Transitioning Cereal Systems to Adapt to Climate Change

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Adapting cereal cropping systems to a changing climate in Australia

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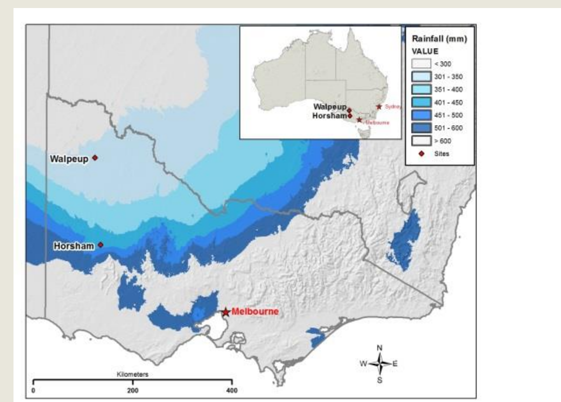
Grains Innovation Park, Department of Economic Development, Jobs, Transport and Resources, Horsham Victoria
The University of Melbourne, Parkville Victoria

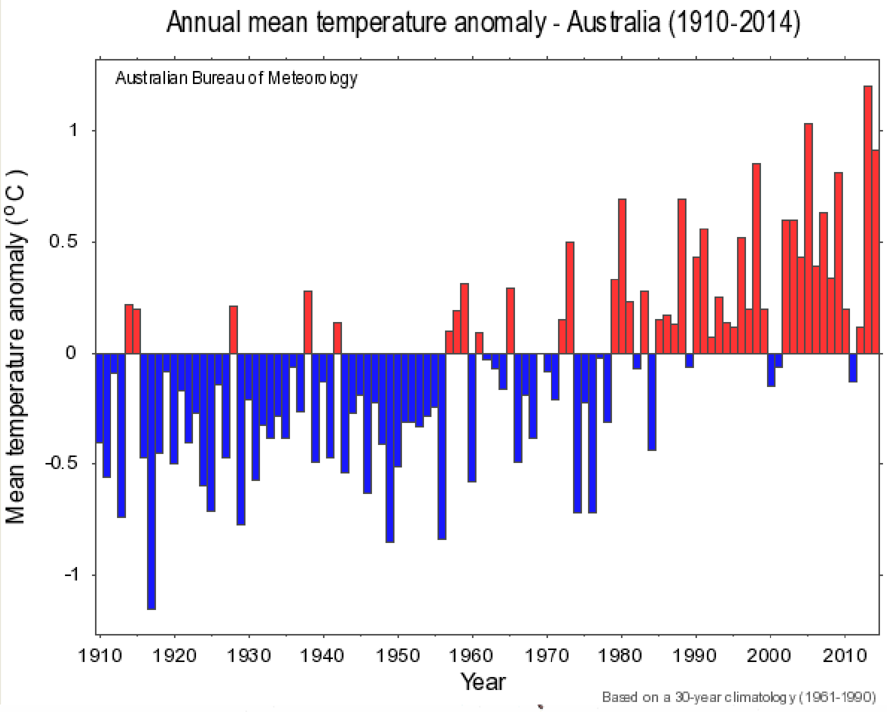


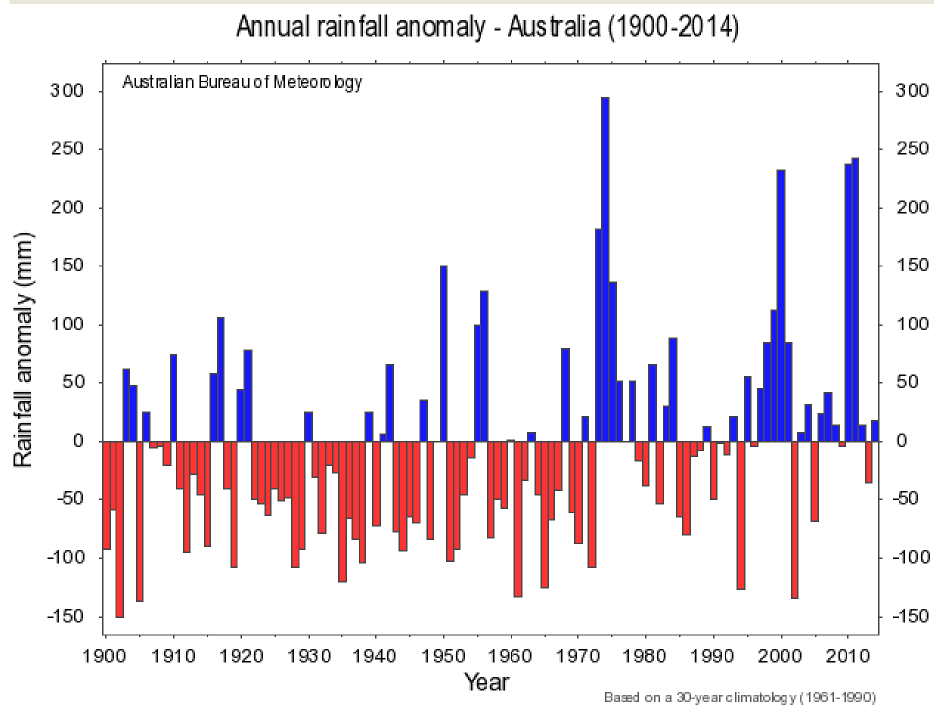
Introduction

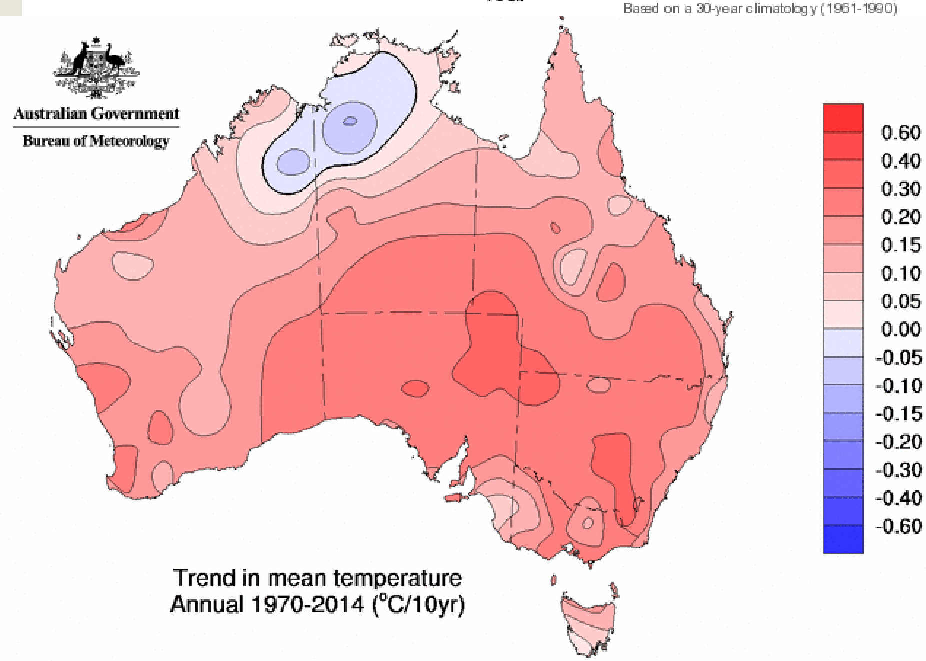
- Evolution not revolution
  - but much research and development to aid it (Connor 2004)
- Water shortage and high and low temperatures
  - critical environmental factors for wheat production in Australia
- Objective of presentation
  - A brief overview of factors affecting crop adaptation in Australia
  - The climatic trends
  - The present pace of adaptation
  - The links between water supply and temperature
  - Regional climatic and crop yield projections
  - Addressing the challenges with some field and modelling results
  - Not addressing extension or policy activities

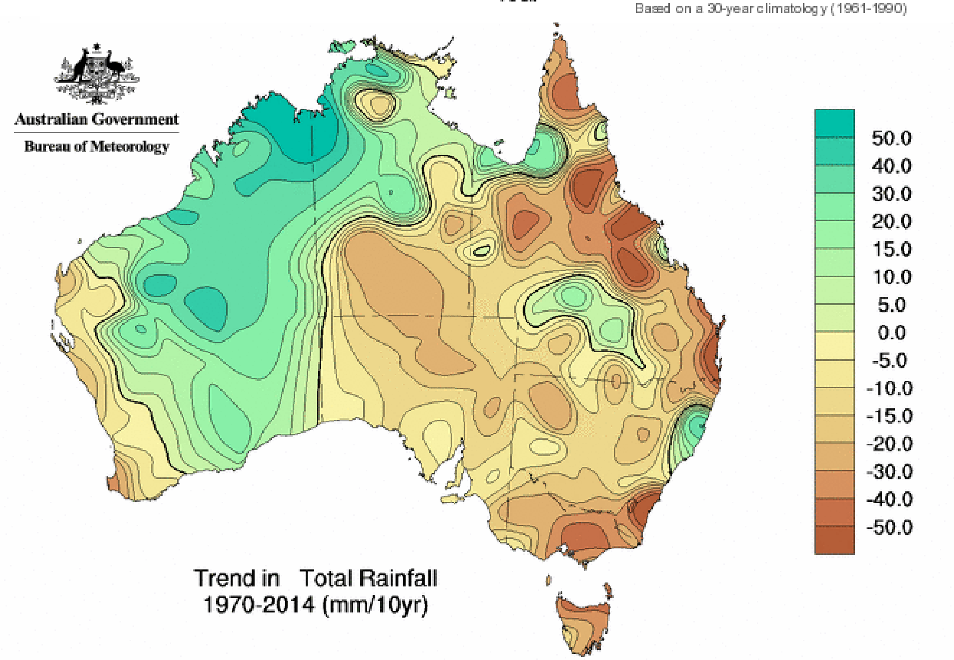
Historical trends in Climate

- Evidence in shifts in temperature in recent decades
- Cyclical changes in rainfall (ENSO) produce high variability
- No overall national trend in rainfall
  - But significant regional trends


Annual mean temperature anomaly - Australia (1910-2014)
Australian Bureau of Meteorology
Mean temperature anomaly (°C)
1
0.5
0
-0.5
-1
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
Year
Based on a 30-year climatology (1961-1990)

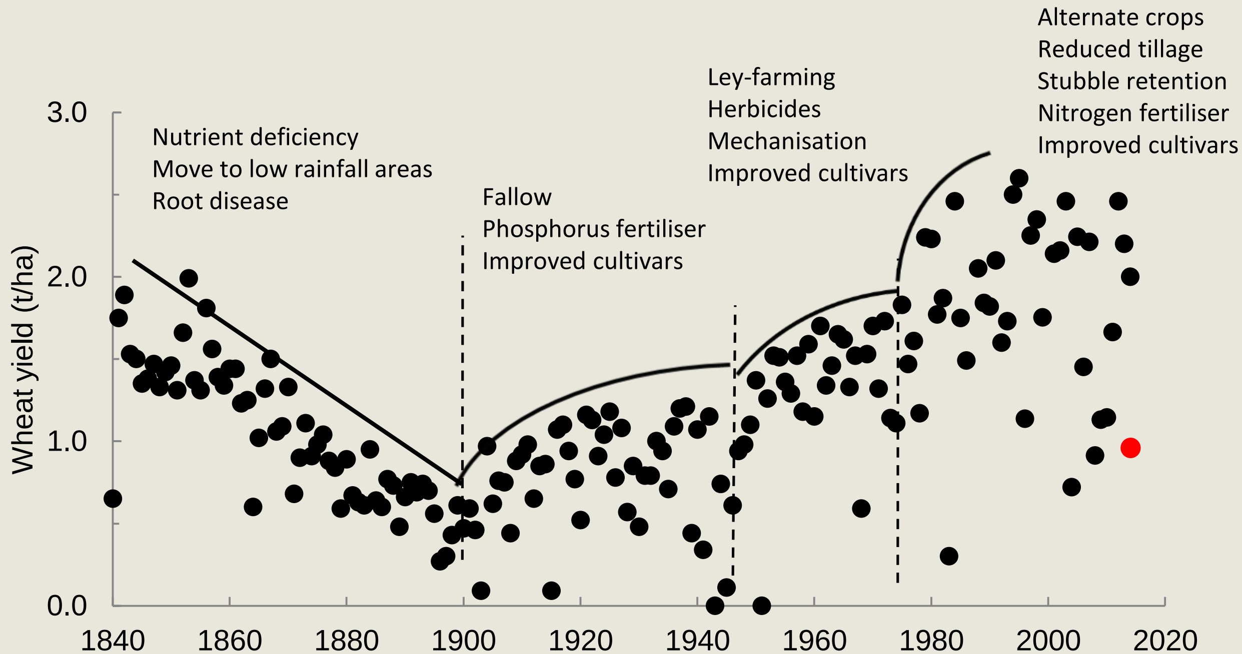

Annual rainfall anomaly - Australia (1900-2014)
Australian Bureau of Meteorology
Rainfall anomaly (mm)
300
250
200
150
100
50
0
-50
-100
-150
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
Year
Based on a 30-year climatology (1961-1990)


Australian Government
Bureau of Meteorology
0.60
0.40
0.30
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
-0.15
-0.20
-0.30
-0.40
-0.60
Trend in mean temperature
Annual 1970-2014 (°C/10yr)


Australian Government
Bureau of Meteorology
50.0
40.0
30.0
20.0
15.0
10.0
5.0
0.0
-5.0
-10.0
-15.0
-20.0
-30.0
-40.0
-50.0
Trend in Total Rainfall
1970-2014 (mm/10yr)

Crop adaptation – not new

- Since crops have been grown in Australia they AND MANAGEMENT have been adapted for increased productivity
- Adaptation greater than the past climatic changes over the last 100 years e.g. Victoria



Victorian Average annual wheat productivity 1840-2014

Adapted from Connor et al. 2011

Historical Trends in Yield

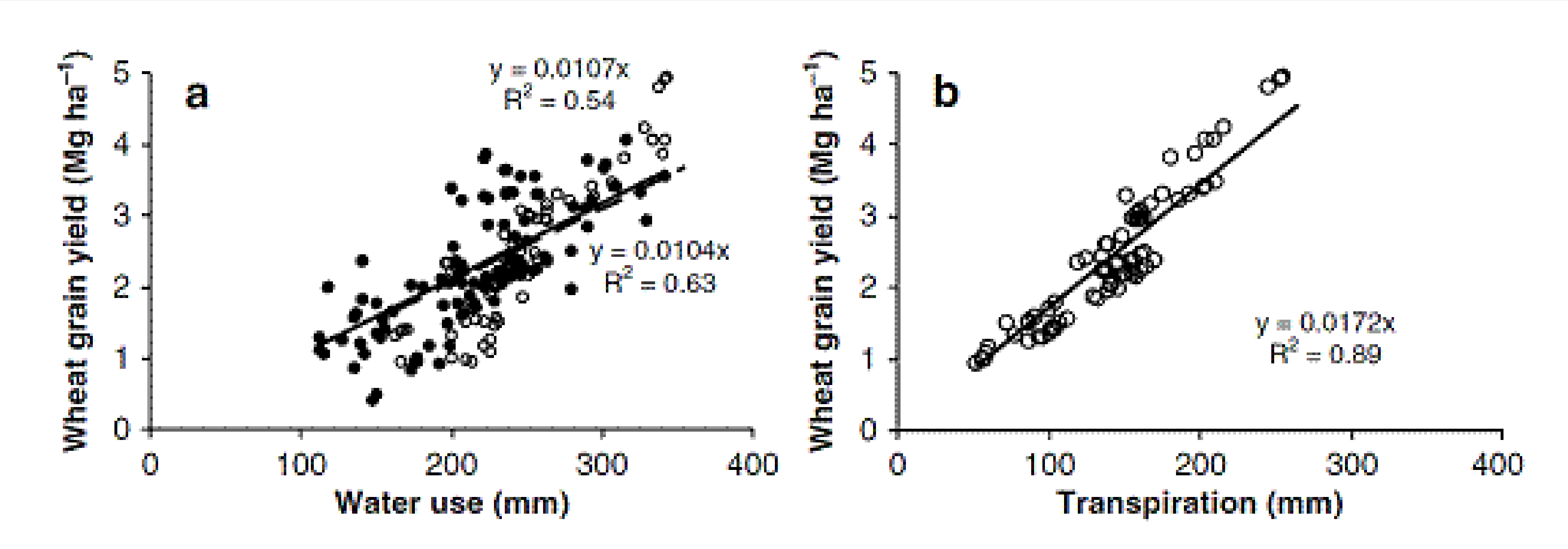
- Major increases in yield due to application of science and technology
- Trends show impact of variability of rainfall but no general trends
- Management changes much greater than historical climate change

Crop adaptation – the changing climate

- Need to define the climate at the local/regional scale
- But the climate is changing
  - The direction of change and variance are very important
  - Elevated temperature VARIANCE low
  - Elevated atmospheric CO_2 VARIANCE low
  - Lower/higher rainfall VARIANCE high
  - Elevated VPD VARIANCE high
  - Global/local economics VARIANCE high
- How?
  - Experiment with known cultivars and management
  - Define an ideotype – the ideal crop
  - Look for genetic evidence of ideotype features
  - Experiment with computer models across GxExM
  - Go make a proof-of-concept crop

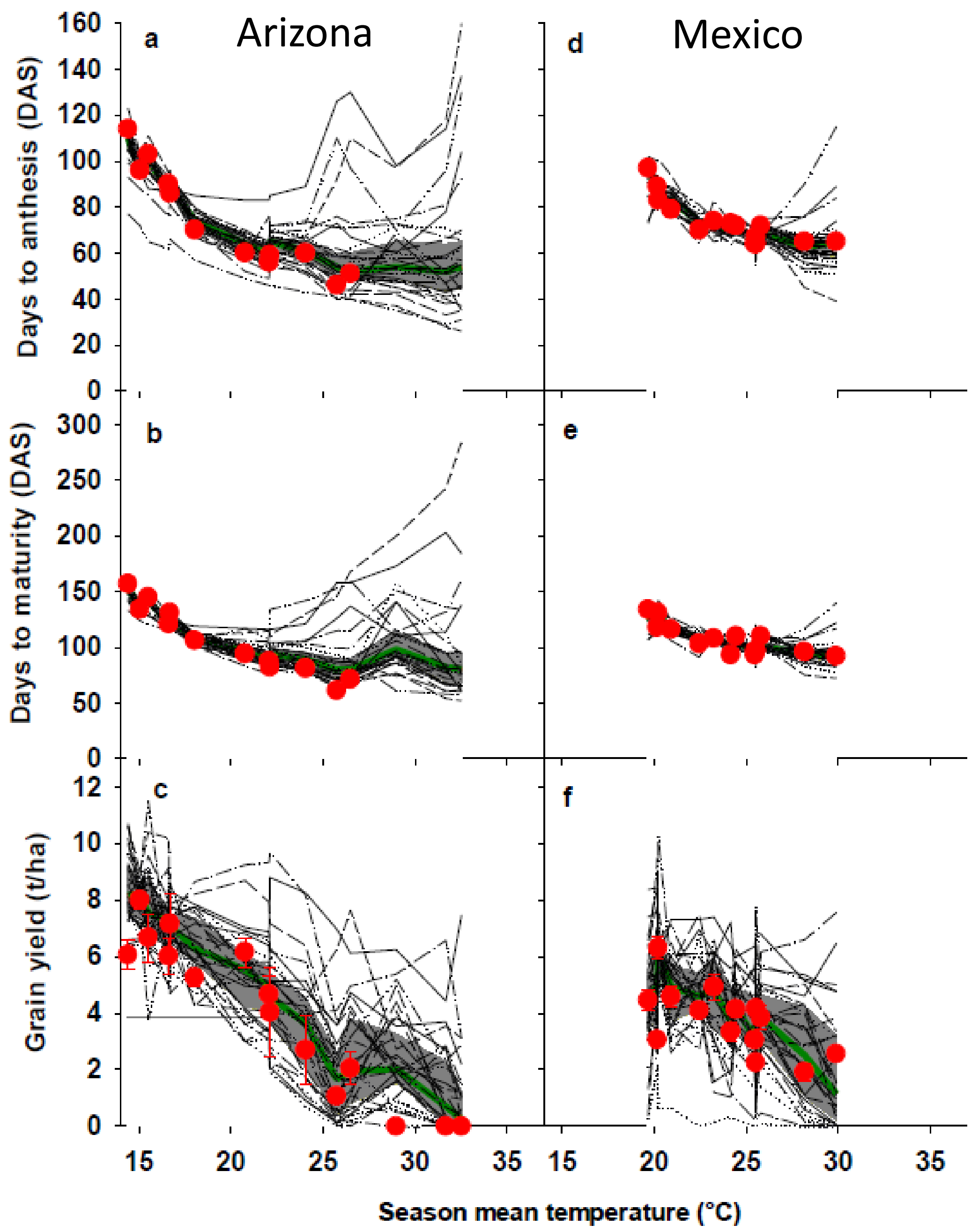
Understanding crop response

- Role of water and temperature
- Free Air CO_2 Enrichment (FACE) and CO_2 response



Latta and O'Leary 2003

Effects of high mean temperatures on wheat yield

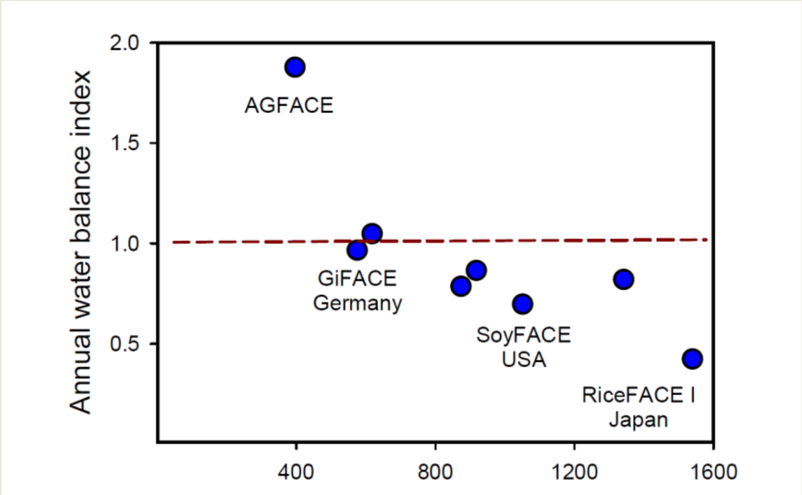


Comparison of 30 different crop models (grey shade) against measured data (red dots)

Note:
(1) Some model failures
(2) Actual crop failures

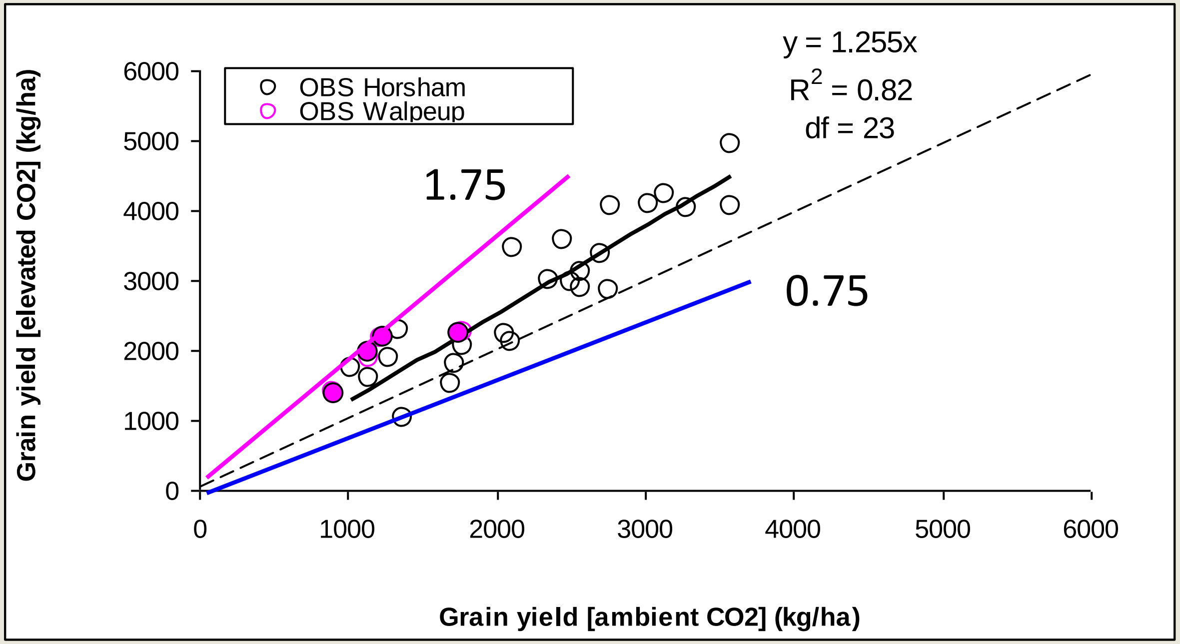
Asseng et al. 2014

The Australian Grains FACE experiment (AGFACE)



- Create range of environments to test effect of **interactions** with elevated CO_2 (550 ppm) in low production (1-4 t/ha) zones
- Provide validation data set under future CO_2 - rich atmosphere
- AGFACE is in lowest rainfall zone of all FACE projects internationally
- Agronomy and physiology
  - Traits (tillering, stem carb, TE)
  - Yield, grain quality (nutrition, bread/noodles)
- C & N dynamics
  - wheat-pea rotation
- Crop-pest dynamics
  - Crown rot, BYDV, (stripe rust)

Growth under elevated CO_2

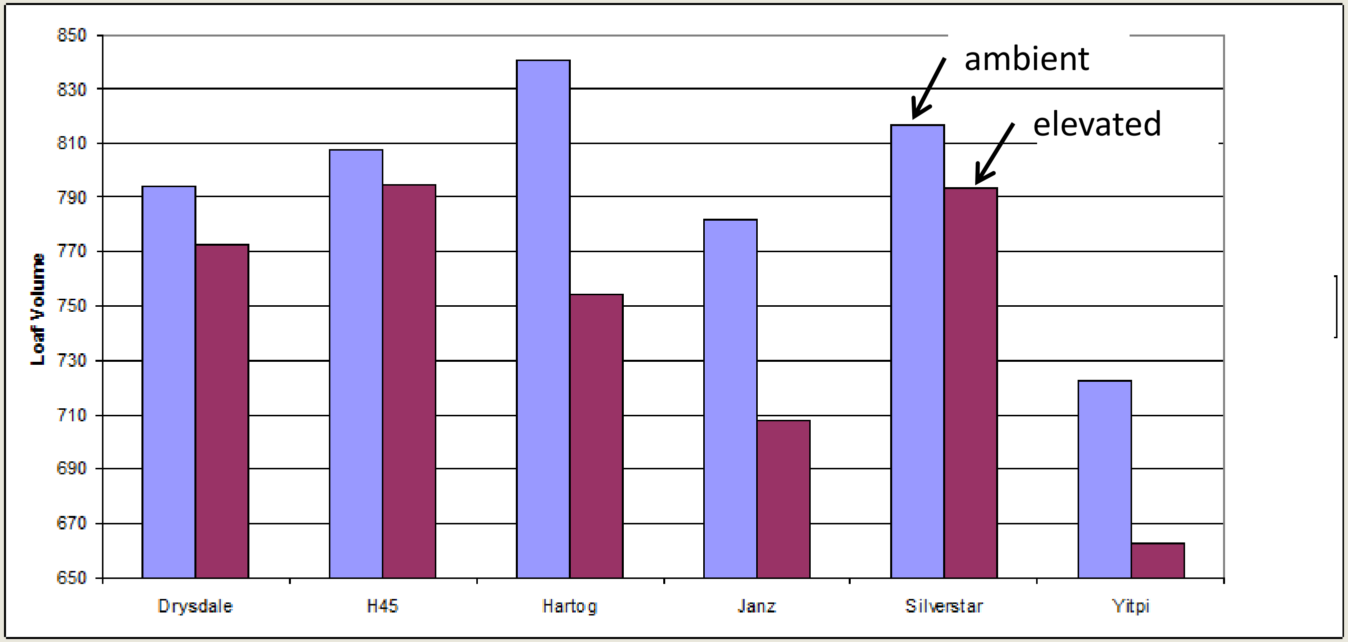


Slope through zero 95% confidence interval 1.18 to 1.33

Yield variability - wheat

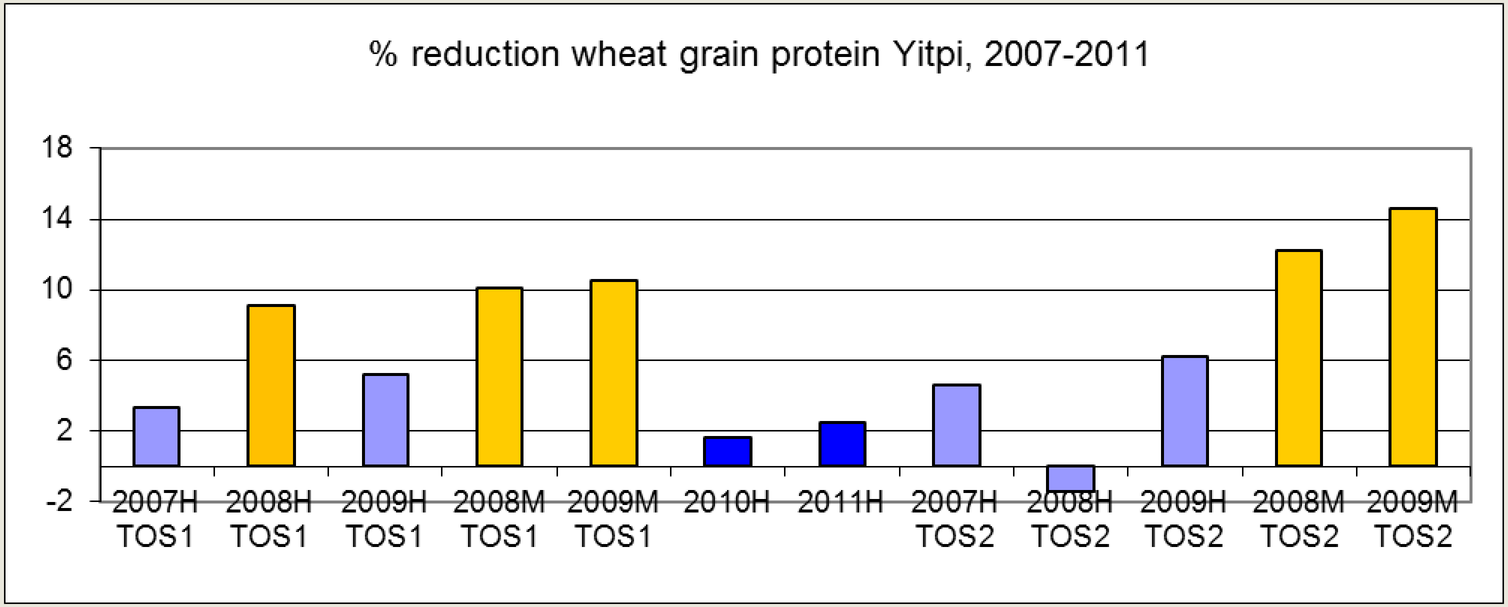
Cultivar	% increase						
	2007	2008	2009	2010	2011	2012	2013
Yitpi, N0	18	20	35	44	3	19	27
Yitpi, MRS		60	54				
Janz	19	31	35	9	16	29	
Drysdale			20	32			
Gladius			22				
H45			26	23	28		
Hartog			0	14			
Zebu			38	21			
Silverstar			37	23	34	25	
SSR T65 hi					32	25	
SB003 low					12	31	
SB062 hi					29	25	
Impala							35
Bolac							35
Scout							33
Rosella							47
Spitfire							21
Mean	**19**	**24**	**27**	**23**	**21**	**26**	**33**

Baking Quality



Panozzo et al. 2014

Grain Quality: Environment

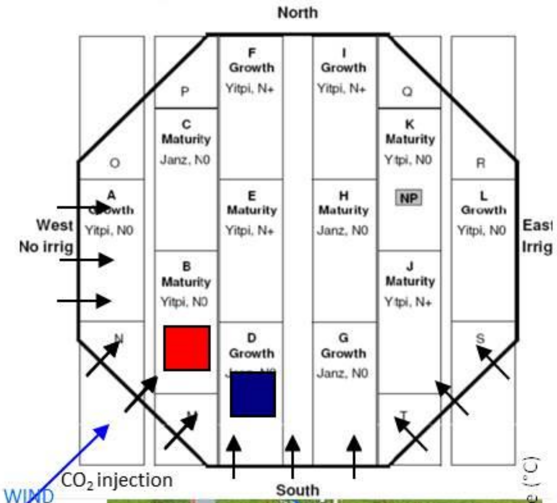


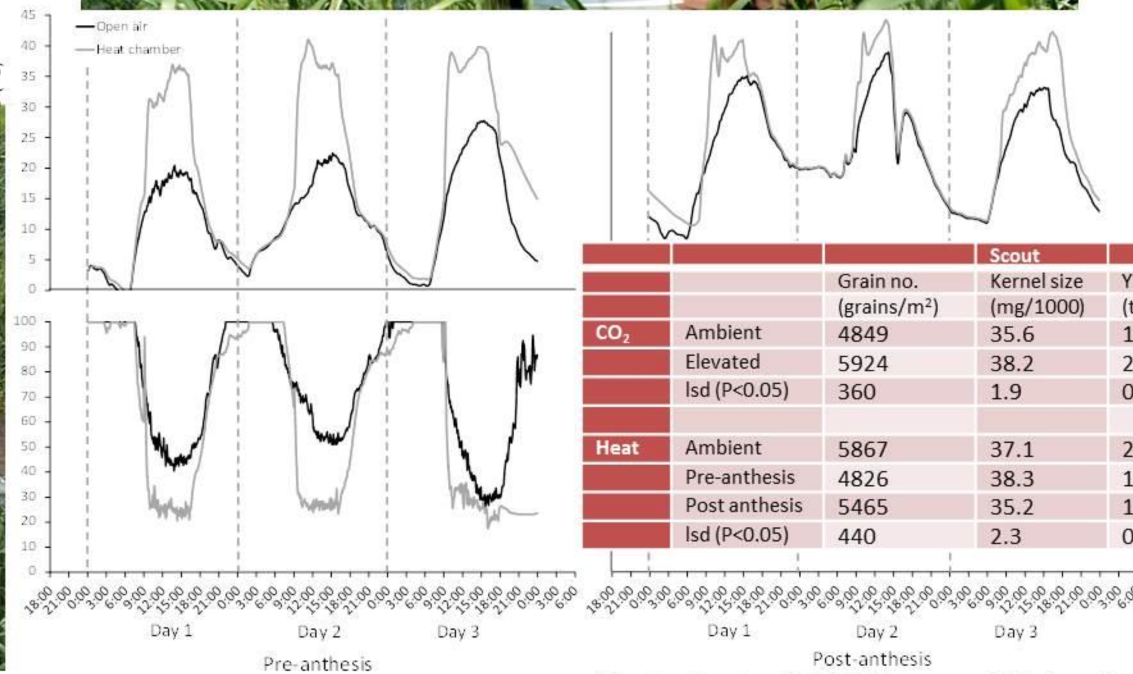
Dry = yellow, Wet = blue, Intermediate = purple

Greater reductions in drier environments

Heat waves and wheat growth under a future climate

Simulated heat waves applied to wheat 36 to 38°C for 3 days at flowering and early grain filling at 390 and 550 ppm CO_2 at AGFACE

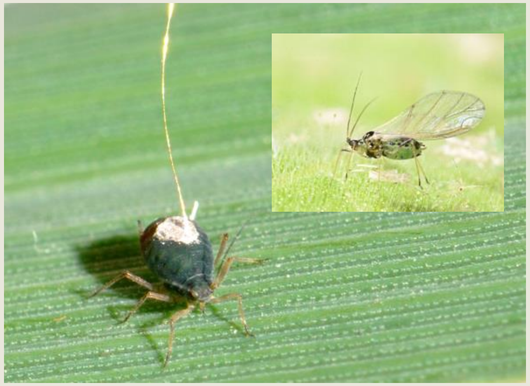




			Scout		
		Grain no. (grains/m²)	Kernel size (mg/1000)	Yield (t/ha)	HI
CO_2	Ambient	4849	35.6	1.7	0.35
	Elevated	5924	38.2	2.2	0.35
	lsd (P<0.05)	360	1.9	0.2	ns
Heat	Ambient	5867	37.1	2.2	0.37
	Pre-anthesis	4826	38.3	1.8	0.35
	Post anthesis	5465	35.2	1.9	0.35
	lsd (P<0.05)	440	2.3	0.2	ns

Nuttall et al 2015 unpublished data

Climate change: pests and diseases



Insect pests
Biology
Feeding behaviour
Virus transmission and acquisition efficiency
Host selection

Plant
Growth and yield affected by pests and pathogen
Quality; C:N, amino acids
Defence mechanisms, pests and pathogens resistance

Pathogen
Barley yellow dwarf virus (BYDV)
Severity; yield and quality
Virus titre determination

Trebicki et al. 2015

Summary of field results

- Large biomass and yield gains under eCO_2 (25%)
- Crop leaf area increases (17-21%)
- Specific leaf nitrogen (AND GRAIN N) decreases (5-12%) (consistent with biomass and N uptake responses - lower bread-making quality
- Increased Barley Yellow Dwarf Virus in wheat
- More nutrients required
- Very small reductions in water use under eCO_2 (-6%) but large water use efficiency gains under eCO_2 (31%)
- Beneficial crop traits identified
- Managing crop water supplies is critical

Modelling approaches

- Modelling widens the experimental space
  - Provides a probabilistic approach
  - Provides a spatial approach
  - Lower costs
  - Can afford higher innovation risks
  - Goes beyond experimental data by design

- Modelling must be linked to reality
  - Notwithstanding the need to go beyond the data - some model output needs to be compared to real data
  - Hypotheses need to be tested against measured data
  - Models can be compared against other models

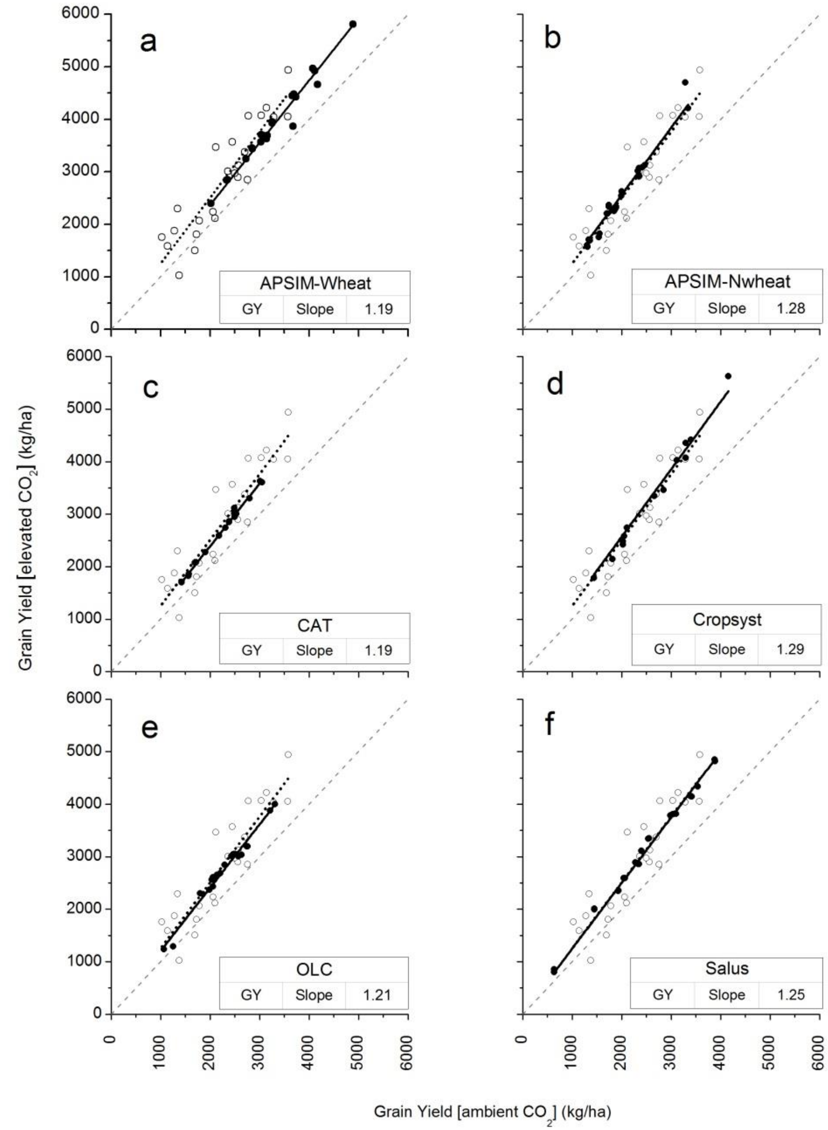
Previous modelling studies

- Wide range of studies (QLD, WA, NSW, VIC)
- Wide range of suitable models (APSIM, DSSAT, CROPSYST, WANG & CONNOR)
- Larger range of assumptions of future climate
- Varied conclusions
  - Elevated CO_2 increased wheat yields – greater % increase in dry years
  - Higher temperatures reduced these CO_2 yield gains with some lower yield response under low rainfall
  - eCO_2 increased grain yield (+18 to +36%)
  - At Birchip eCO_2 + Increased T + reduced rain
  - => (-20%) [APSIM=CROPSYST=DSSAT]
  - High quality grain under threat
  - Long season types beneficial

Crimp et al. 2008 (Garnaut review) and many others

Recent modeled responses to elevated CO_2

APSIM-Wheat	1.19
APSIM-NWheat	1.28
CAT	1.19
CROPSYST	1.27
OLEARY & CONNOR	1.21
SALUS	1.25
Observed data	1.26 (1.19-1.32)



O'Leary et al. 2015

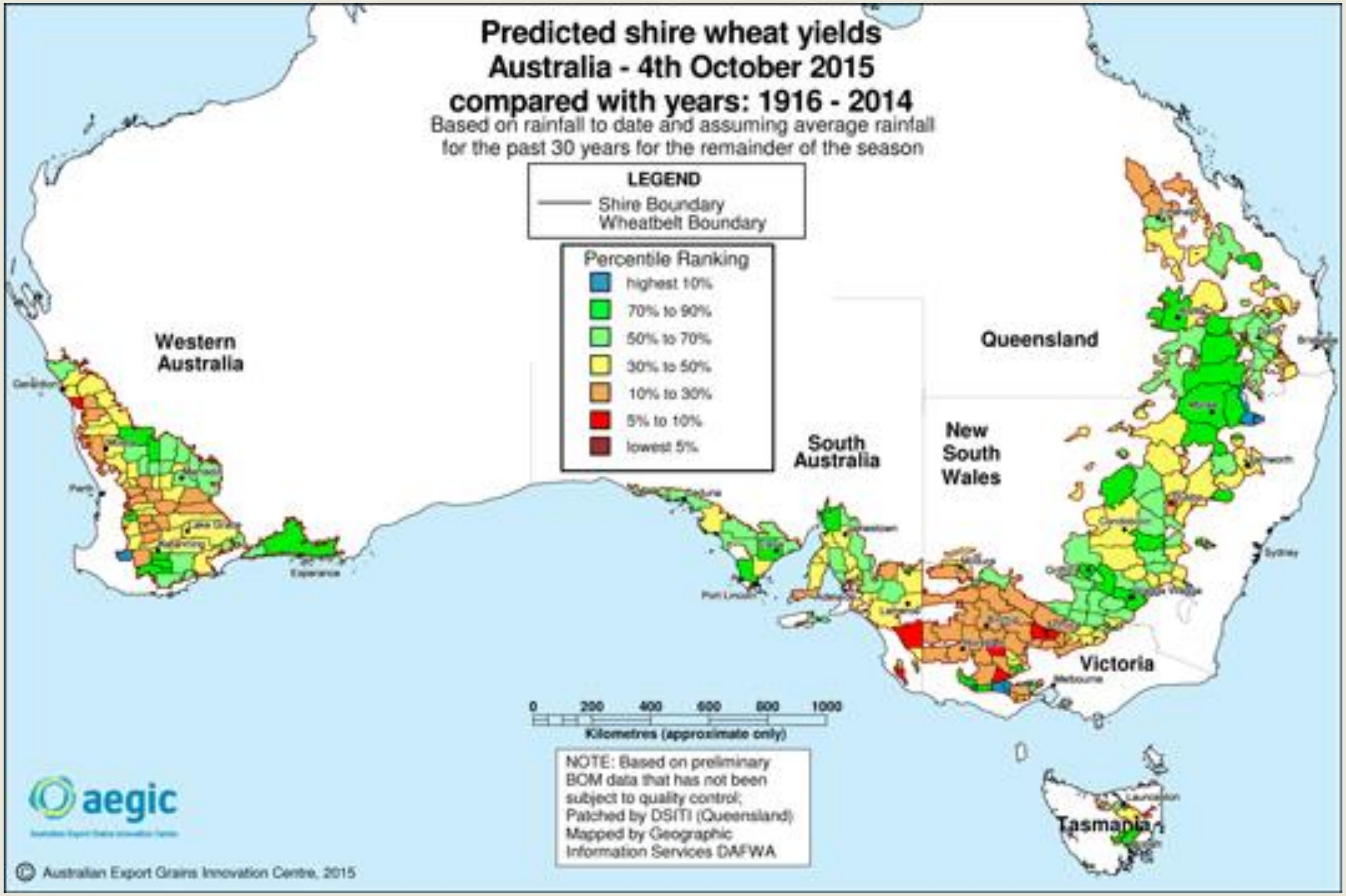
Regional climate projections

- Projected mean wheat yield losses (%)

	2030	2050
New South Wales	8.4	11.6
Victoria	9.6	13.4
Western Australia	8.9	13.4

Bureau of Meteorology 2015

Regional wheat yield prediction for 2015

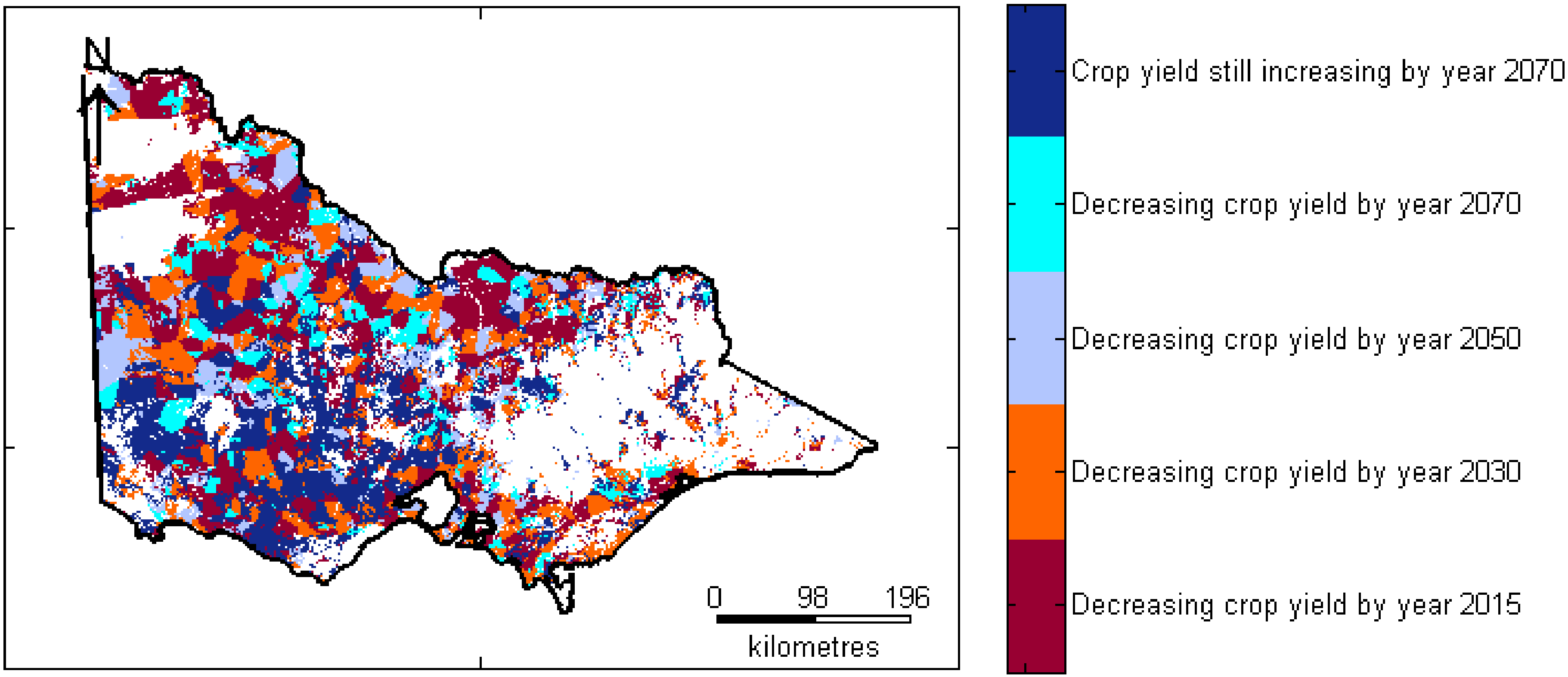


Australian Export Grains Innovation Centre 2015

Model Projections of response

- A range of modelling studies
- Some general – results
- Others local – some with greater decreases
- General conclusions of significant impacts
- Yield losses
- Evident need for adapted phenological development patterns

Direction of Change



CSIRO CCAM Mark 3 present-day long-season cultivar under IPCC A1Fi scenario

O'Leary et al. 2011

Key Findings for Australia

- Climate change is making weather patterns more extreme and unpredictable, with serious consequences for Australia's agricultural production

- More frequent and intense heatwaves and extreme weather events are already affecting food prices in Australia

- Climate change is affecting the quality and seasonal availability of many foods in Australia

Feeding a Hungry Nation: Climate change, Food and Farming in Australia

Climate Council of Australia 2015

Key Findings for Australia…

- Australia is extremely vulnerable to disruptions in food supply through extreme weather events

- Australia's international competitiveness in many agricultural markets will be challenged by the warming climate and changing weather patterns

- If the current rate of climate change is maintained, adaptation to food production challenges will be increasingly difficult and expensive

Feeding a Hungry Nation: Climate change, Food and Farming in Australia

Climate Council of Australia 2015

Summary

- Past productivity gains have been greater than what can be attributed to past climatic change
- Projected climatic changes should be taken seriously
- Crop adaptation is best advanced by incremental changes
- eCO_2 increases crop yield
  - BUT temperature and drought effects are greater
- Semi-arid zone: Potential yield LOSS (-10 to -20%)
- Higher rainfall zone: Yield GAINS (+10 to +20%)
- Higher rainfall zone: Yields still increasing by 2070
- Higher rainfall zone: Need longer-season spring types
- All zones: Present-day long-season cultivars behave like short-season cultivars under warmer climates
- All zones: Poor grain quality still an issue

- The task is large but not underestimated
- Need greater collaborative efforts from scientists, society, farmers and Government

Addressing the challenges

- Increased weather variability
- Crop adaptation
- Management adaptation
- Understanding pests and disease
- Better models and apps
- Better experiments
- Multi-discipline teams – virtual institutions
- Food supply and prices

Acknowledgements

- Department of Economic Development, Jobs, Transport and Resources, Victoria
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AgMIP The Agricultural Model Intercomparison and Improvement Project

Grains Innovation Park – Horsham Victoria

Transitioning Cereal Systems to Adapt to Climate Change

REACCH
Regional Approaches to Climate Change –
PACIFIC NORTHWEST AGRICULTURE

Thank you!

University of Idaho

Washington State University

USDA NIFA

United States Department of Agriculture
National Institute of Food and Agriculture

Oregon State University OSU

CHS

Pacific Northwest Farmers Cooperative

Monsanto