Australian Grains Free Air CO_2 Enrichment (AGFACE) program

AGFACE: Elevated CO_2 Research in the Great Southern (dry) Land

AGFACE team

DEPI and UM

piccc
Primary Industries Climate Challenges Centre

State Government Victoria
Department of Environment and Primary Industries

THE UNIVERSITY OF MELBOURNE

GRDC Grains Research & Development Corporation

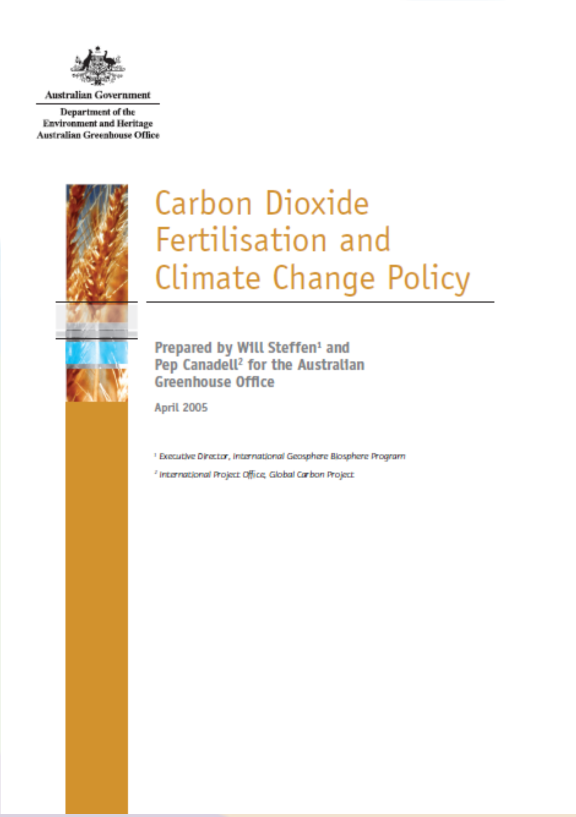
Australian Government
Department of Agriculture
Australian Research Council

AGFACE is a collaborative research program led by the Department of Environment and Primary Industries Victoria and the University of Melbourne, with core funding support from the Grains Research and Development Corporation and the Australian Government Department of Agriculture.

History – Why a FACE in Oz?

- Uncertainty about climate change impact in Oz
- Crop models required verification/validation
  - Links to climate models
- No CO_2 data for crop systems typical of Australia
- Need to understand interactions of eCO_2 with H_2O, N, C allocations in plants
- Three year AGFACE project
  - University of Melbourne & DPI Victoria
  - Data for wheat model verification
- Kimball visit 2005 to AGO

Reports – Laying the groundwork


Australian Government
Department of the Environment and Heritage
Australian Greenhouse Office

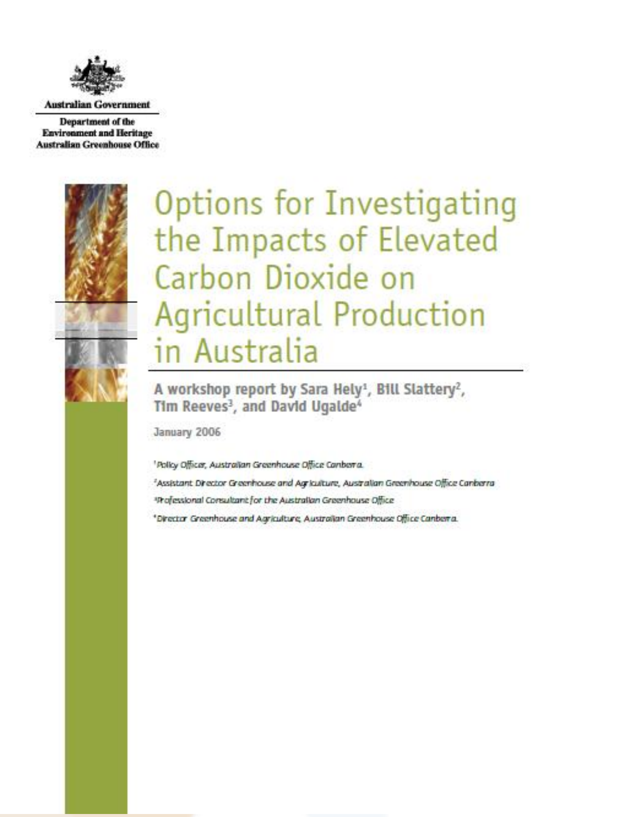
Carbon Dioxide Fertilisation and Climate Change Policy

Prepared by Will Steffen[1] and Pep Canadell[2] for the Australian Greenhouse Office

April 2005

[1] Executive Director, International Geosphere Biosphere Program
[2] International Project Office, Global Carbon Project

2005


Australian Government
Department of the Environment and Heritage
Australian Greenhouse Office

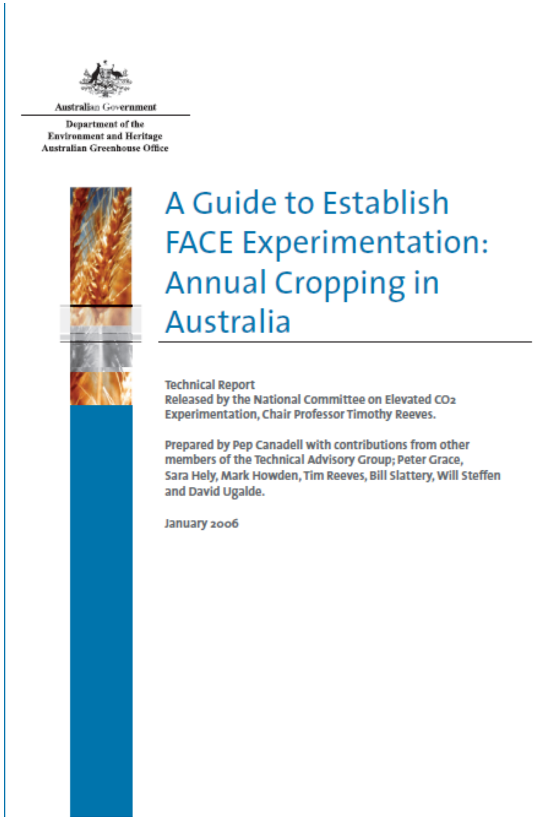
Options for Investigating the Impacts of Elevated Carbon Dioxide on Agricultural Production in Australia

A workshop report by Sara Hely[1], Bill Slattery[2], Tim Reeves[3], and David Ugalde[4]

January 2006

[1] Policy Officer, Australian Greenhouse Office Canberra
[2] Assistant Director Greenhouse and Agriculture, Australian Greenhouse Office Canberra
[3] Professional Consultant for the Australian Greenhouse Office
[4] Director Greenhouse and Agriculture, Australian Greenhouse Office Canberra.

2006


Australian Government
Department of the Environment and Heritage
Australian Greenhouse Office

A Guide to Establish FACE Experimentation: Annual Cropping in Australia

Technical Report
Released by the National Committee on Elevated CO_2 Experimentation, Chair Professor Timothy Reeves.

Prepared by Pep Canadell with contributions from other members of the Technical Advisory Group; Peter Grace, Sara Hely, Mark Howden, Tim Reeves, Bill Slattery, Will Steffen and David Ugalde.

January 2006

2006

Reports – Laying the groundwork

- **From Steffen and Canadell, 2005:**
- Additional experimental work on the effects of elevated CO_2 on Australian plant-based systems –

  (1) in situ wheat crops using standard management regimes of the semi-arid Australian wheat belt, and

  (2) whole tree studies in water-limited systems;
- Studies of multiple interacting factors on terrestrial production systems;
- Analysis of interactive effects of elevated CO_2 and extreme climate events (eg, drought);
- Adaptability of Australian terrestrial production systems;
- Pest and disease dynamics

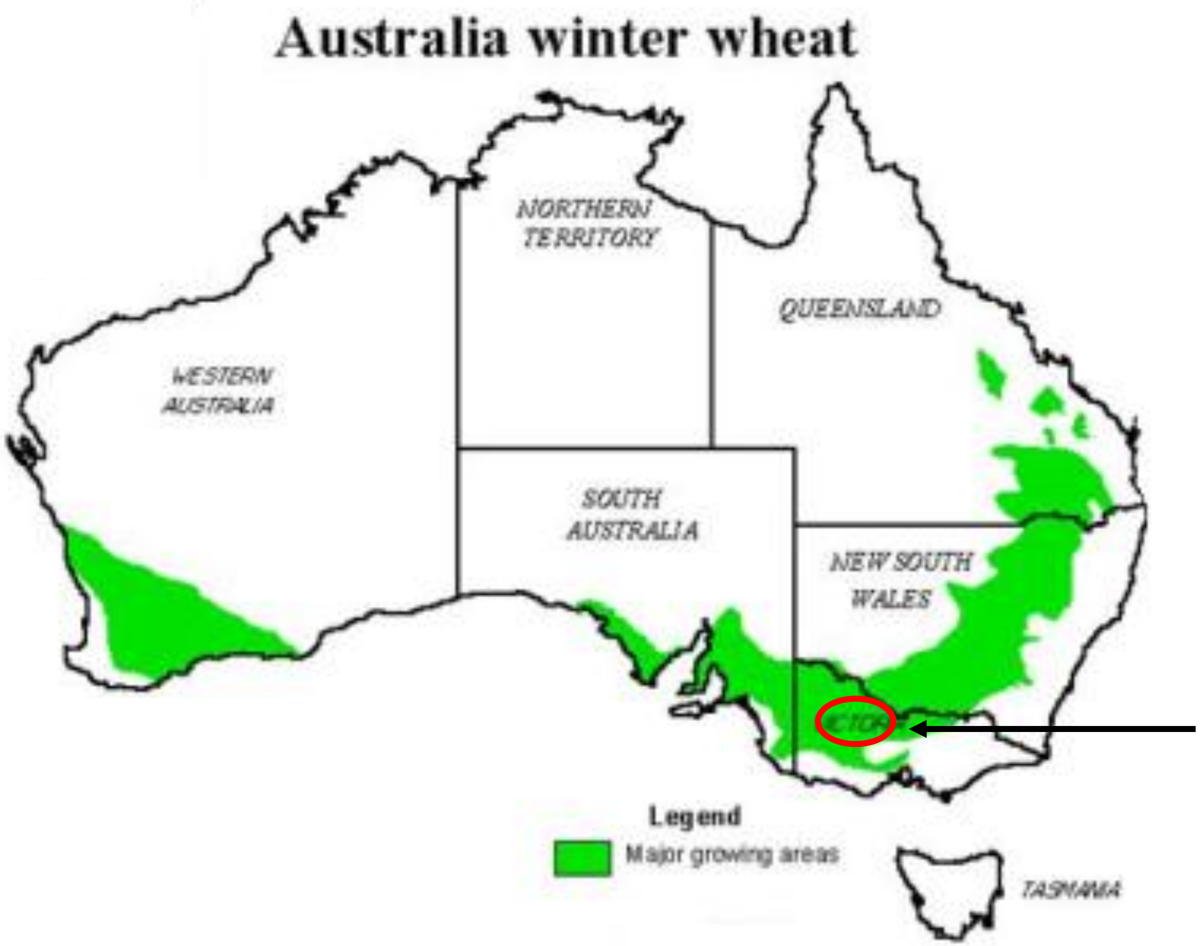
Reports – Laying the groundwork

- **From Canadell, 2006 (original research questions):**
- Will elevated CO_2 concentrations partially alleviate water stress and the effects of increased climate variability in a future warmer climate?
- Will higher yields in a rich-CO_2 world come at a financial cost? (e.g. need for larger nitrogen additions to maintain grain protein content)
- Are there significant differences in the CO_2 responses from different genotypes that could be utilised to maximise productivity?

Adaptation

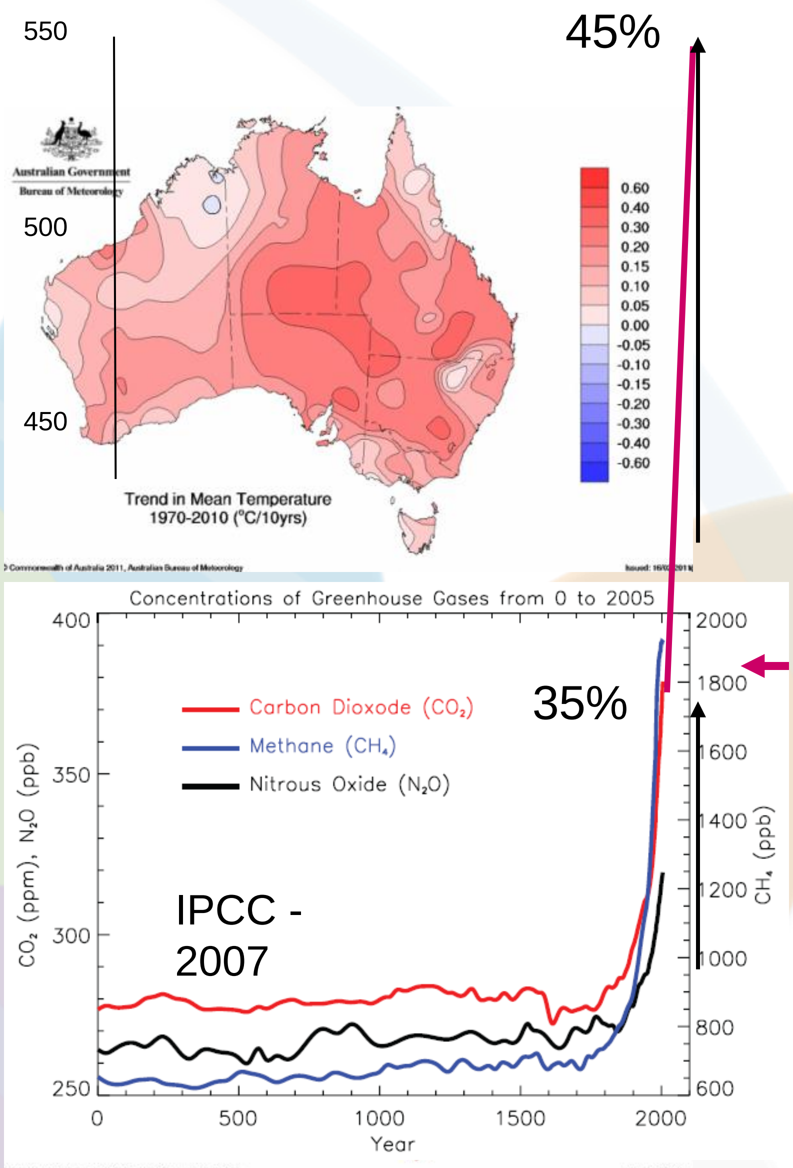
What are the combinations of management techniques and germplasm across environments that will ensure sustainable production in the Australian grains industry in the future?

Australian Wheat Belt



Horsham
& Walpeup

A Changing Environment



- Atmospheric CO_2 levels are rising (1860 ~280 ppm, 2012 ~ 385 ppm, 2050 = 550 ppm, ~2.5 ppm pa)
- Plant growth, yield and water use efficiency increase within this range of CO_2 (non-limiting factors)
- Temperature increasing and rainfall decreasing
- Extreme events predicted to become more frequent

What will be the effects of eCO_2 (and climate change) on Australian grains and …

How can we adapt?

Techniques to Study eCO_2

- Glasshouses
- Open topped chambers
- Gradient tunnels
- Enclosed Chambers

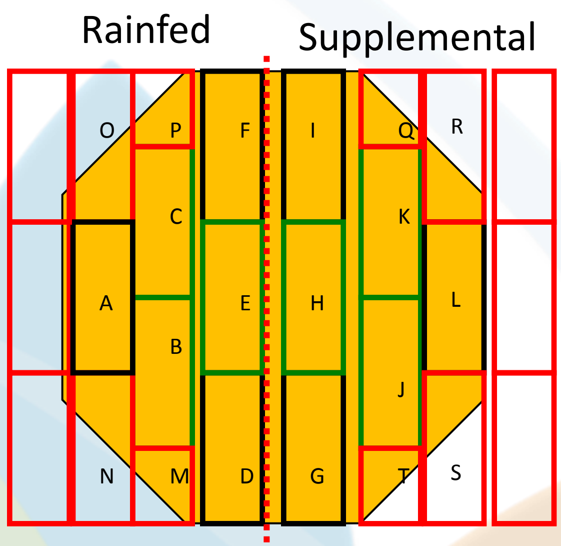
- Free Air CO_2 Enrichment (**FACE**)

FACE provides the most realistic assessment of elevated CO_2 on plant/crop responses because plants are not enclosed and can study whole system.

AGFACE Rings

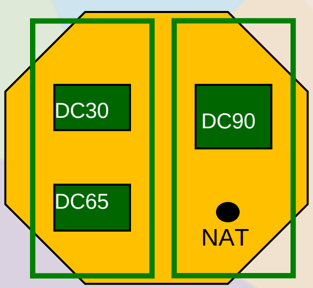
- 16 m ring, Horsham
- 4 m ring, Walpeup
- Aerial view, Horsham

AGFACE Design



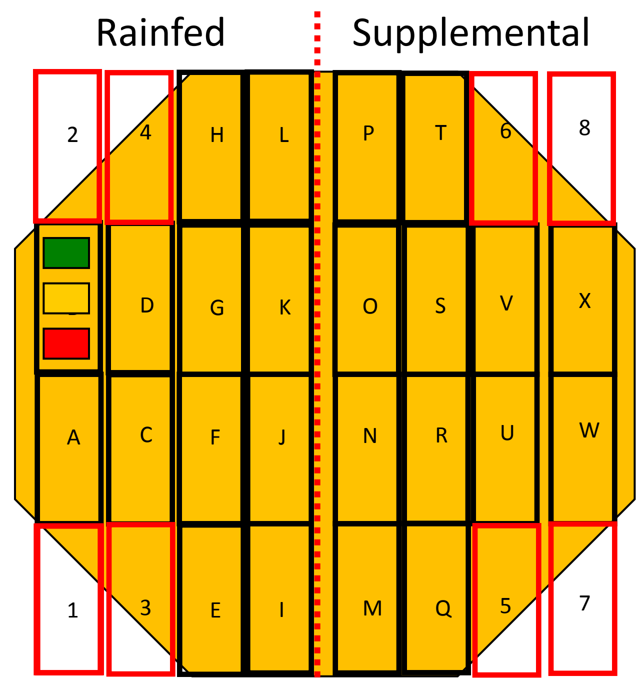
2 CO_2
2 TOS
2 Irr
2 var
2 N
4 reps
3 samples

Horsham, AGFACE: 2007-08, 12 m



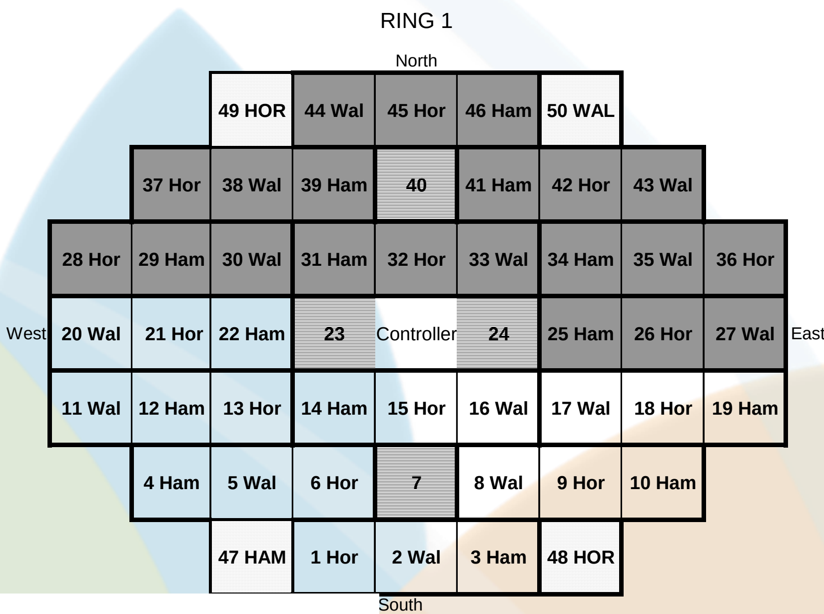
2 CO_2
2 TOS
4 reps
3 samples

Walpeup: 2008-09, 4 m



Horsham, AGFACE: 2009-13, 16 m

SoilFACE



SoilFACE designed to understand soil nutrient supply and dynamics.

1) eCO_2 impacts on root ability to access nutrients and water

2) Soil type effects on nutrient supply

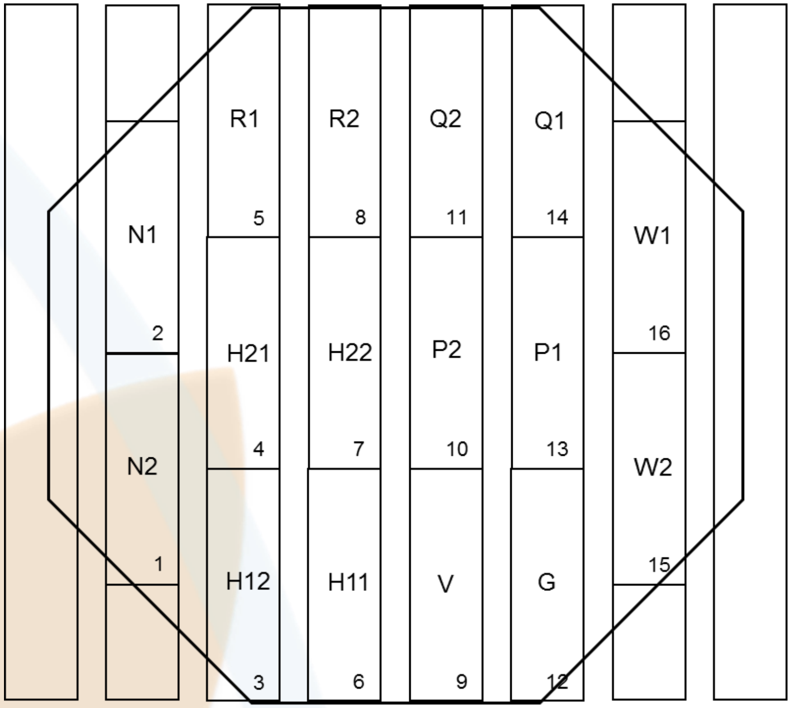
3) eCO_2 effects on N, P and C dynamics (incl. N fixation)

AGFACE 2014 +

TraitFACE

Test:

1) root, protein quality, NUE traits;
2) BYDV & aphid responses;
3) Heat shocks,
4) Multigeneration eCO_2



Example

eCO_2 X Wheat

12m ring

Treatments
Roots (R) – Scout, Yitpi
Quality (Q) – RS4 11-1, RS4 11-5
Wet – Scout, Yitpi
Nitrogen Use Efficiency (N) – Gladius, Wyalkatchem
Heat Shock (H) – Scout, Yitpi
Pests (P)
Multiple varieties (V)
Generational response (G)

1) Can we reduce/ reverse the reduction in grain protein through genetics or management?

2) Impact of eCO_2 on water and N resource use?

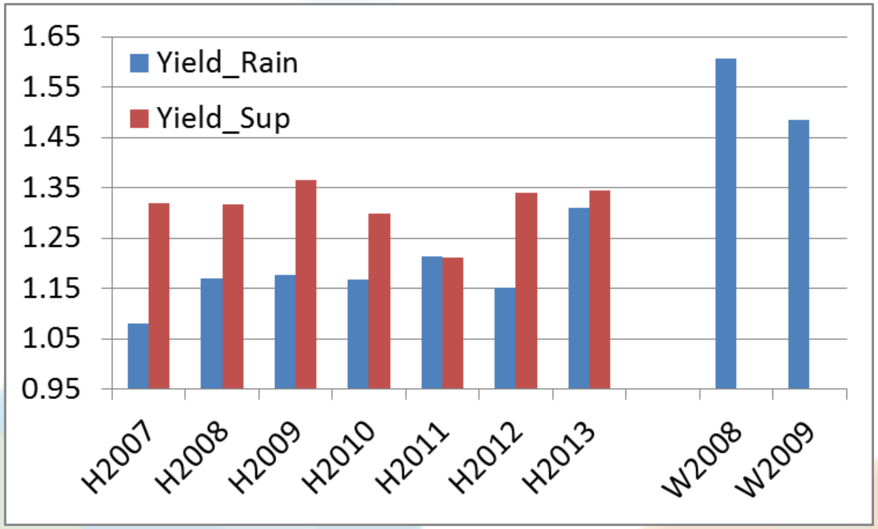
Yield variability – wheat

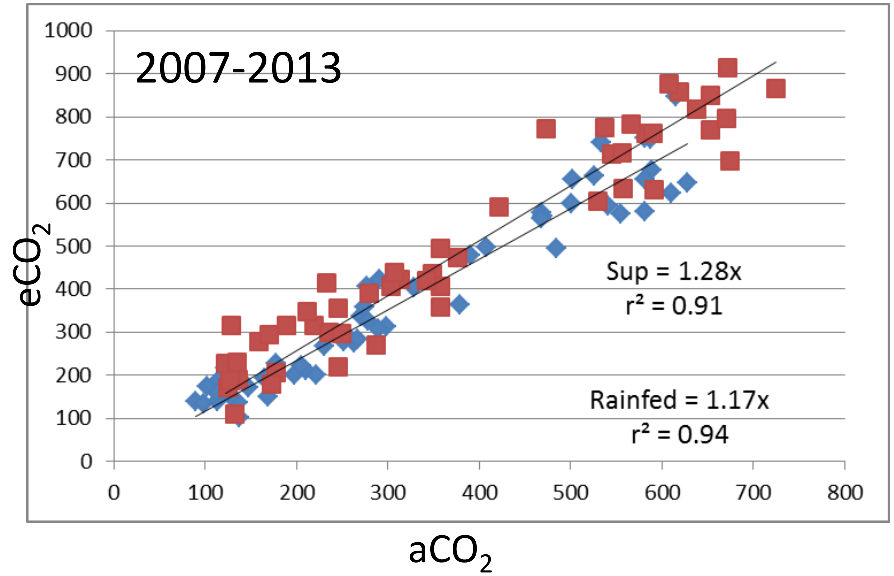
Cultivar	% increase						
	2007	2008	2009	2010	2011	2012	2013
Yitpi, N0	18	20	35	44	3	19	27
Janz	19	31	35	9	16	29	
Drysdale			20	32			
Gladius			22				
H45			26	23	28		
Hartog			0	14			
Zebu			38	21			
Silverstar			37	23	34	25	
SSR T65 hi					32	25	
SB003 low					12	31	
SB062 hi					29	25	
Impala			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

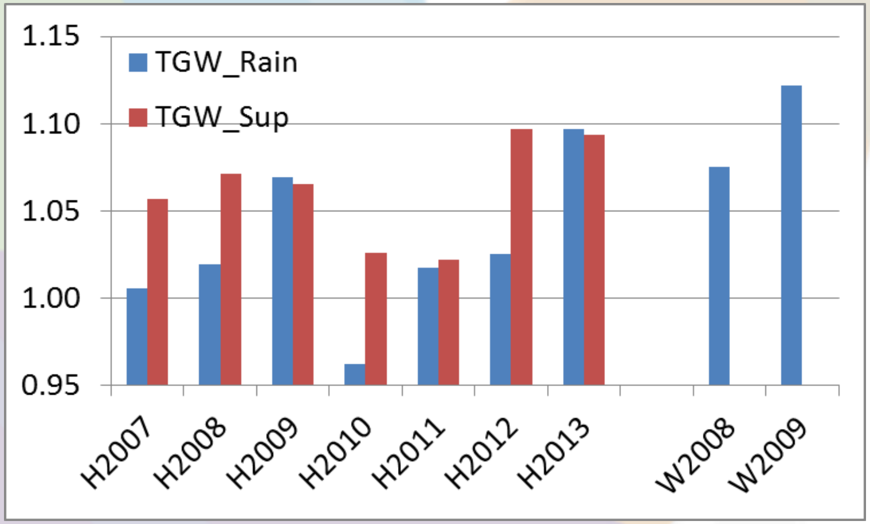
Yield variability – field pea

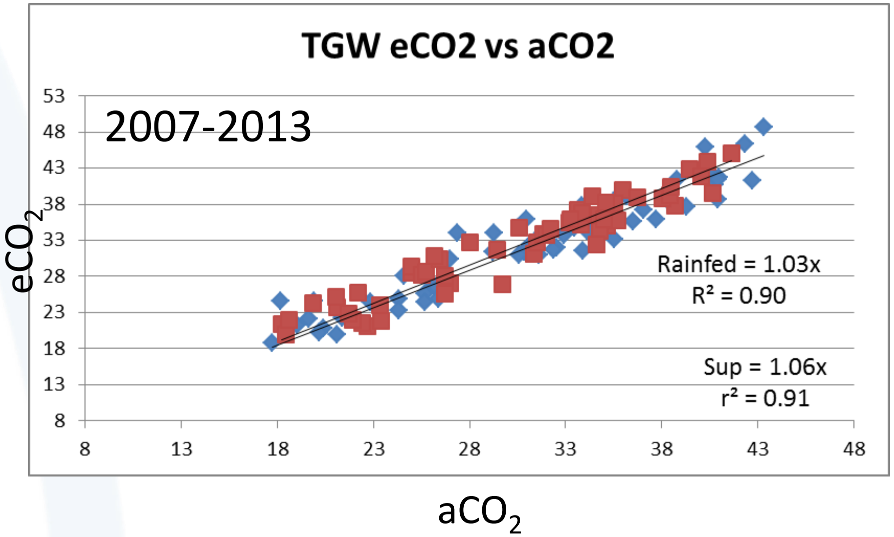
Pea cultivar	% increase		
	2010	2011	2012
Bohatyr	--	2	55
Kaspa	18	37	49
OZP0902	50	9	36
Twilight	33	0	29
Sturt	19	25	31
Mean	**27**	**14**	**40**

Responsiveness to eCO_2 by H_2O trmt

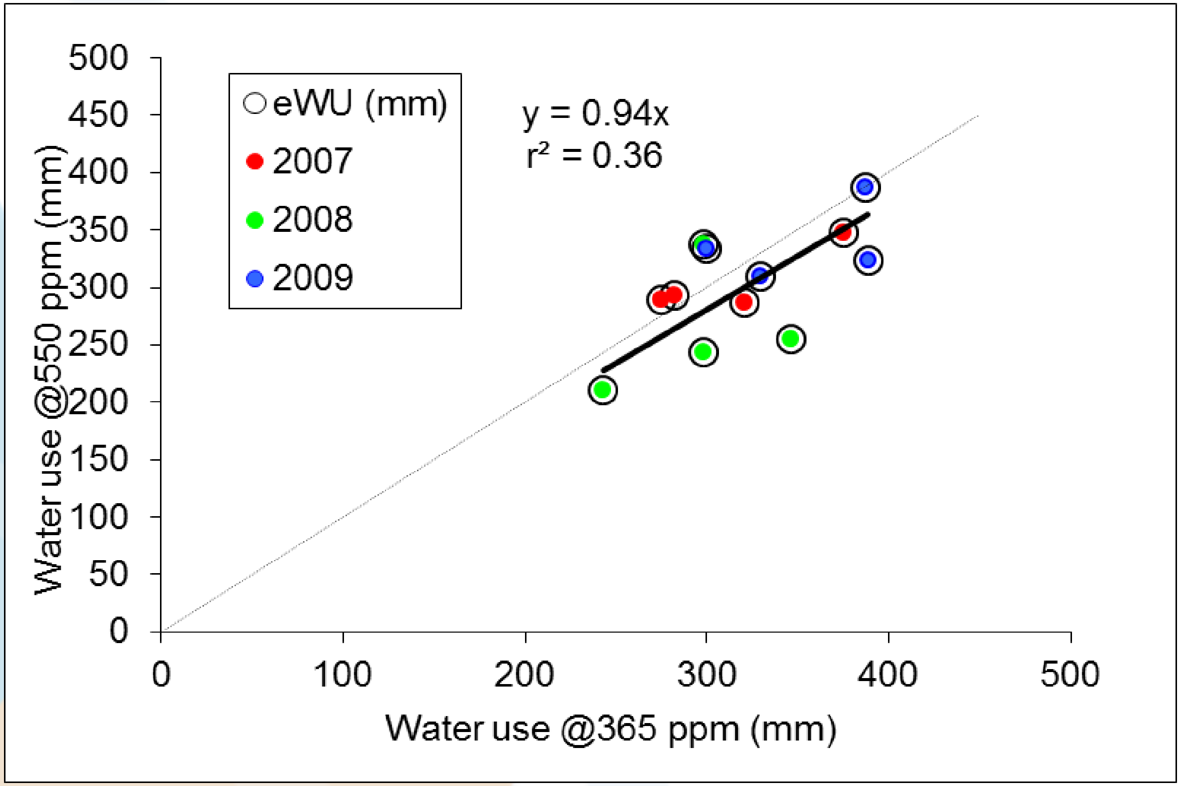








Water Use – aCO_2 vs eCO_2

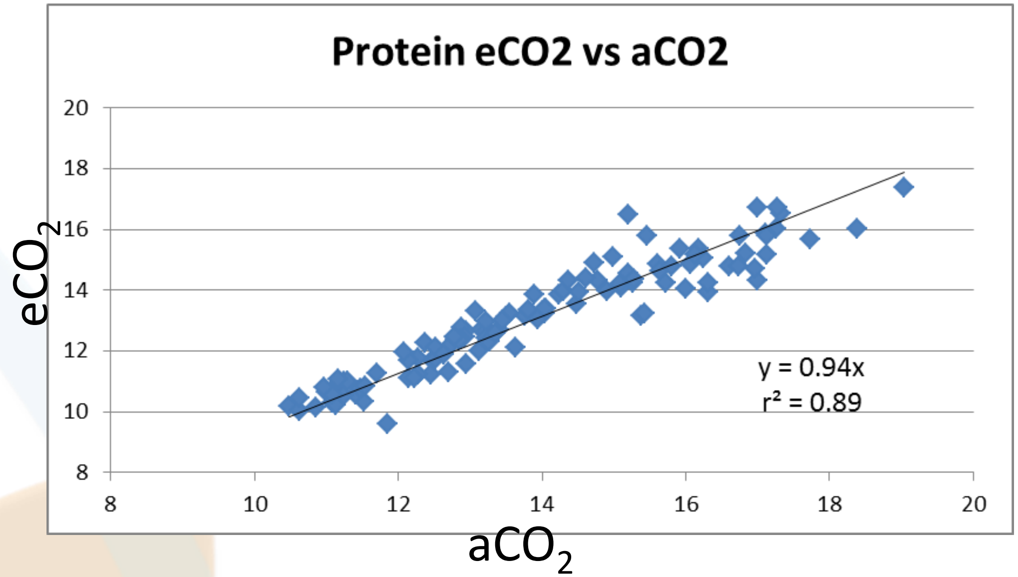


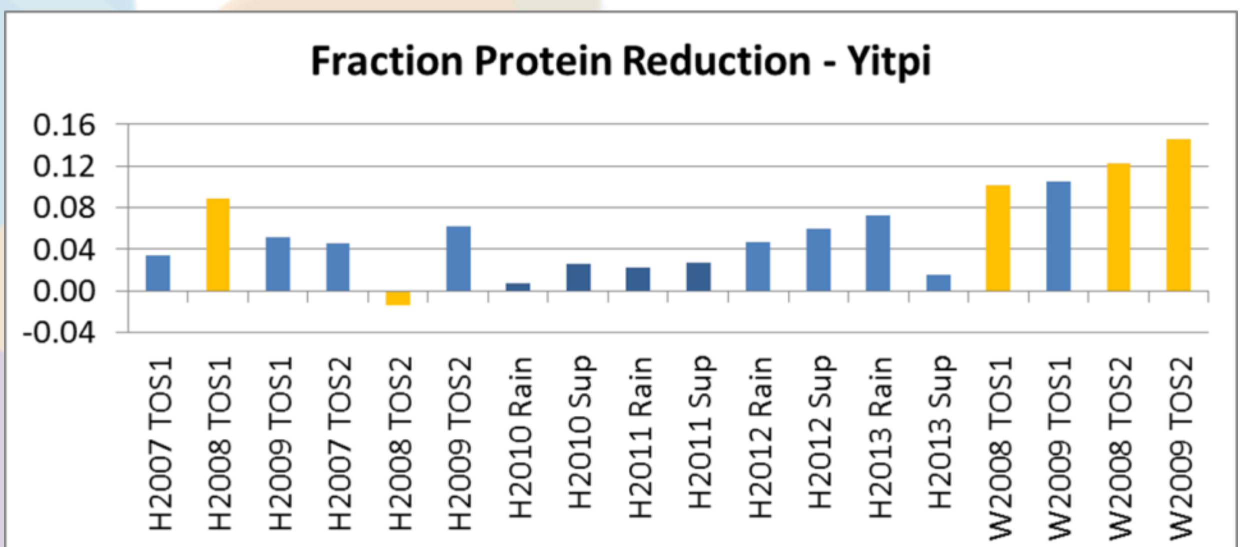
Water use (mm) Horsham 2007-09

Protein – Reduction across environments

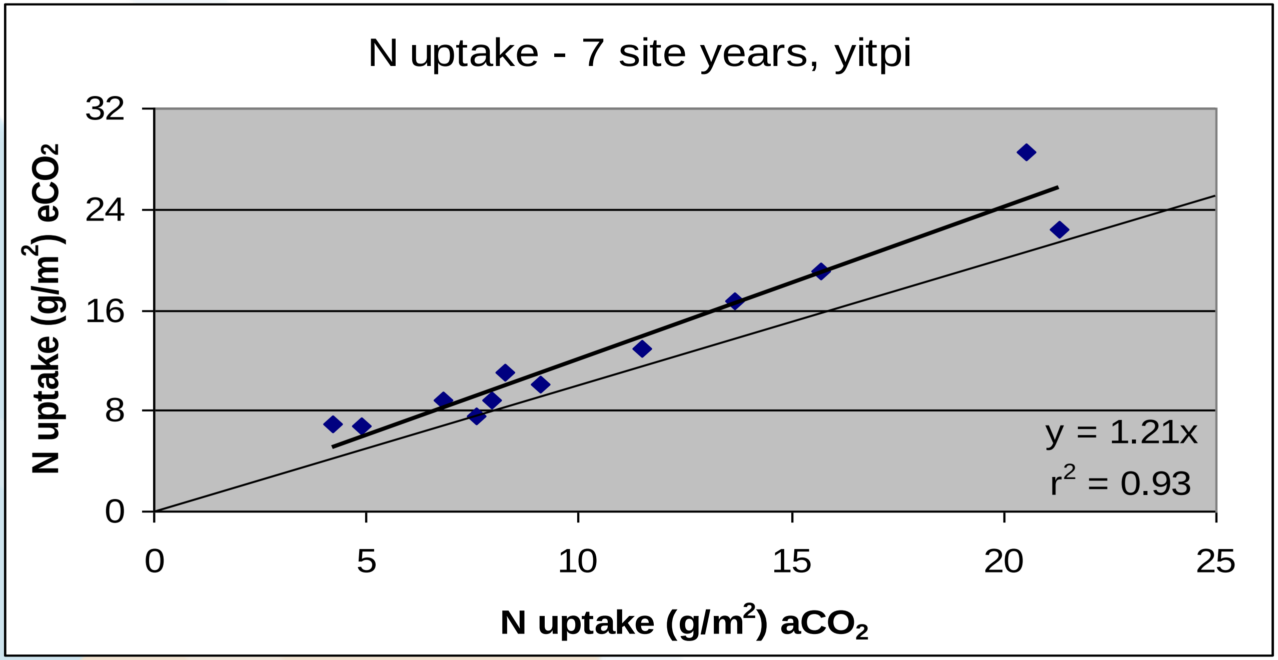
Horsham and Walpeup:

Drier environments (yellow) = greater reduction in response





Plant N uptake



Horsham and Walpeup 2007-11

What Have We Learned?

Under eCO_2:

- Yield response is highly variable by environment and cultivar but may be controlled by water
- Protein concentration may be reduced more under eCO_2 in dry conditions and varies by cultivar
- Bread quality reduced but differs by cultivar
- BYDV effects will increase
- Many micronutrients (eg Fe, Zn) reduced in grain
- More N available from legume stubble but no increase in rhizobium activity
- Traits (TUE, restricted tillering) remain effective in eCO_2
- Most major models can simulate yield response
- Few interactions of other factors with CO_2 (eg, H_2O, TOS)
- Hayoff may be problem in very "dry finish" years

Issues not considered in 2005

- Does eCO_2 increase NOx emissions?
- Physiochemical soil constraints X eCO_2
- Grain end-product quality (e.g., bread)
- Soil type
- C sequestration
- Trait testing to inform adaptation
- Crops other than wheat

Issues that still require study

- Progressive N limitation
- Pathogenicity of certain pests/diseases
- P interactions with N
- Interaction of warming X CO_2 X water X soil N
- Yield response thresholds due to very low water availability on different soils
- Genotype selection for CO_2 response
- Soil biological changes
- Heat shocks X CO_2 and grain yield/quality
- N management to reverse protein reductions

Have we answered these questions?

- **From Canadell, 2006 (original research questions):**
- Will elevated CO_2 concentrations partially alleviate water stress and the effects of increased climate variability in a future warmer climate?
  - Probably depends on timing of rain events (and soil type)
- Will higher yields in a rich-CO_2 world come at a financial cost? (eg need for larger nitrogen additions to maintain grain protein)
  - Probably more cost to N inputs, breeding to maintain grain protein and unclear whether N fertilisers can alter protein
- Are there significant differences in the CO_2 responses from different genotypes that could be utilised to maximise productivity?
  - Yes, and this is a primary road to adaptation

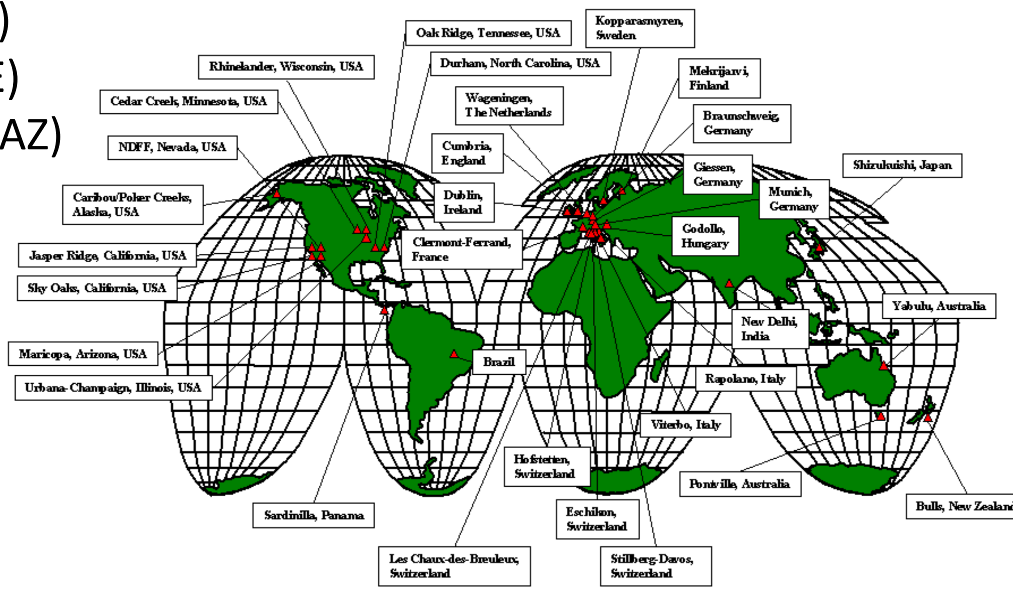
Workshop – 5 themes

- Trait selection –
  - Greg Rebetzke (CSIRO)
  - Fernanda Dreccer (CSIRO)
  - Sabine Tausz Posch (UM)
- Grain Quality –
  - Colin Wrigley (UQ)
  - Russel Eastwood (AGT)
  - Joe Panozzo (DEPI)
- Pests & Diseases –
  - Rebecca Ford (UM)
  - Jo Luck (Plant Biosec CRC)
  - Piotr Trebicki (DEPI)
- Belowground & N –
  - Zed Rengel (UWA)
  - Jairo Palta (CSIRO)
  - Roger Armstrong (DEPI)
- Modelling –
  - Scott Chapman(CSIRO)
  - David Lobell (Stanford)
  - Garry O'Leary (DEPI)

Collaborators

Collaborating scientists

- Sam Myers, Harvard University
- Lisa Ainsworth, Univ Illinois (SoyFACE)
- Andrew Leakey, Univ Illinois (SoyFACE)
- Bruce Kimball, USDA-ARS (Maricopa, AZ)
- Rebecca Ford, UM
- Heinz Rennenberg, Univ Freiburg
- Cynthia Rosenzweig, NASA
- Ros Gleadow, Monash Univ
- Karen Garrett, Kansas State Univ
- Julie Nicol, CIMMYT
- Nilsa Bosque Perez, Univ Idaho
- Malcolm Hawkesford (Rothamsted Research)
- Senthold Asseng, Univ Florida
- Neil Huth, CSIRO Toowoomba
- Hamish Brown, Plant & Food Research, NZ
- Carolyn Maelstrom, Michigan State Univ



- Luit De Kok (Univ Groningen)
- Scott Chapman, CSIRO
- Jairo Palta, CSIRO
- Robert Norton, IPNI

AGFACE team

- Michael Tausz, UM
- Joe Panozzo, DEPI
- Cassandra Walker, DEPI
- Nathan Neumann, DEPI
- Garry O'Leary, DEPI
- James Nuttall, DEPI
- Sabine Posch, UM
- Roger Armstrong, DEPI
- Mahabubur Mollah, DEPI
- Piotr Trebicki, DEPI
- Friday Obanor, CSIRO
- Raymond Lam, UM
- Clayton Butterly, La Trobe
- Caixian Tang, La Trobe
- Chris Korte, DEPI
- Debra Partington, DEPI
- Simone Dalton, DEPI
- Alan Yen, DEPI
- Narelle Nancarrow, DEPI
- Maryse Bourgault, UM
- Markus Loew, UM
- Helale Bahrami, UM
- Alireza Houshmandfar, UM
- Allene Macabuhay, UM
- Rebecca Vandegeer, UM
- Pramesha Madurangi , UM
- Paul Melloy, CSIRO
- Russel Argall, DEPI
- Peter Howie, UM
- Ash Purdue, DEPI
- Jason Ellifson, DEPI
- Simone Vassiliadis, DEPI
- **Members at large**: Rob Norton, UM (IPNI), David McNeil, DEPI (Univ Tas); Jo Luck, DEPI; Saman Seneweera, UM (USQ); Mark Nicolas, UM; Jason Brand, DEPI; Sukumar Chakraborty, CSIRO; Angela Freeman, DEPI; Grant Halloway, DEPI; Janine Fitzpatrick, DEPI; Justine Ellis, DEPI, Jennifer Briggs, DEPI; Nimesha Fernando, Humaira Sultana, UM; Chamindathee L Thilakarathne, UM; Jian Jin, La Trobe; Kyla Finlay, DEPI

More information

www.piccc.org.au/agface

AGFACE partners and supporters

State Government Victoria
Department of Environment and Primary Industries

THE UNIVERSITY OF MELBOURNE

piccc
Primary Industries Climate Challenges Centre

LA TROBE UNIVERSITY

Australian Government
Department of Agriculture
Australian Research Council

GRDC Grains Research & Development Corporation

AGFACE is a collaborative research program led by the Department of Environment and Primary Industries Victoria and the University of Melbourne, with core funding support from the Grains Research and Development Corporation and the Australian Government Department of Agriculture.