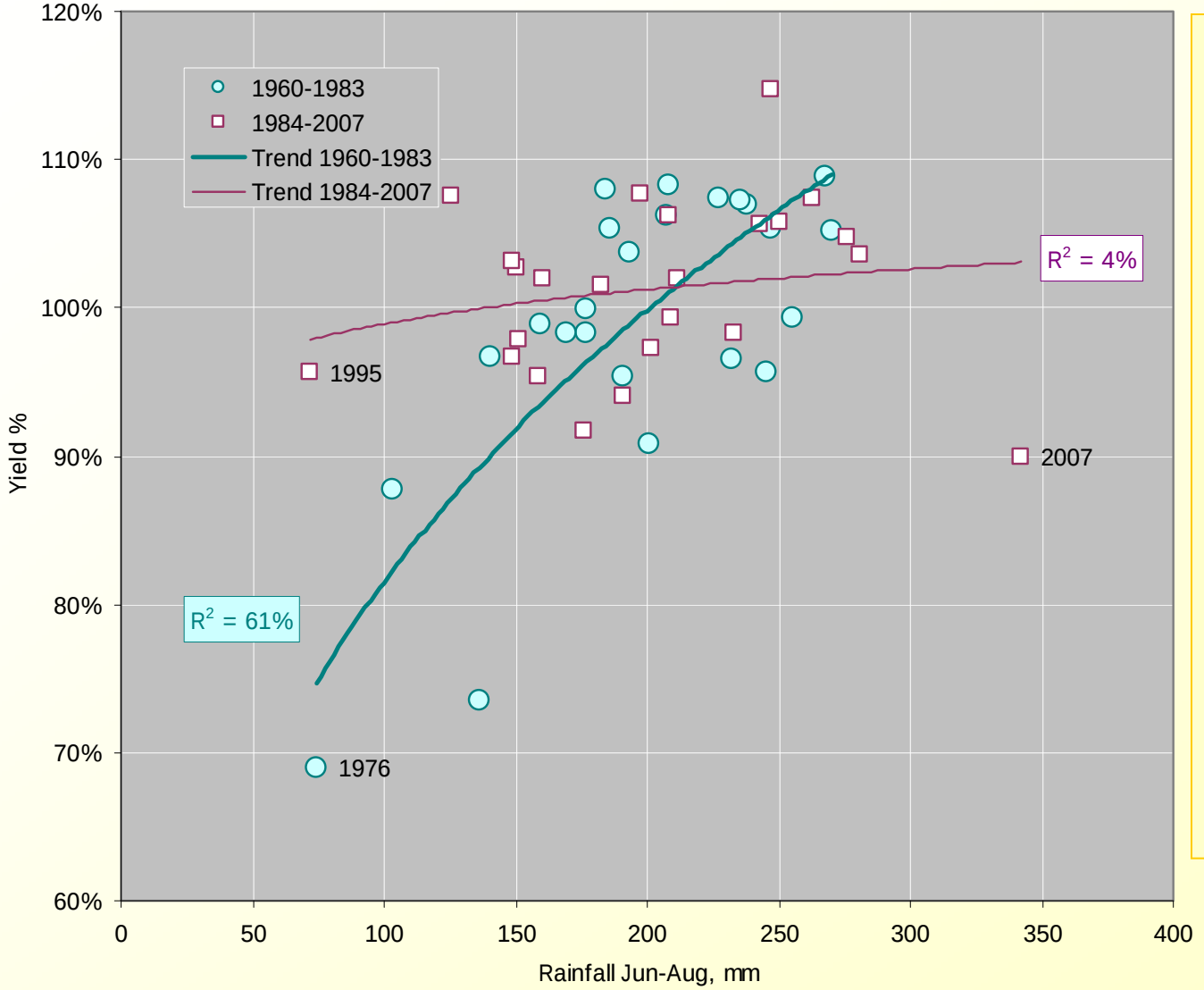


- Explored effect of Sunshine, rainfall and temperature on yield % (de-trended yield).
- Also looked at months that were most significant.
- Jun-Aug Sunshine Hours and June-Aug Rainfall had strongest effect.
- 41% of variantion explained with model shown
- They are only indices of real ecophysiological factors such as leaf surface temperature and soil moisture deficit.

Combined quadratic function for rain and sun effect

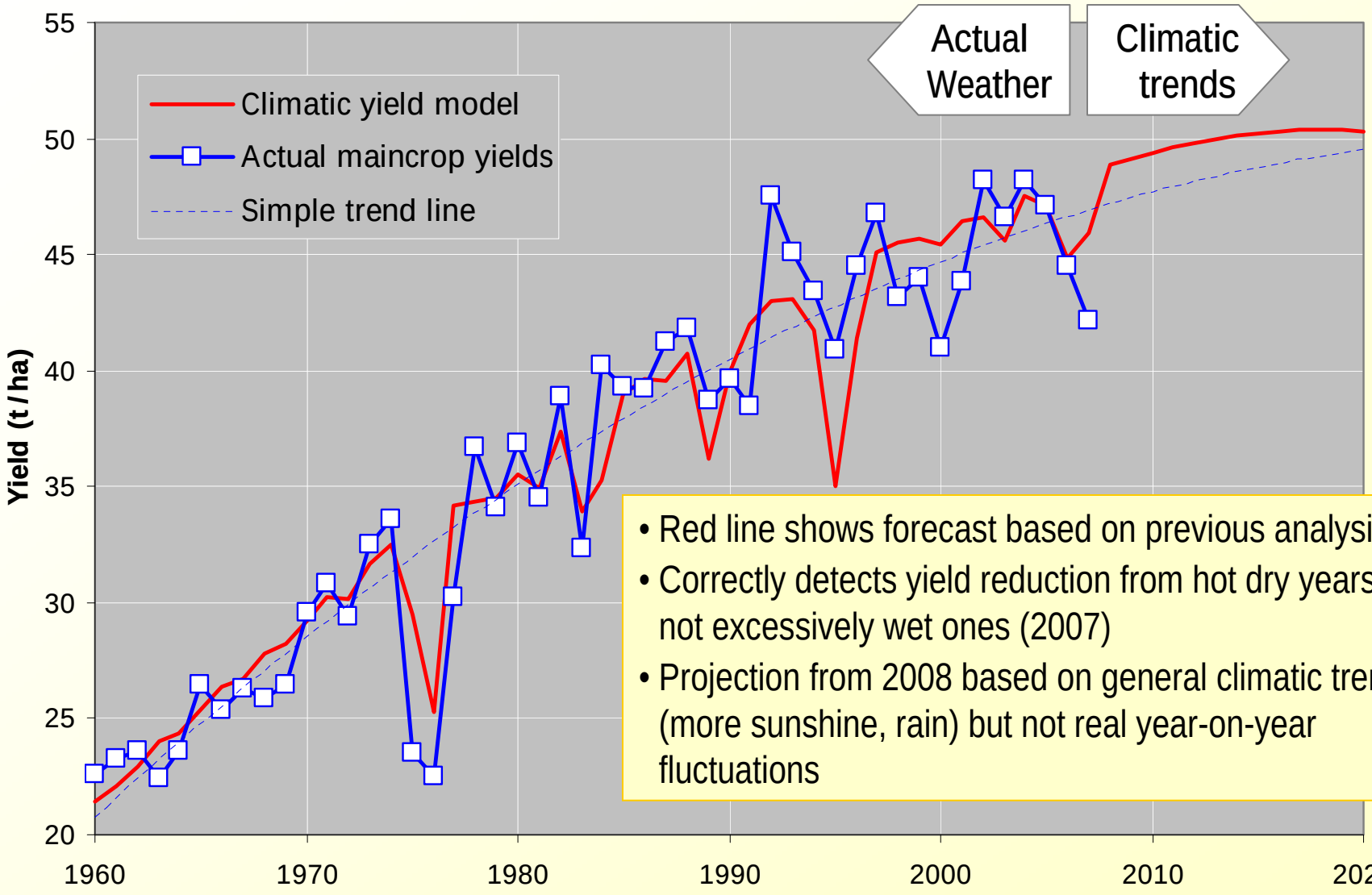
$$\text{Yield \%} = 0.2679\ \text{Rain} + 0.2672\ \text{Sun} - 0.0005599\ \text{Rain}^2 - 0.0002483\ \text{Sun}^2$$

What about irrigation?



- Yield data are GB averages
- Irrigated/non-irrigated crops lumped together
- However, pre-1977 little irrigation, 77-83 transitional, 1983-2007 50% plus crops irrigated.
- Data shows strong effect of rainfall on yield prior to 1983
- Thereafter, no significant correlation as irrigation widespread

Forecast yields to 2020



- Red line shows forecast based on previous analysis
- Correctly detects yield reduction from hot dry years, but not excessively wet ones (2007)
- Projection from 2008 based on general climatic trends (more sunshine, rain) but not real year-on-year fluctuations

Conclusions

- Yields have doubled since 1960.
- Mostly not linked to climate change – due to improvements in agronomy.
- De-trended GB yields correlate with major weather indicators
- Best correlates are summer (Jun-Aug) rainfall and sunshine.
- Excessively low and high rainfall both decrease yield. Optimum is around 250 mm in Jun-Aug.
- Summer sunshine hours also correlate with declining yields
- Irrigation is a major factor not properly accounted in these models.
- Climate trends : Increasing temperature, sunshine, rainfall more variable
- Climate change is probably causing declining yields already
- Direct climate change effects unlikely to be major in next 20 years
- However irrigation restrictions would have drastic effect on yield.

Sources

- **Yield data** 1960-2008 are average GB maincrop yields, see:
  http://www.potato.org.uk/media_files/MIS_reports_2006_07/keydatanov07.pdf

- **Weather data** for England and Wales from Met Office website.
  http://www.metoffice.gov.uk/climate/uk/seriesstatistics/ewrain.txt
  http://www.metoffice.gov.uk/climate/uk/seriesstatistics/ewtemp.txt
  http://www.metoffice.gov.uk/climate/uk/seriesstatistics/ewsun.txt
  for rainfall, temperature and sunshine respectively.

- **Climate change** science and policy is covered at the IPCC website
  http://www.ipcc.ch