Climate change & nutrient demand

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F. Garcia – for translation of paper.

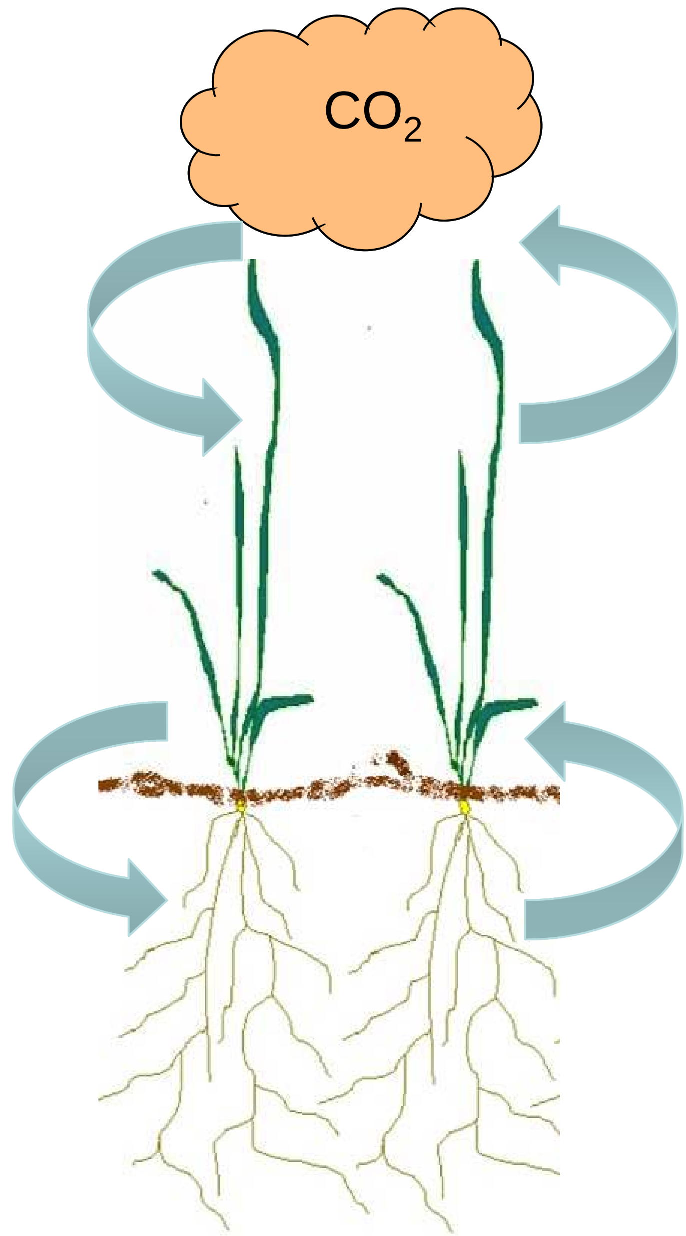
XXIV Congreso Argentino de la Ciencia del Suelo,Bahía Blanca, Buenos Aires, Argentina.

The future?

- Neils Bohr
  - Making predictions is difficult, especially when they are about the future…

Outline

- The challenge!
- Why is Australia concerned?
- Climate change and crop responses
- Impact on plant demand
- Impact on soil supply
- Reviewing the 4Rs for future management.



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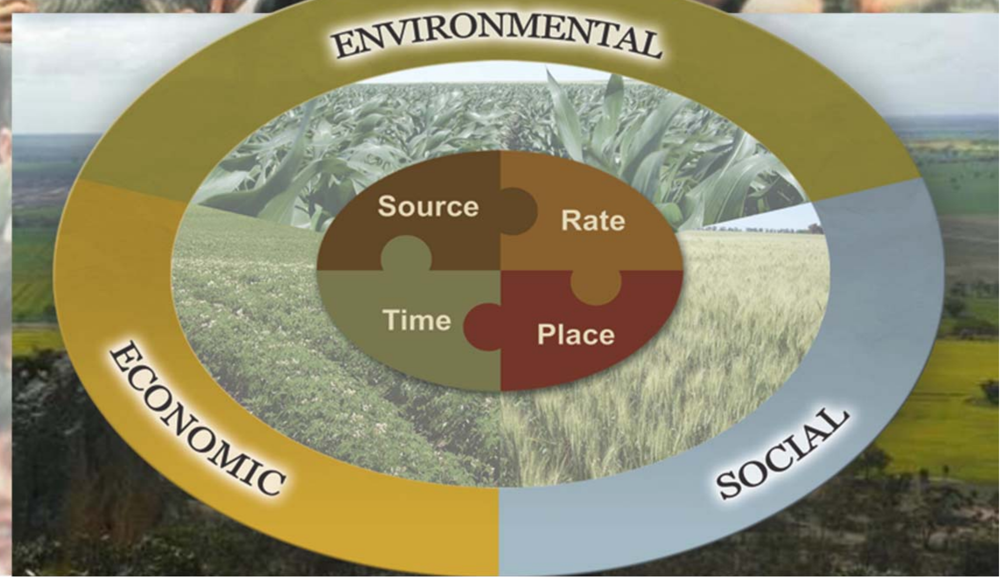
What is challenge?

- Population growth
- Change in diets due to increasing household incomes in developing countries … incomes above $16,000 per yr will rise from 352 mil in 2000 to 2.1 bil by 2030 (World Bank)
- Demand for non-food uses of crops.

Food demand to double by 2050

- Static world land area
- Climate change
- Land for nature
- Social justice
- Sustainable resource use
- Energy & Resource availability



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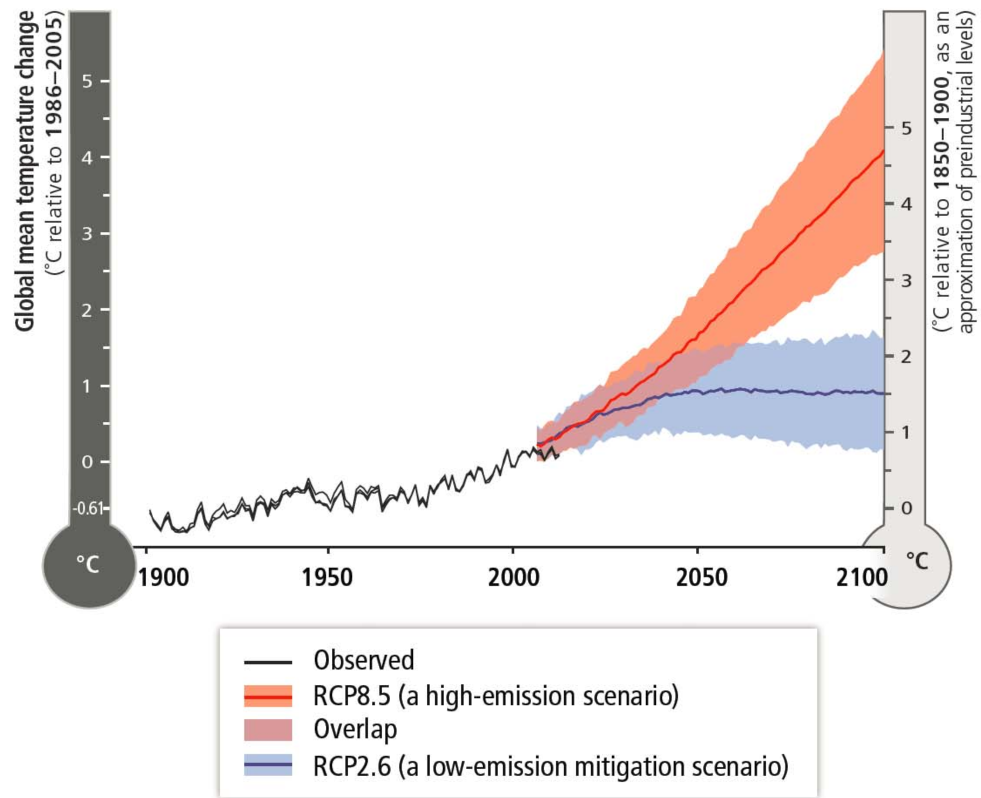
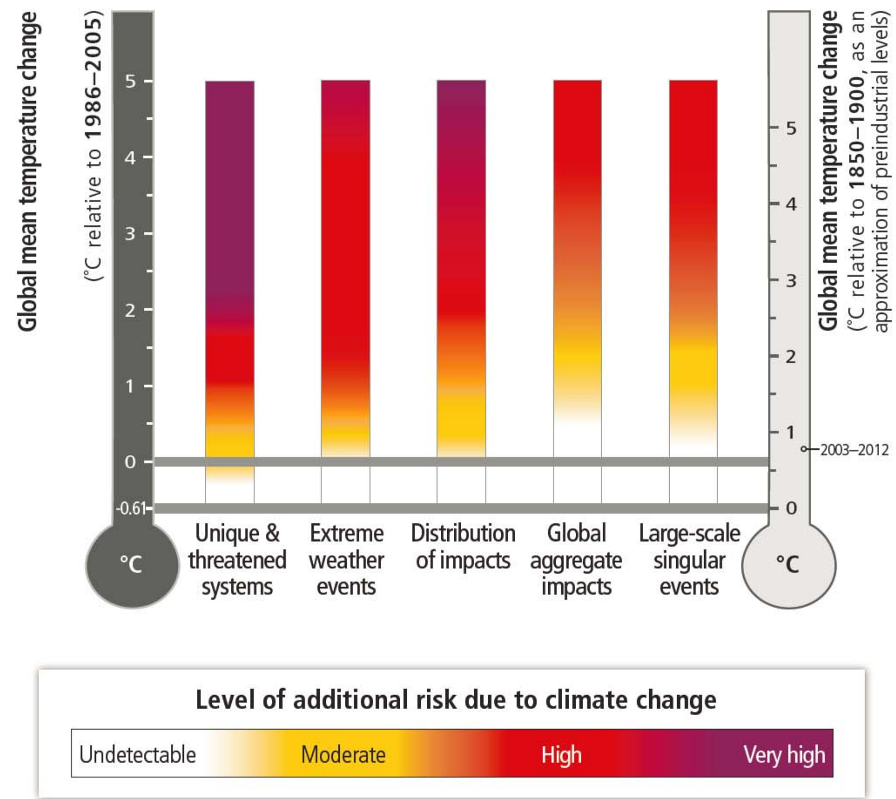
INTERGOVERNMENTAL PANEL ON climate change





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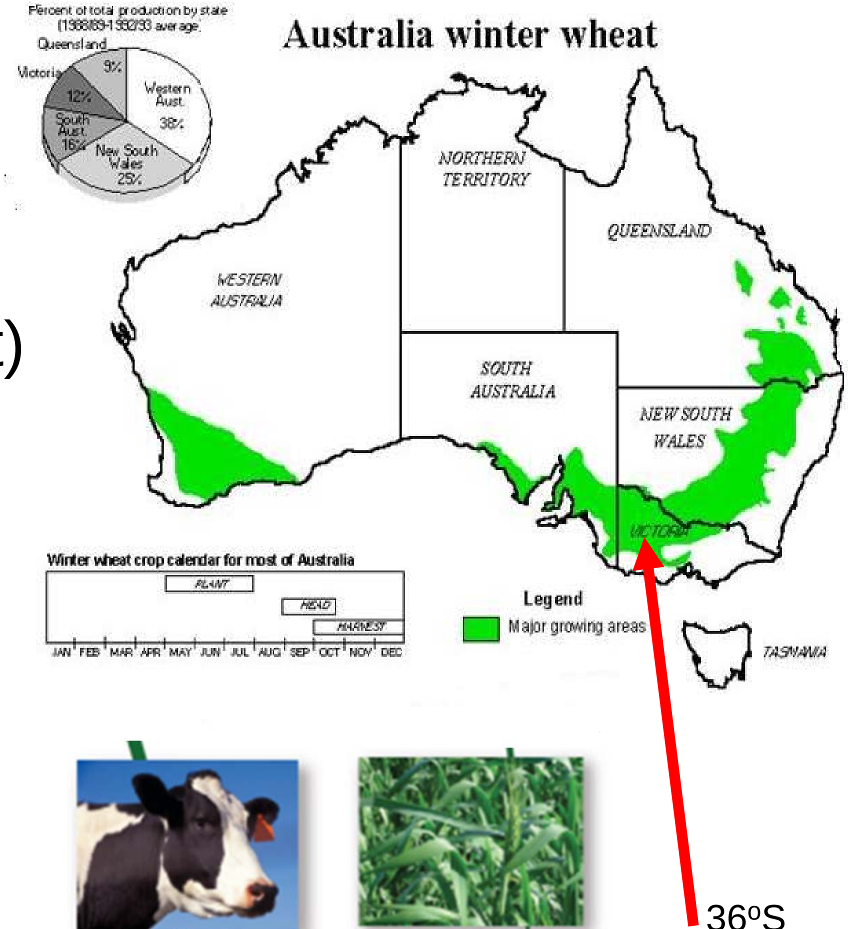
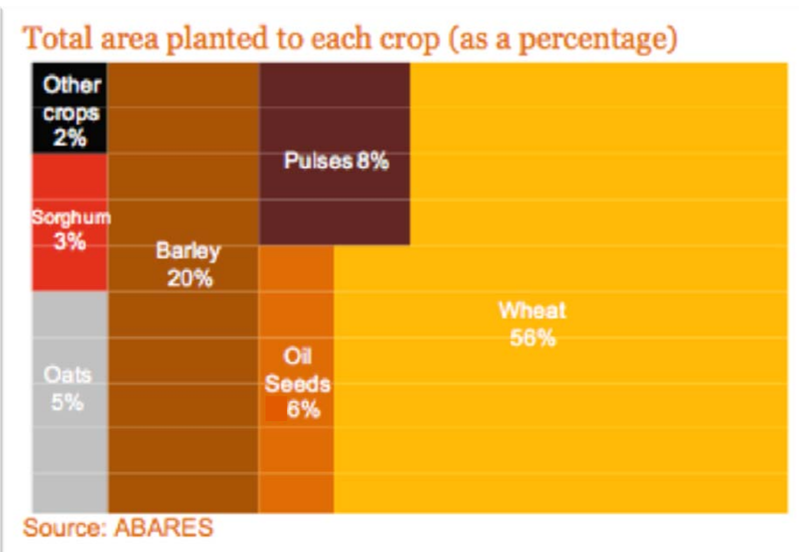
Why is Australia concerned?

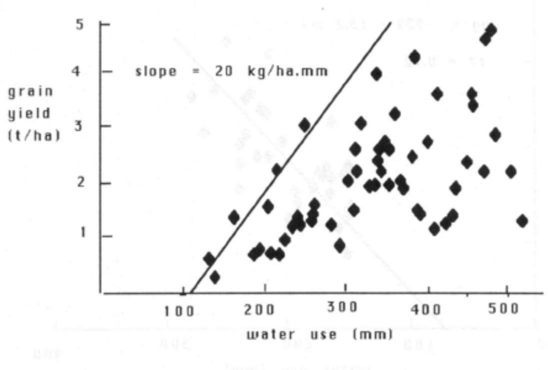
- Agriculture ~4% of GDP
- 500 Mha of farming land (~60%)
  - 50 Mha cropping
- Grains Industry = $7 billion (45 Mt)
- Dairy Industry = $2.5 billion
- Beef and sheep meats = $9 billion
- Sugar Industry = $1.3 billion



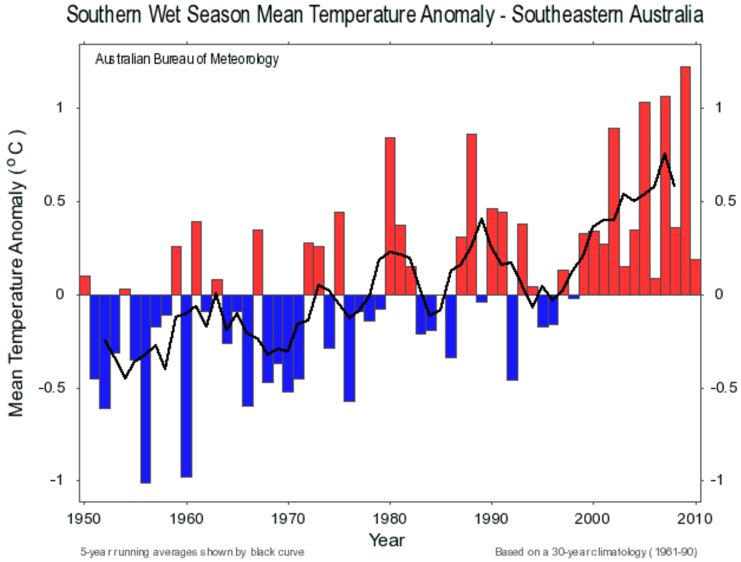


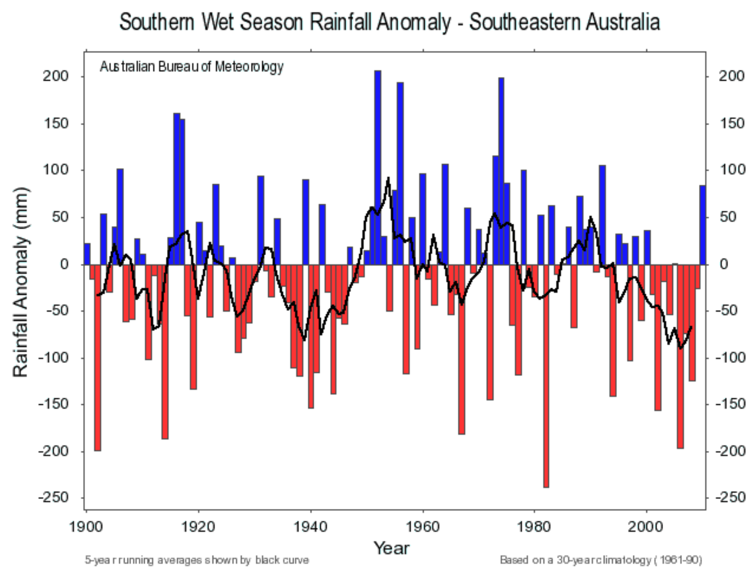
South-eastern Australia

- Farmers have faced difficult times
- Warmer temperatures
- Lower rainfalls
  - LTA Horsham = 417 mm (±107)
  - Decade 2001-2010 = 346 mm
- Yield strongly linked/limited rainfall



WUE = Y/(ET-SE) WUE = Y/ET





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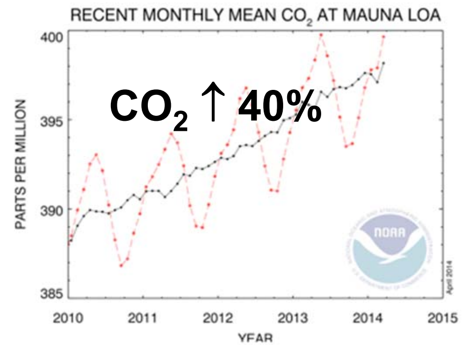
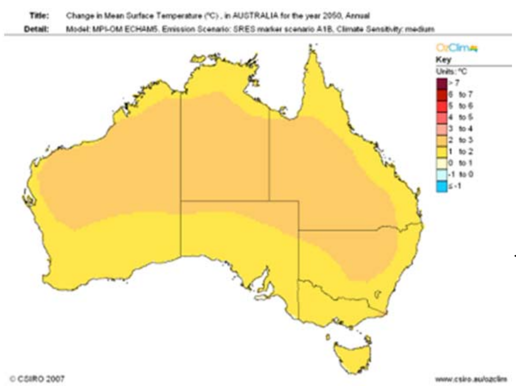
Projected climate – 2050 - A1B -Australia

CO_2

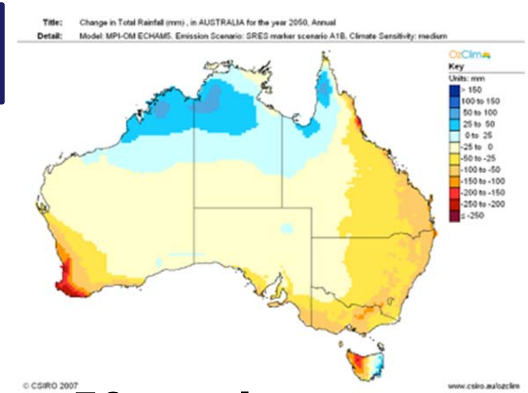


Temperature

Water



Interactions



1-2°C warmer

50mm lower

Elevated CO_2 improves photosynthesis and plant water use efficiency, but, high temperature and lower rain fall have a negative impact on crop growth and productivity in most parts of Australia.

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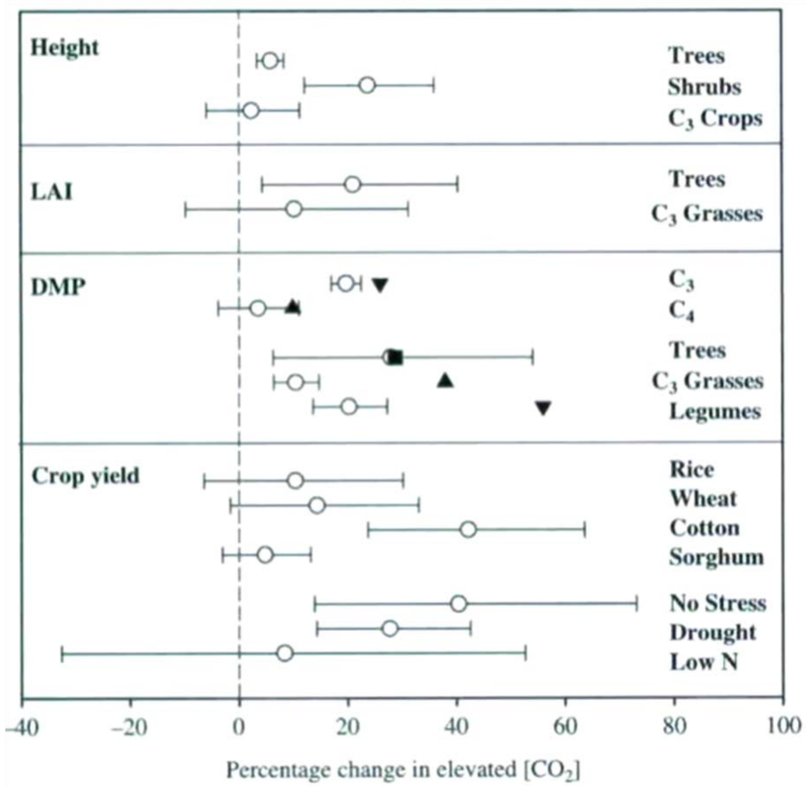
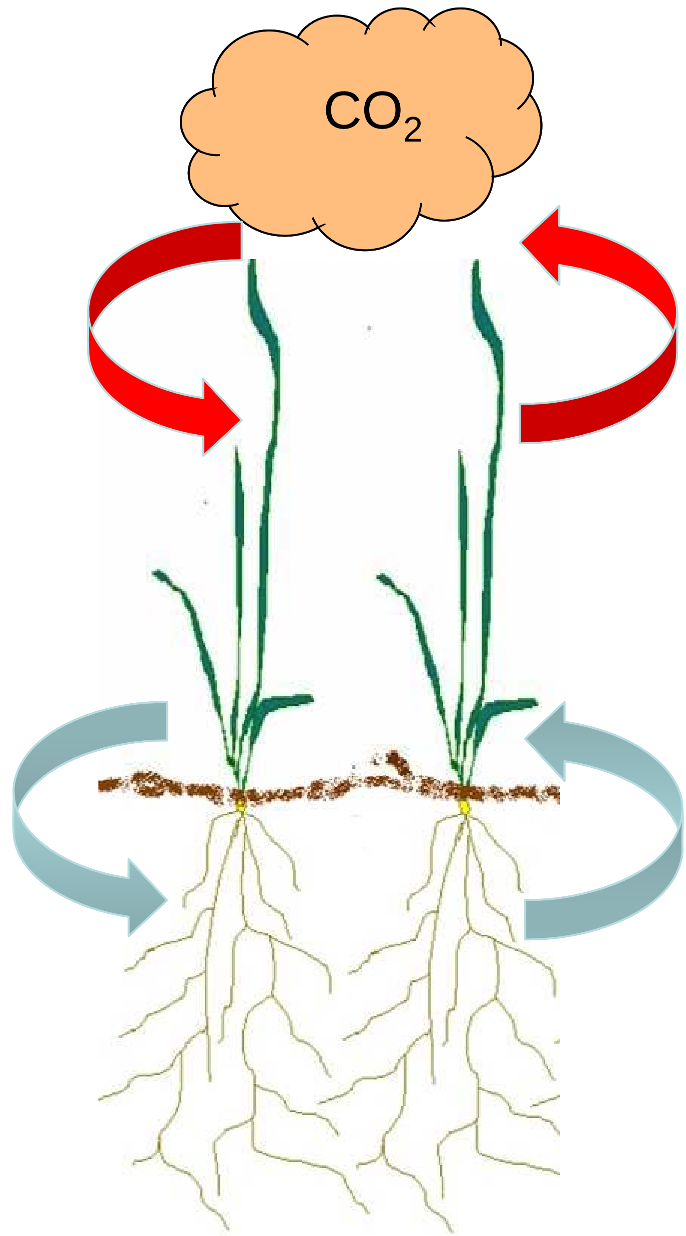
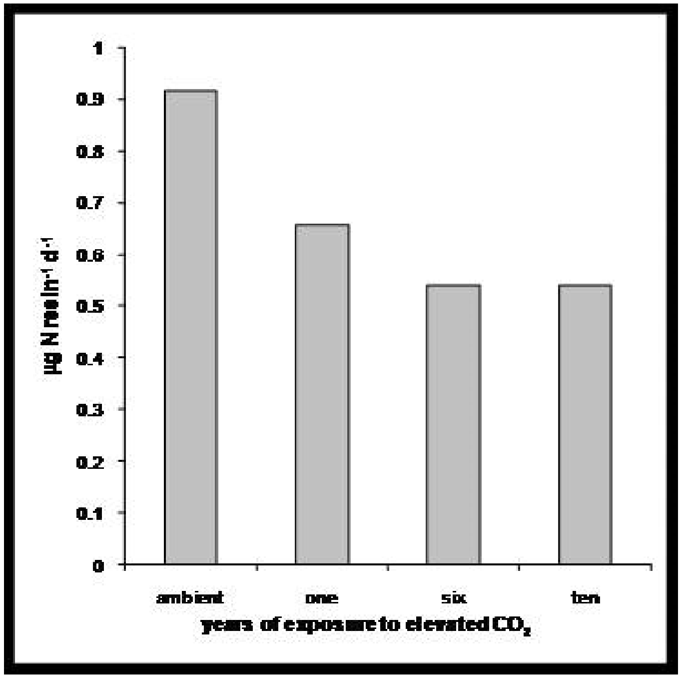
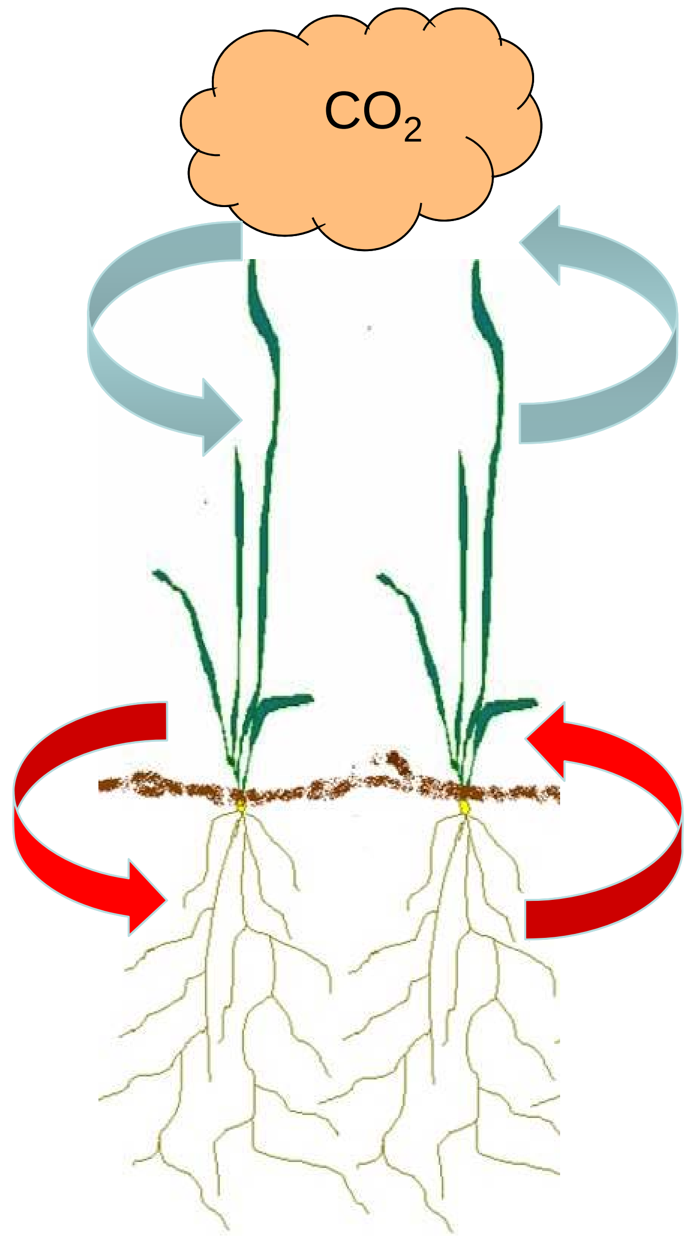


- Elevated $[CO_2]$ increased dry matter production of trees (28%), legumes (24%), C_3 species (20%) but not much for C_4 species (Ainsworth and Long 2005).
- Change in N (& water) uptake and C input
- Consequent change in soil N dynamics



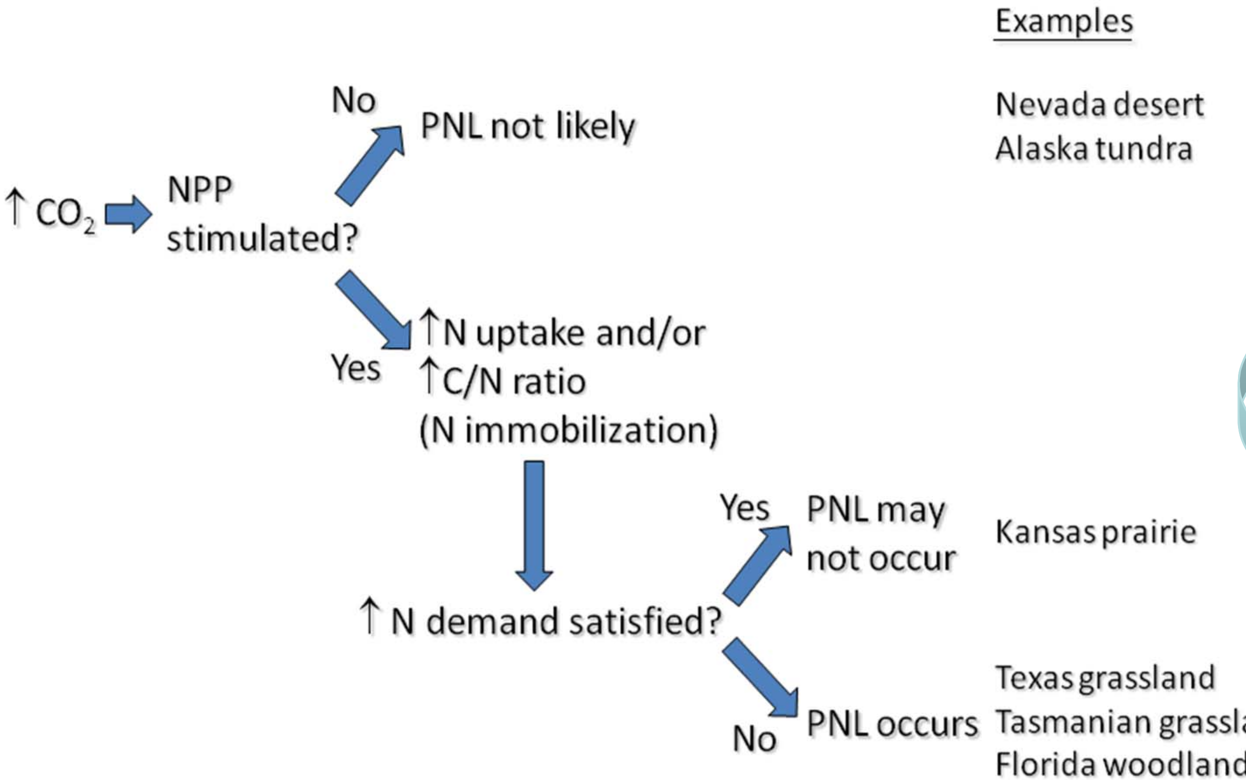


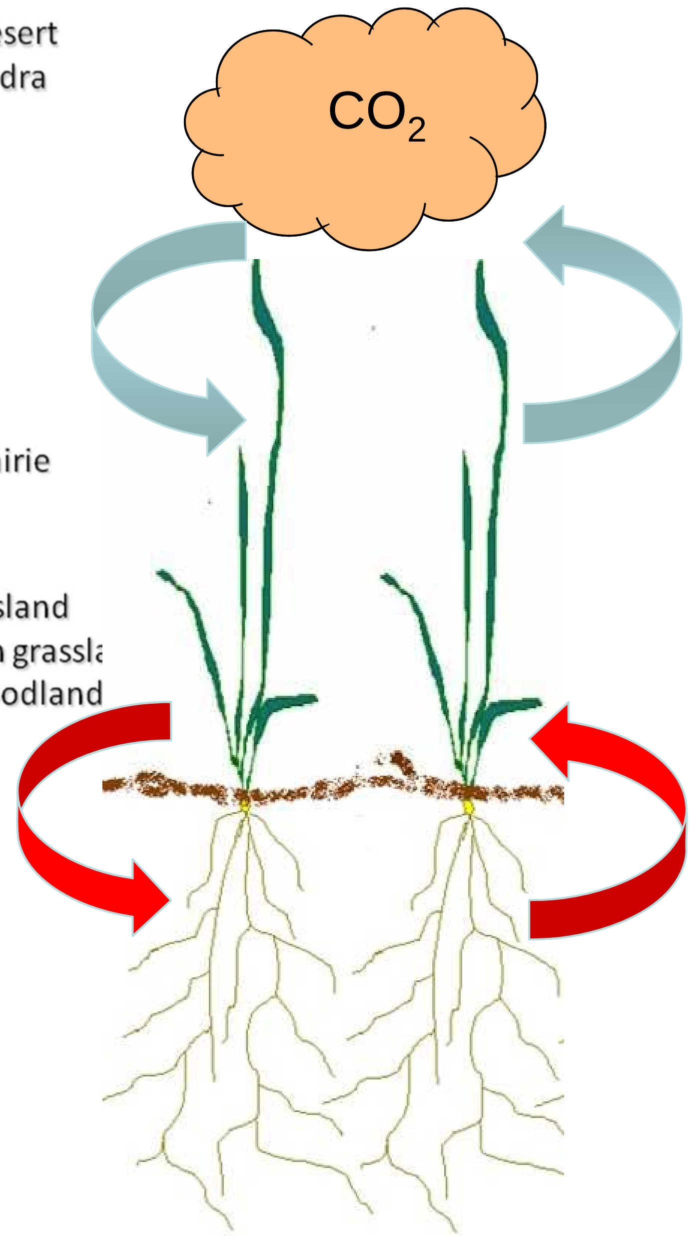


Progressive Nitrogen Limitation

The decline of the availability of mineral N over time (e.g. 6-7 years) at elevated [CO_2] when compared to ambient, if there is no new N input or reduction in N losses (Luo et al. 2004).

Adapted and modified from Luo et al. 2004





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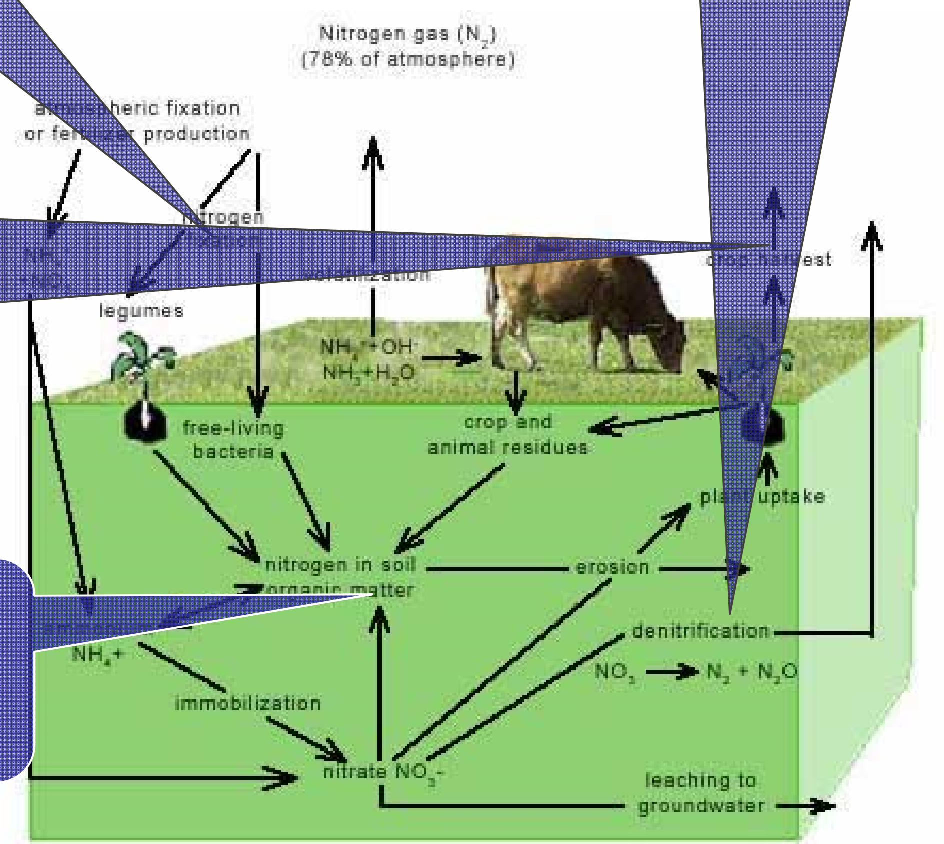
Possible eCO_2 effects on soil N dynamics

eCO_2 → more C supply to nodules → fix more N_2?

eCO_2 → more C substrates for denitrifiers → higher N_2O emissions?

eCO_2 → higher root and biomass → better access to N sources → higher N uptake and grain N removal?

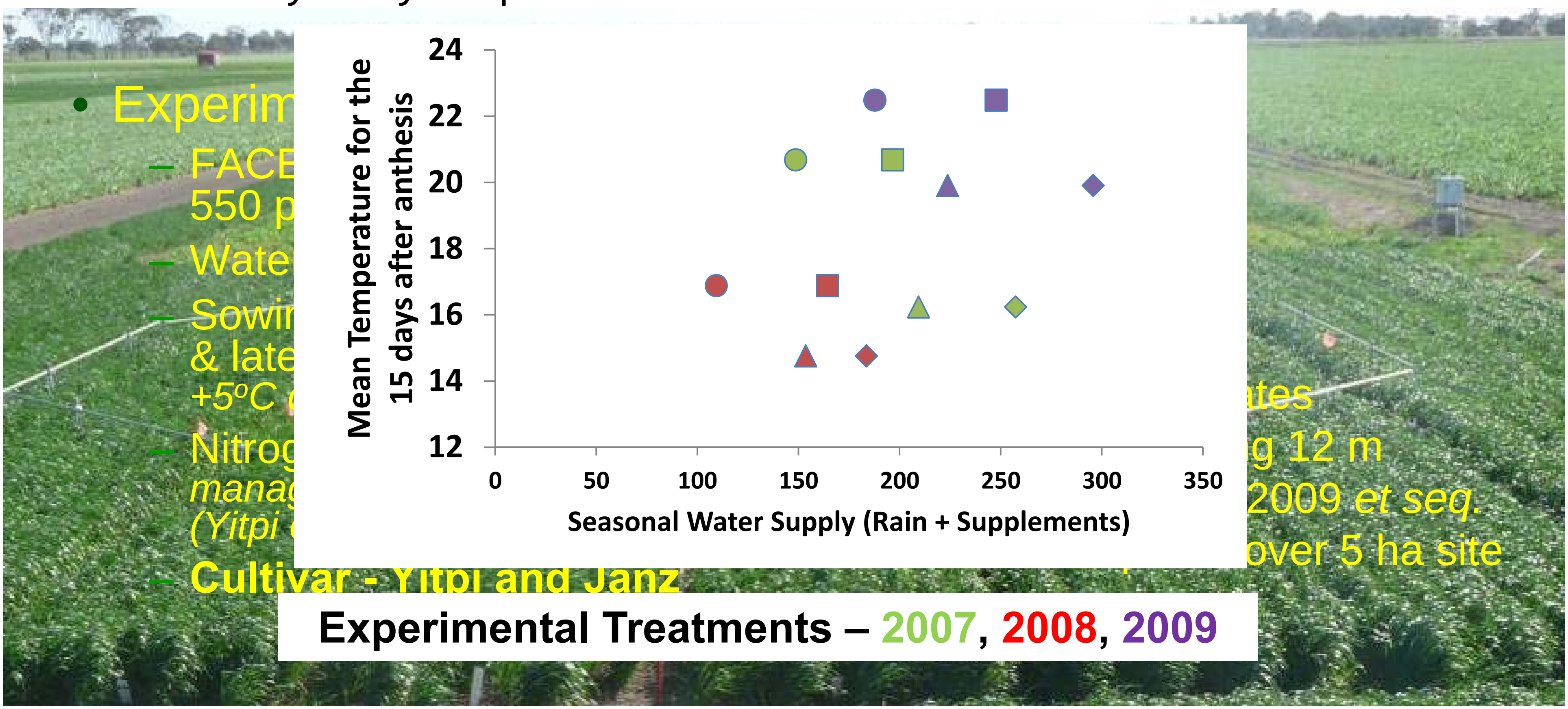
eCO_2 → higher N demand → higher fertilizer-N uptake/efficiency?



Adopted from National Sustainable Agriculture Information Service

Australian Grains Free Air Carbon Dioxide Enrichment Facility (AGFACE)

- Located at Horsham in southeastern Australia – 36°S.
- Aim to answer the fundamental question of how the supply of N and water interact with higher temperatures under elevated CO_2 in relatively low yield potential situations *ie* 1 to 4 t/ha



Experimental Treatments – 2007, 2008, 2009

Meta-analysis of

"N dynamics in grain crop and legume pasture systems under elevated CO_2"

366 observations from 127 studies

Lam et al., 2012, Global Change Biology, 18, 2853–2859

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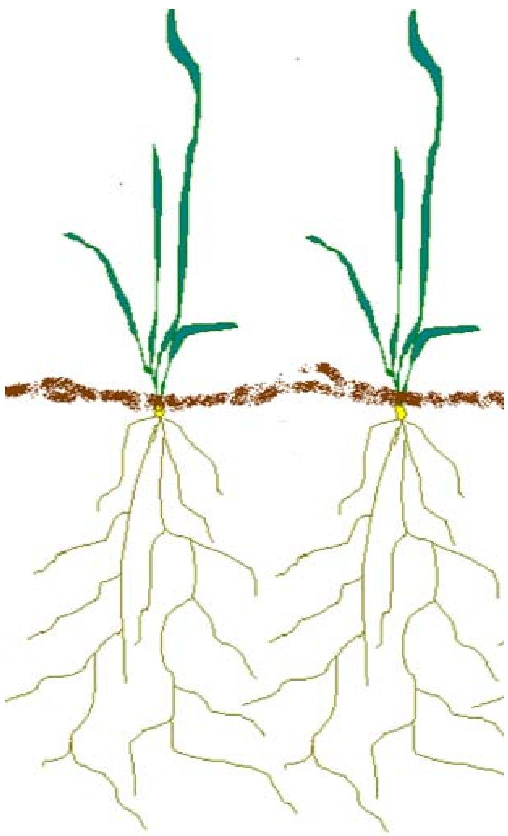
Impact on plant demand (N)

effects at crop flowering

385 ppm CO_2

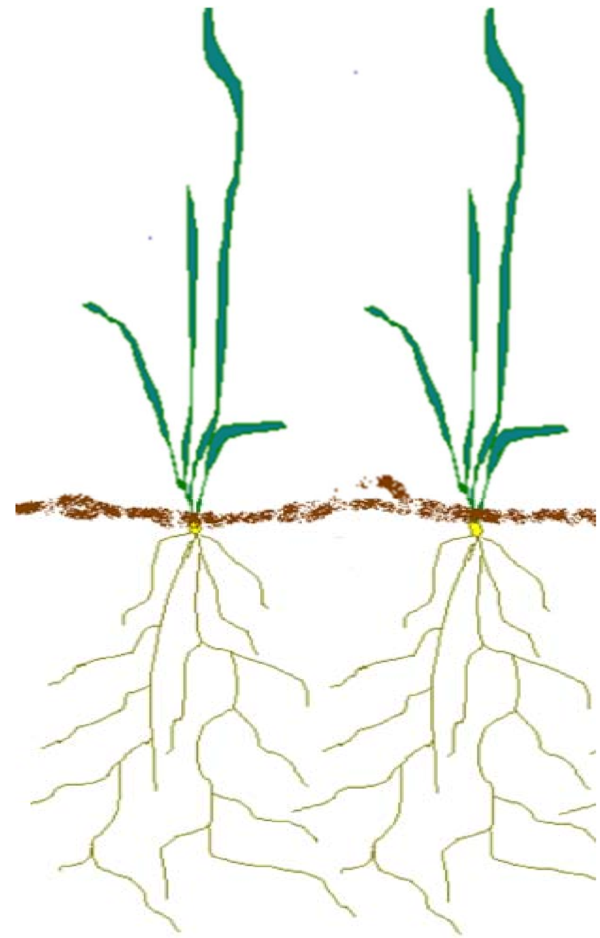
550 ppm CO_2



- Inconsistent response during vegetative growth (Temperature)
- +21% Top Growth @ Flowering
- -7% Plant N content
- Some differences in root density (cm/cm^3)

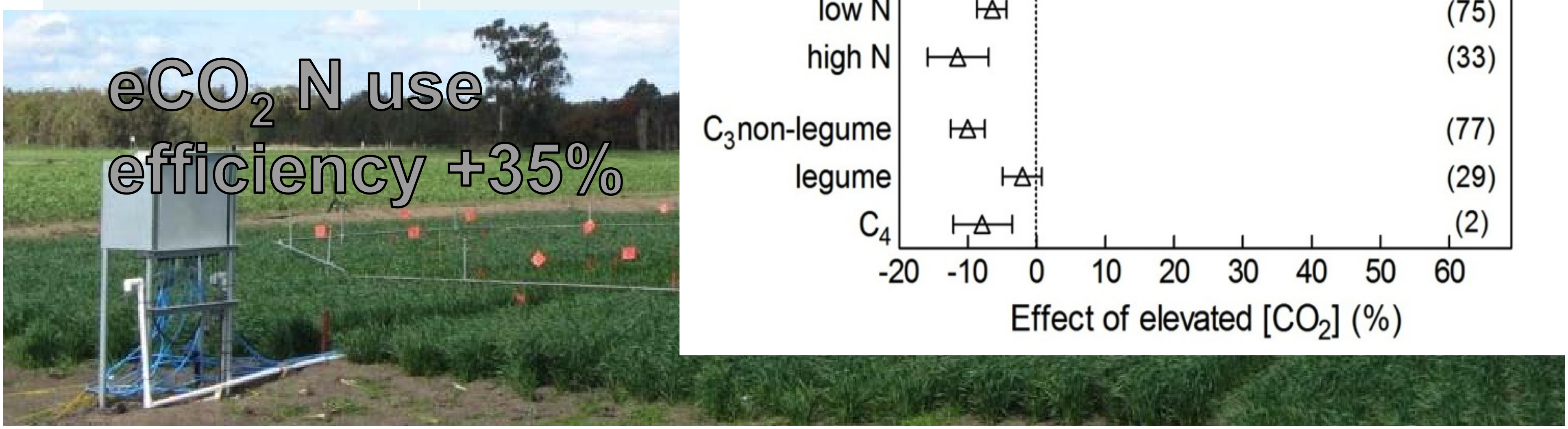
Root Length Density

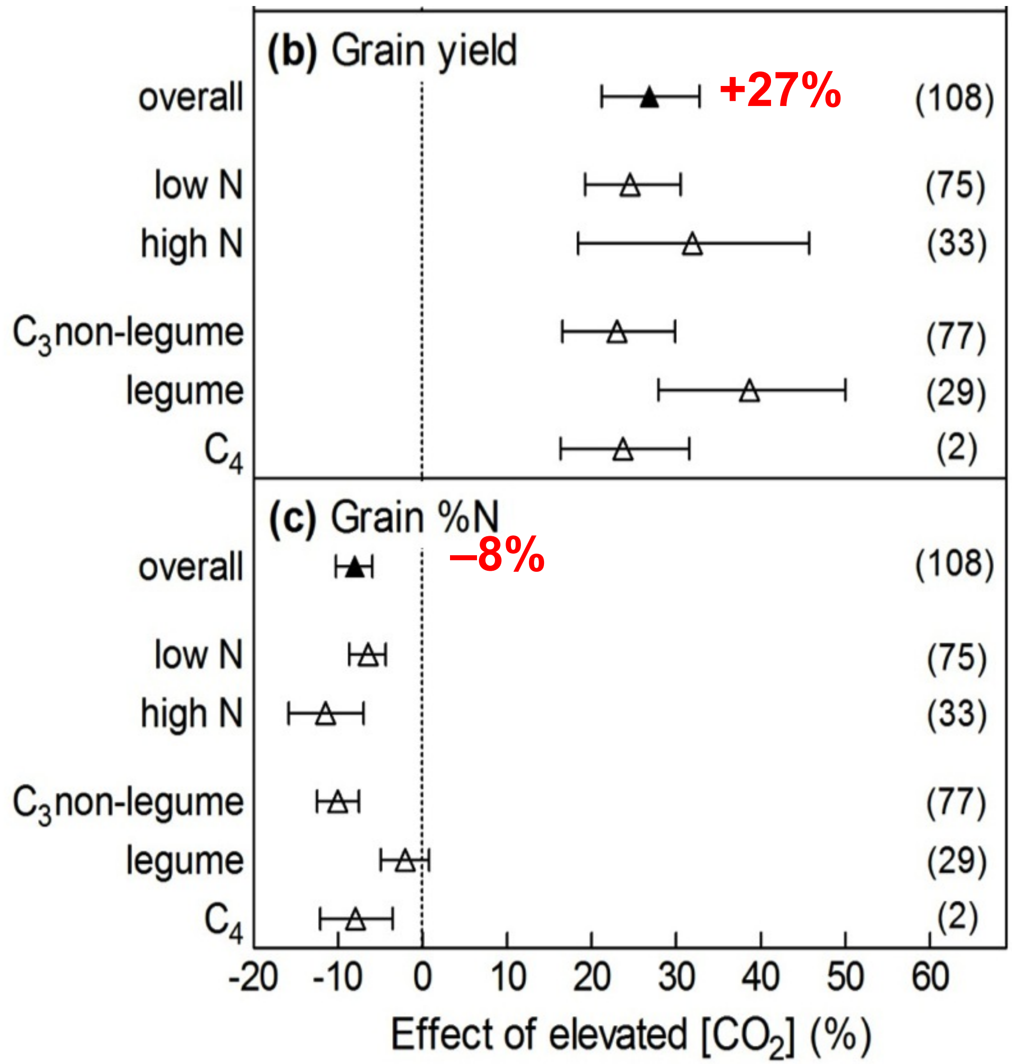
Year	aCO_2	eCO_2
2007	**1.14**	**1.82**
2008	**2.45**	**3.00**
2009	0.86	0.96



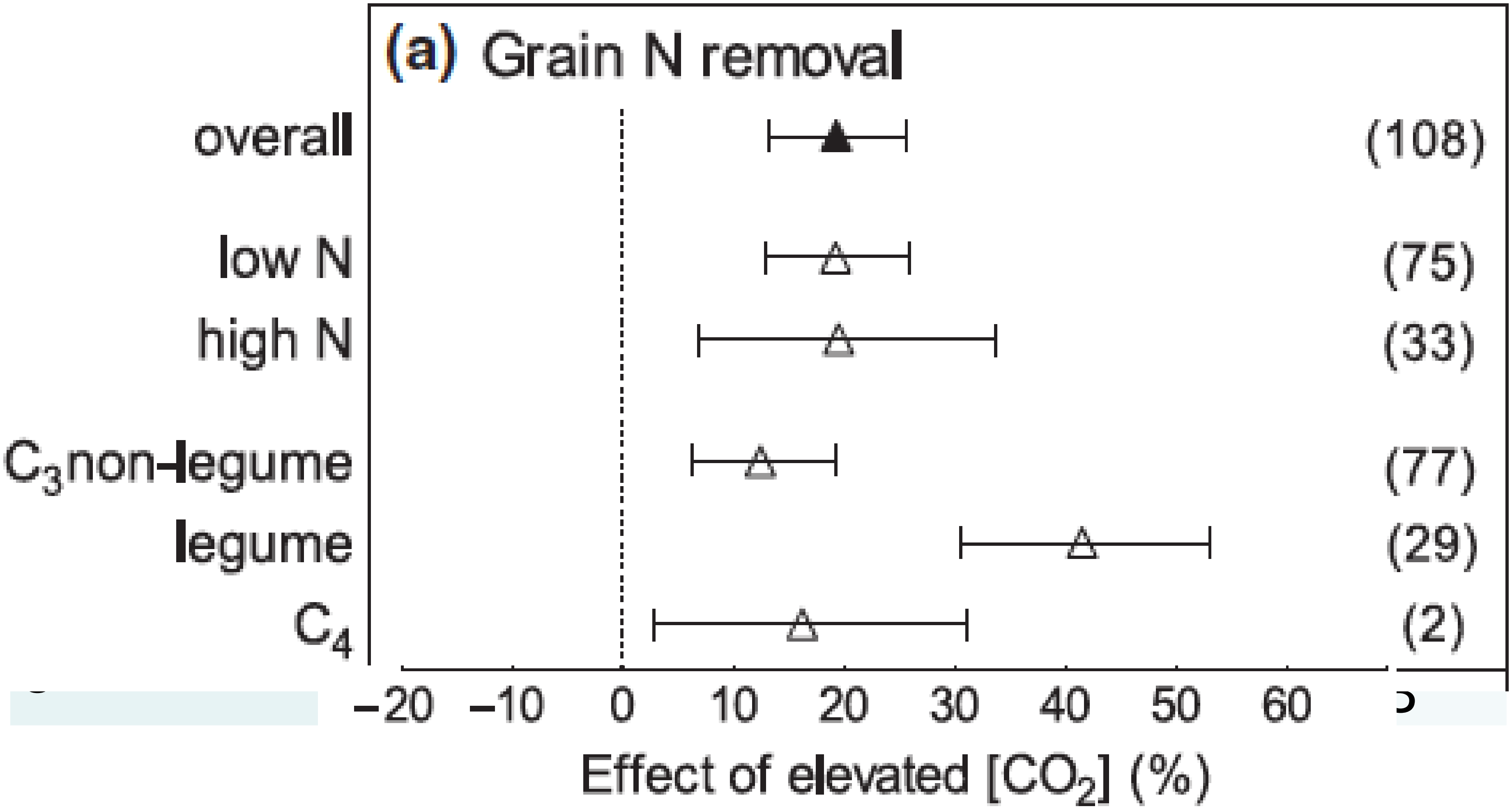
Mean effects of eCO_2 at maturity

Factor	$[CO_2]$ (μmol/mol)	
Grain yield (g m^{-2})	380+	*+27%*
	550	
Grain N content (%)	380+	*-5%*
	550	





Mean effects of eCO_2 on N demand



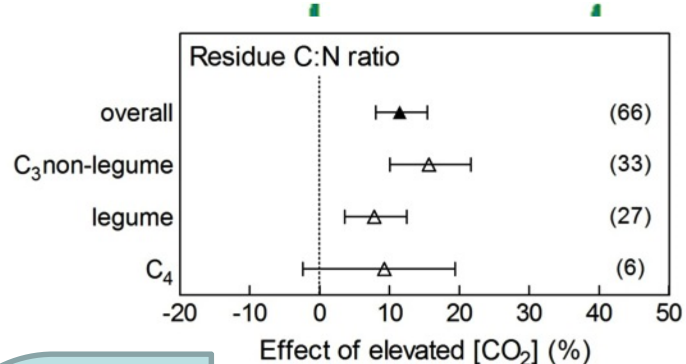
+20% N removal under eCO_2

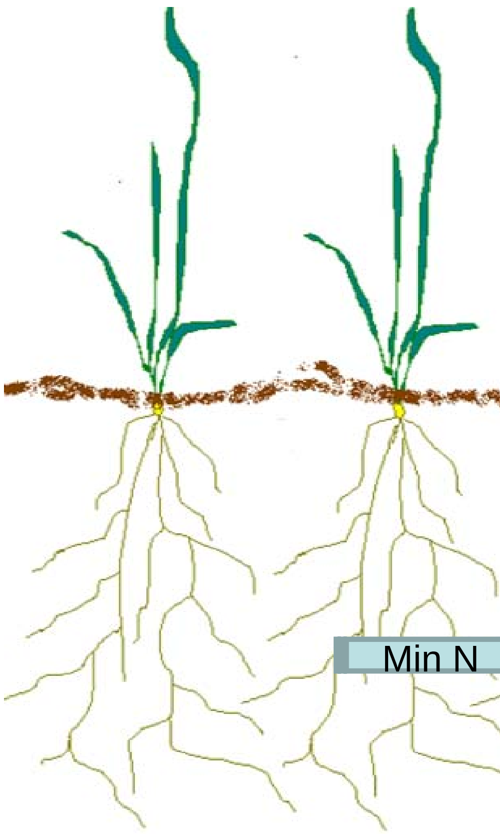
Effect on soil mineral N supply

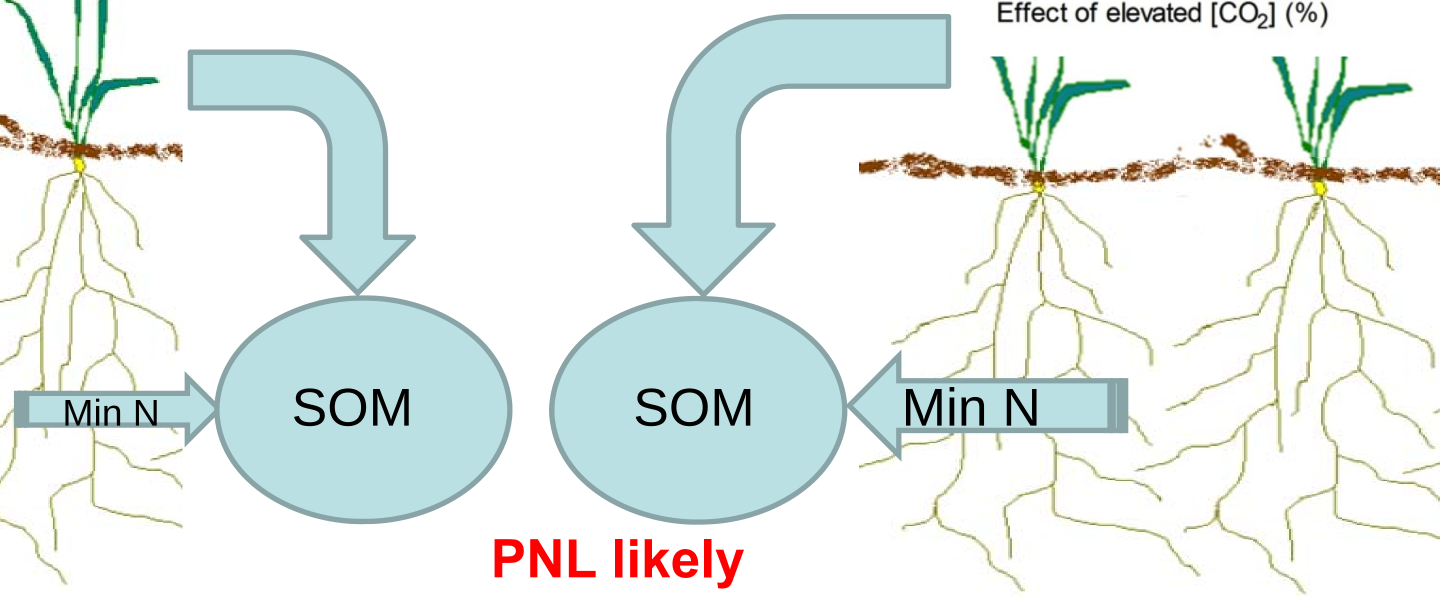
385 ppm CO_2

550 ppm CO_2

- +27% Top Growth
- -6% Plant N content
- Less N in grain
- 27% biomass to soil
- ~42 C:N in straw



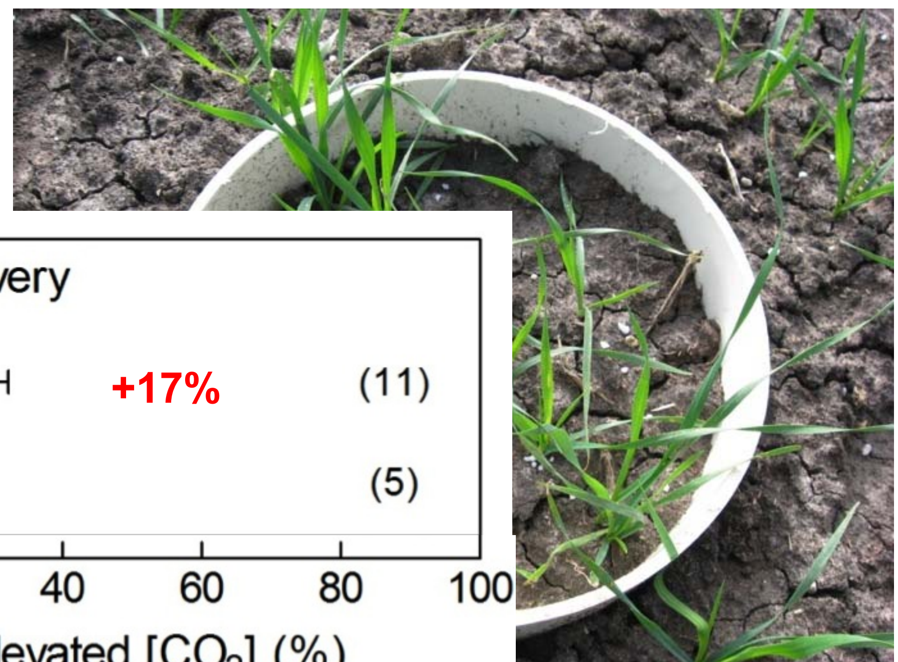


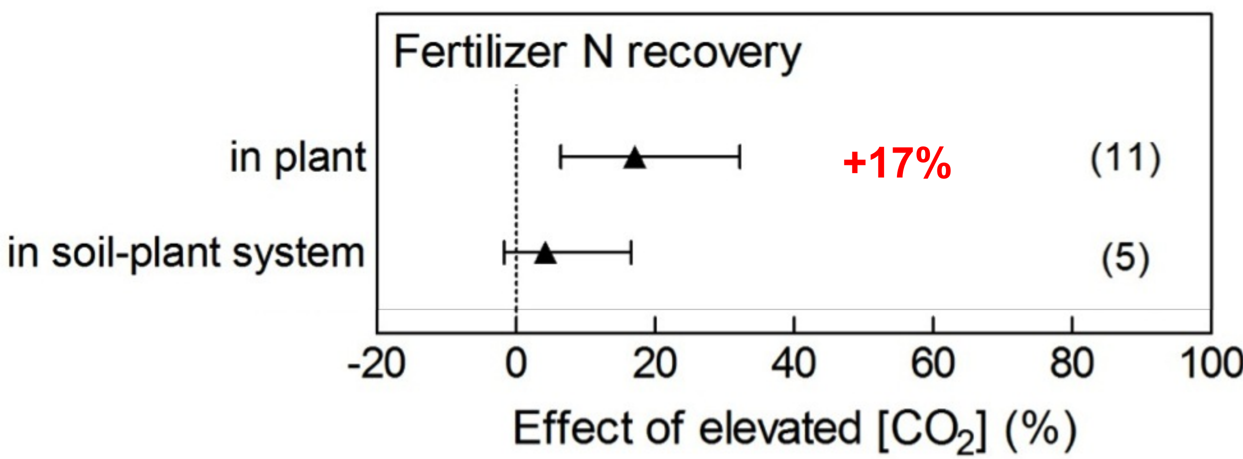


PNL likely

Fertilizer N recovery – wheat

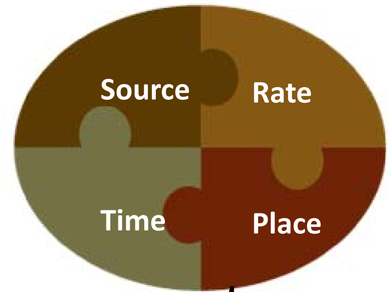
- PVC micro-plot (diameter 0.24 m; height 0.25 m) inserted to 0.20 m depth
- ^{15}N-enriched (10.22 atom%) granular urea applied at 50 kg N ha^{-1}
- ^{15}N atom% analysis by IRMS
- No significant CO_2 effect seen



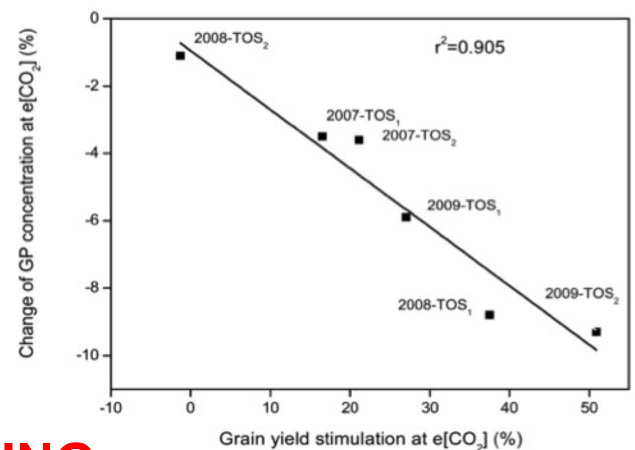


Lam et al., 2012, Nutr Cycl Agroecosyst , 92:133–144

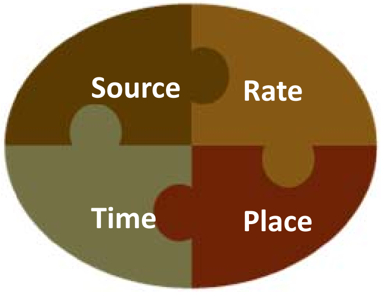
Implication – N demand



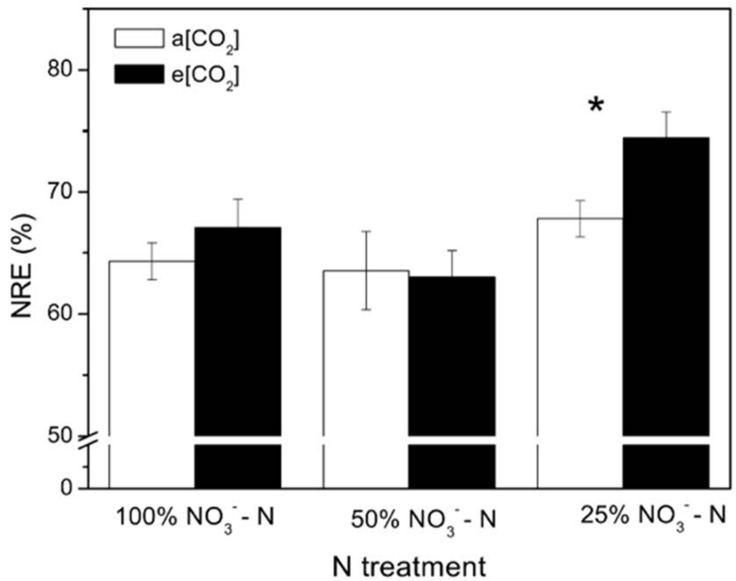
- 20% increase in N removal – irrespective of temperature and rainfall changes
  - **REVIEW THE RIGHT RATE**
- Most increase is after stem elongation (temperature).
  - **REVIEW THE RIGHT TIME/RATE – HIGHER RATES/LATER?**
- The <u>protein concentration </u>decline occurs with bigger yield stimulation – changes in N metabolism
  - Down-regulation of photosynthetic proteins
  - Lower protein/N content in leaves (NR)
  - Less N for remobilization to grain.
  - **LATE FOLIAR N (HIGH EFFICIENCY)**
  - **NEW MORE INTERNALLY N-EFFICIENT WHEAT TYPES, NON-DOWNREGULATING**



N recovery and N source



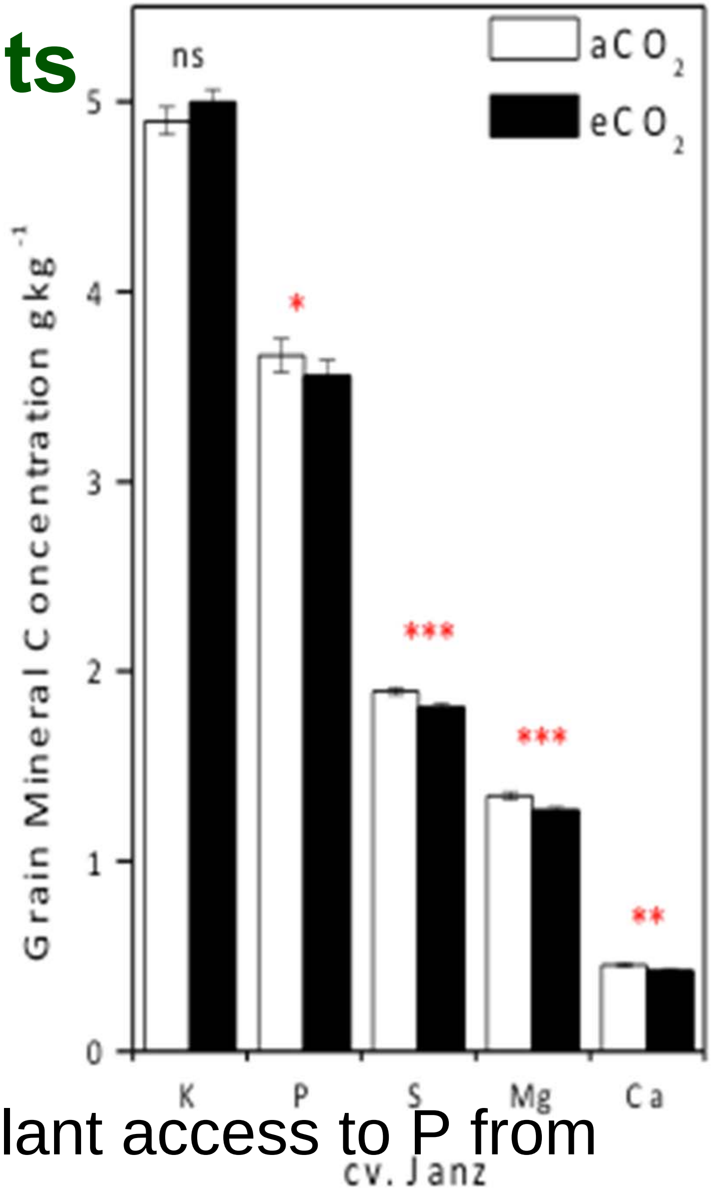
- If N>50% NH_4, higher N recovery under eCO_2
- Under ammonium dominant supply, significant response in N recovery
  - **SHIFT TO AMMONIUM BASED N-SOURCES**
  - **ENHANCE AMMONIUM ACCESS (eg DMPP)**



Fernando et al. JCS submitted

Demand for other nutrients

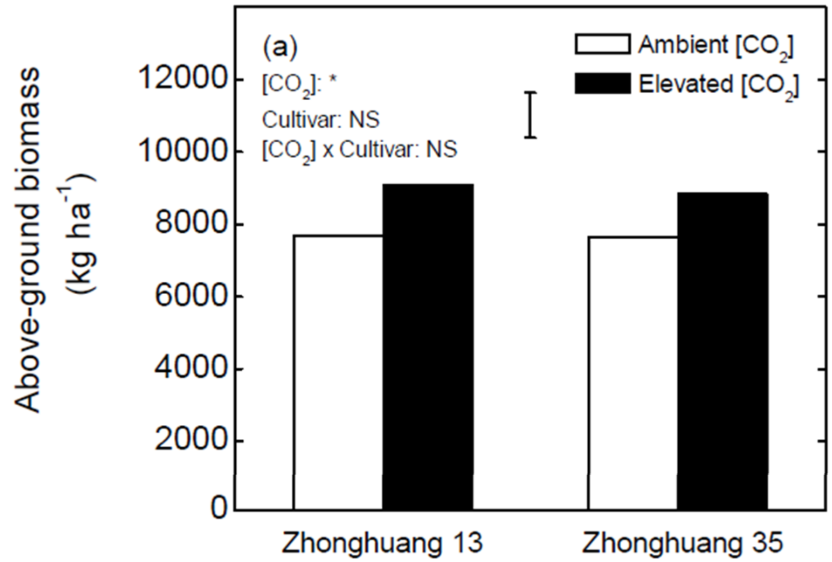
- Wheat from AGFACE
  - No change in grain K
  - Small decrease in grain P & S
    - N:S ratio & protein quality
  - Changes not just "dilution"
- Similar responses in soybean.
- Large grain response means:
  - 20% + K removal.
  - 20% + P removal

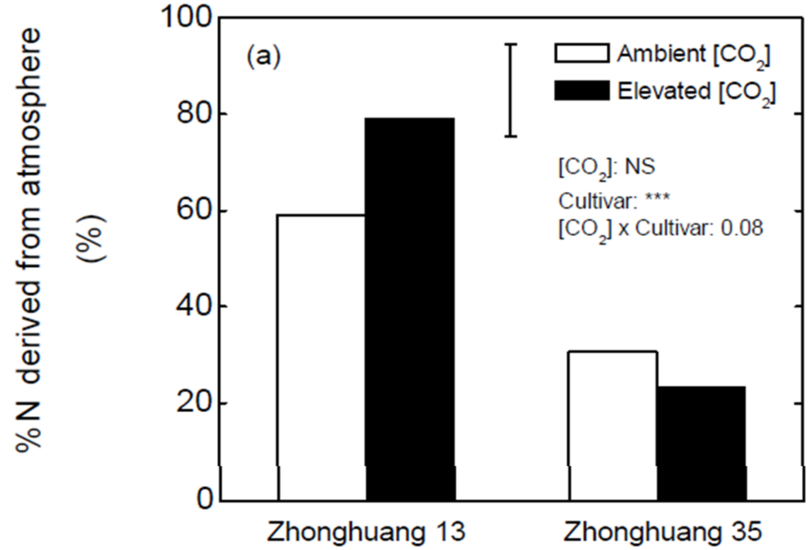


eCO_2 does not specifically affect plant access to P from sparingly soluble P sources. (Jin et al. 2013. P&Soil, 368, 315-328)

Soybean responses to eCO_2

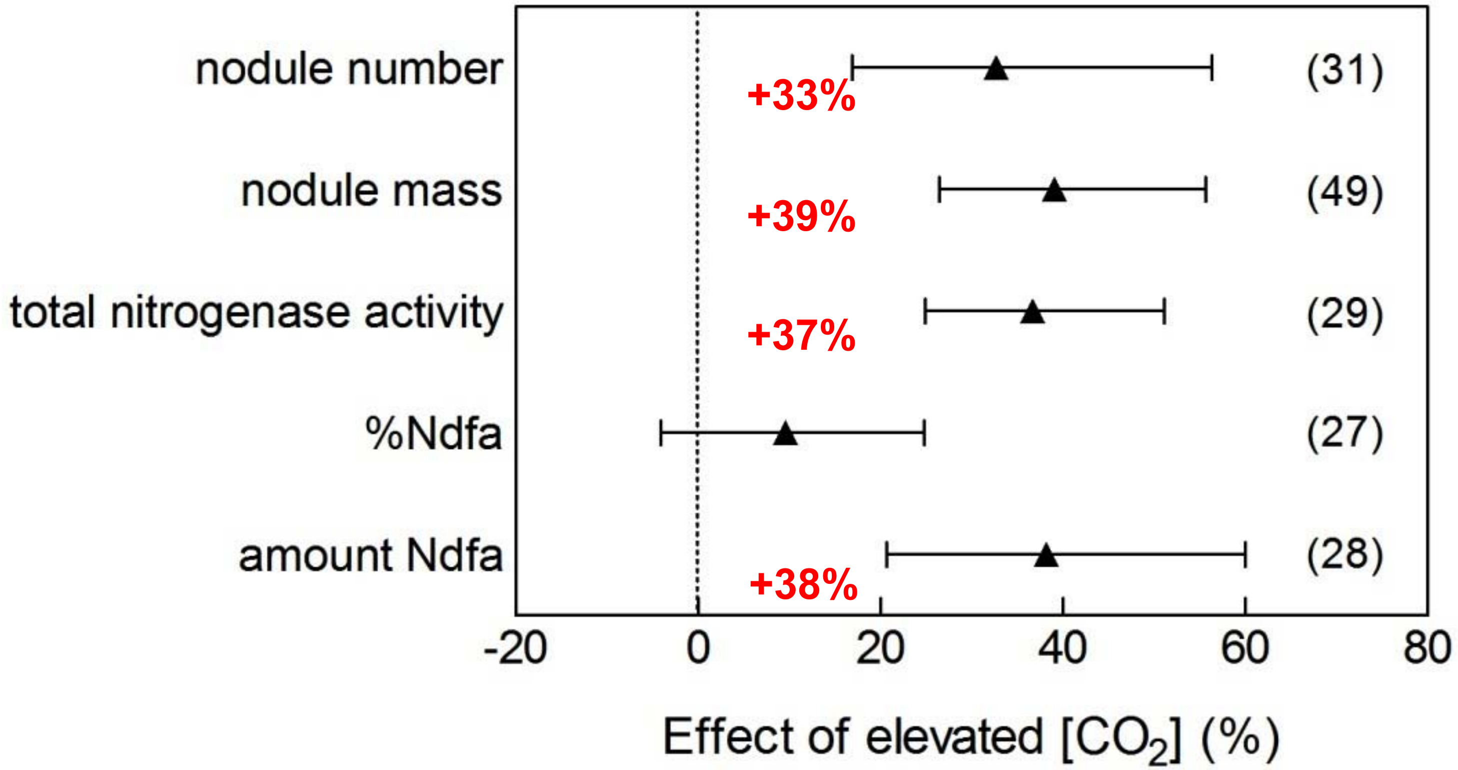
- Experiments in China with CAAS.
- Elevated CO_2 increased growth of soy 16-18%
- Variety difference in %Ndfa.
- The amount of N fixed increased from 165 kg N/ha to 275kg N/ha.
- Expect legumes to be more responsive





Lam et al., 2012, Biol Fertil Soils, 48: 603–606.

eCO_2 effects on N_2 fixation parameters



Effect of eCO_2 on pulses/legumes

(Lam et al. 2012, CPS)

- Glasshouse experiments +/-P; aCO_2, eCO_2 – 3 species
- Legumes responded to eCO_2 if P was supplied.
- No differences in %Ndfa due to [CO_2]
- N fixed increased due to growth stimulation
- Net negative N balance in pulses irrespective….
- **Adequate P is important reducing the N deficit.**

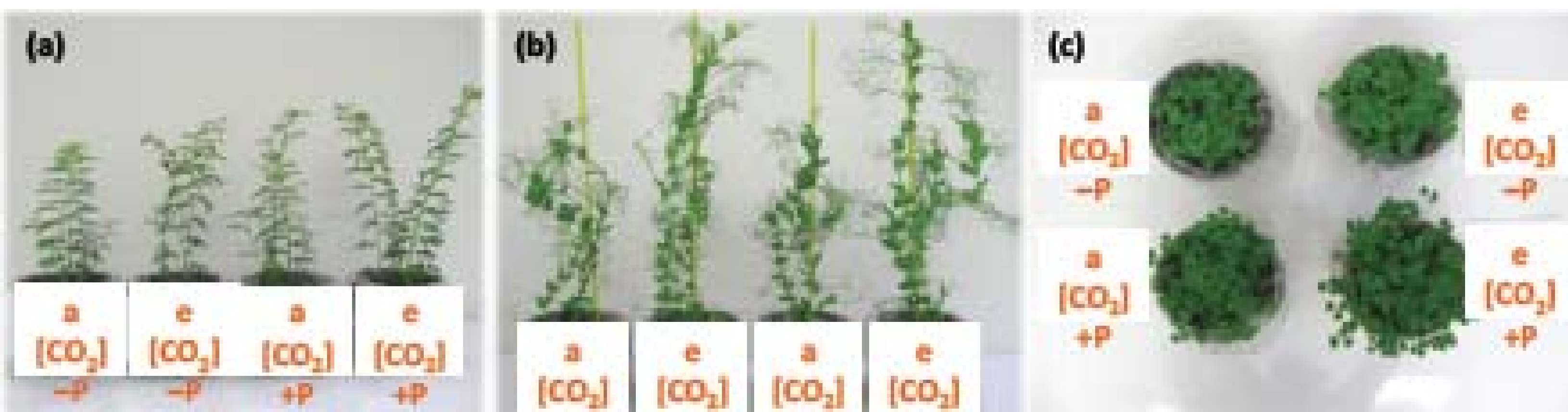


Fig. 1 Chickpea (a), field pea (b) and barrel medic (c) grown under different [CO_2] (a: ambient; e: elevated) and P inputs on Vertosol

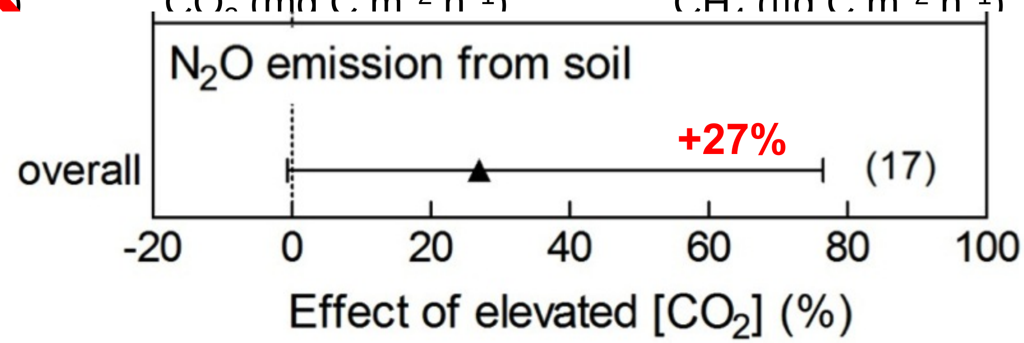
Greenhouse gas emissions

- Static chambers (diameter 0.24 m; height 0.25 m)
- Sampled 5 times during season
- N_2O, CO_2 and CH_4 were analysed by gas chromatography
- CO_2+/- Irrigation

Effect of eCO_2 on GHG emissions

- Elevated [CO_2] increased the emissions of N_2O (92-134%) and CO_2 (16-46%), but had no significant effect on CH_4 flux.
- Supplementary irrigation appeared to reduce N_2O emissions (36%), suggesting the reduction of N_2O to N_2 in denitrification process (WFPS > 70%).

	N_2O (μg N m^{-2} h^{-1})
Ambient [CO_2]	
Rainfed	27.7 (± 8.6)
Supplementary irrigated	15.6 (± 3.8)
Elevated [CO_2]	
Rainfed	53.3 (± 14.6)
Supplementary irrigated	36.5 (± 9.8)



Lam et al., 2012, J Agric Sci, doi: 10.1017/S002185961200055X

eCO_2 effects on N budget

$[CO_2]$-induced changes in N budget in various cropping systems

	$[CO_2]$-induced changes in						
	grain N removal (I)		N_2O emission (II)		amount of N fixed (III)		net effect
	mean	95% CI	mean	95% CI	mean	95% CI	(III – I – II)
	kg N ha^{-1} $season^{-1}$						
C_3 non-legume	12.4	4.6 to 20.4	0.22	–0.06 to 0.50	0	NA	–12.6
grain legume	59.6	35.8 to 86.7	0.60	0.13 to 1.06	25.0	5.3 to 53.0	–35.2
pasture legume	0	NA	–0.04	–0.12 to 0.05	53.0	28.3 to 81.1	53.0
C_4	11.8	1.5 to 22.1	0.16	–0.04 to 0.36	0	NA	–12.0

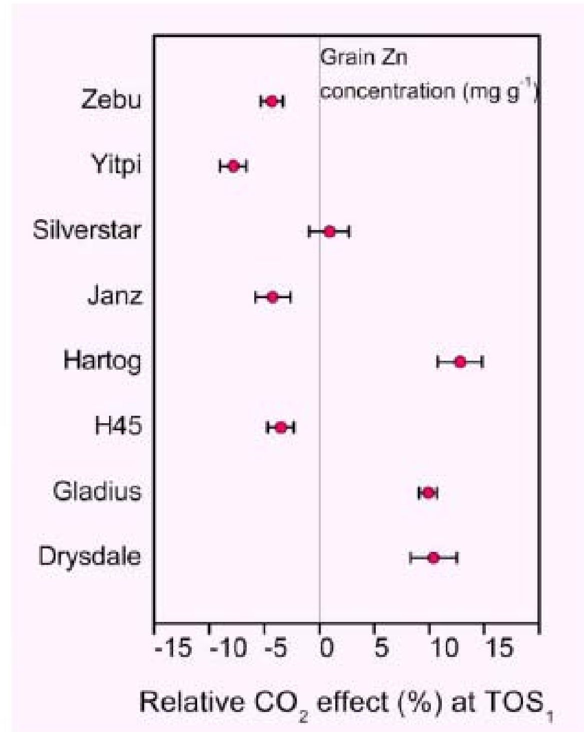
The estimation was made based on the assumption that elevated $[CO_2]$ does not affect ammonia volatilization, N leaching plus runoff, removal by grazing and N deposition. Although predicted shifts in human diets and increasing per-capita consumption from 2000 to 2050 are associated with increased atmospheric N deposition onto global agricultural land (14 Tg yr^{-1}), the increase will be counterbalanced by the corresponding increases in ammonia volatilization (12 Tg yr^{-1}) and N leaching plus runoff (3 Tg yr^{-1}) (Bouwman *et al*. 2011)

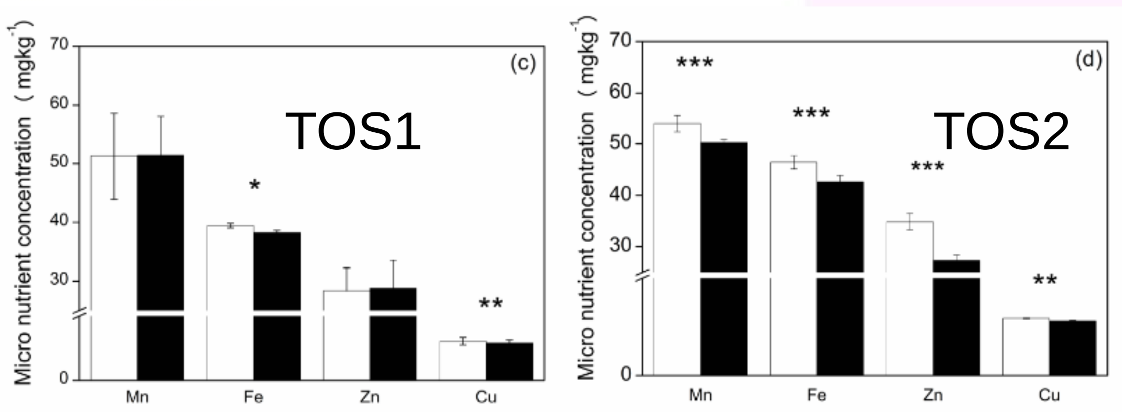
Compared using yields from the experiments undertaken

eCO_2 & grain micronutrient concentration

Fernando et al. 2013 JAFC

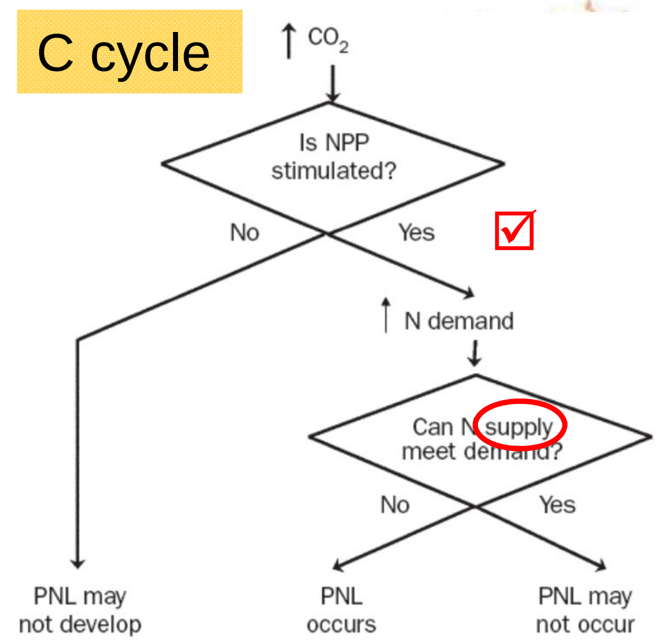
Wheat cultivars differentially responded to increased atmospheric [CO_2] in terms of grain Zn, Fe, Mn and Cu, and flour rheologicial properties

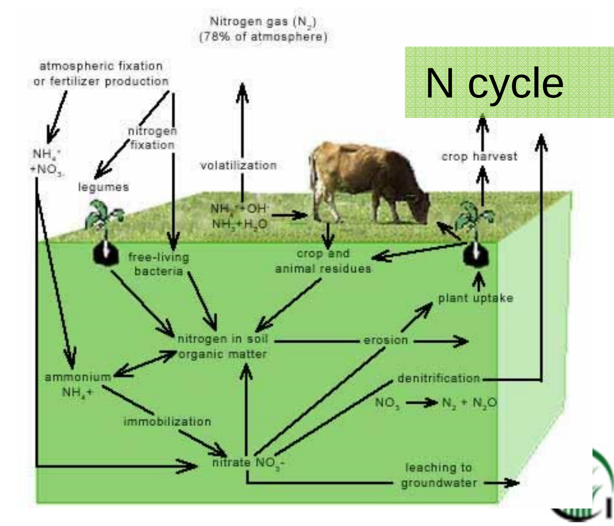




Conclusions about eCO_2 and nutrition

- Supply capacity
  - No increased efficiency of accessing N from fertilizer
  - More roots at a higher density access more soil N
  - Higher OM input but similar C:N ratio
  - May lead to N immobilization – ***likely that N limitation will occur***
- Potential for input
  - Fertilizer N rate/source/time
  - P supply at least maintained to ensure N input from legumes.





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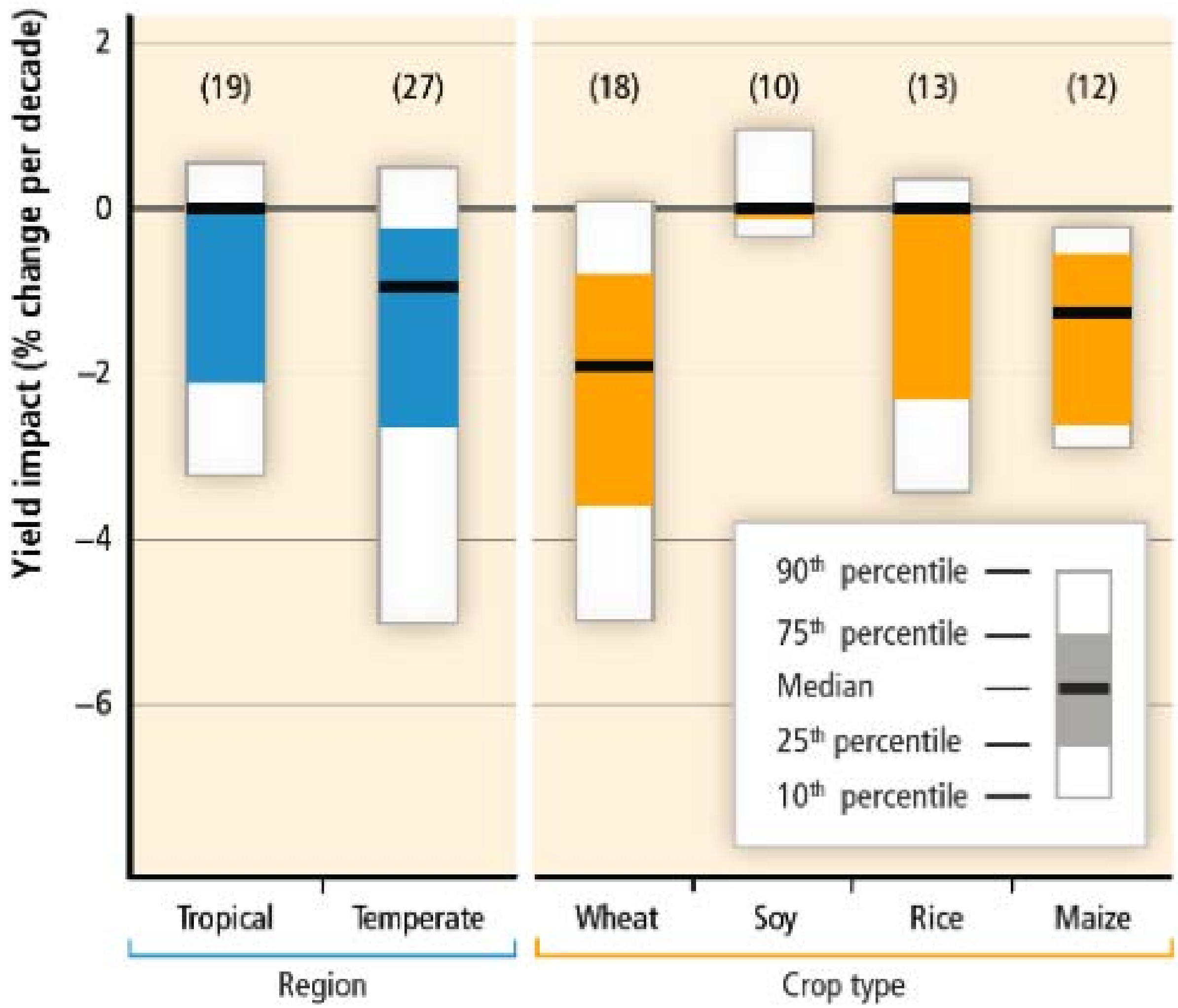
Conclusions related to eCO_2

- Higher N use efficiency, with reduced grain N concentration, but increased N removal in grain cropping systems.
- Extra N will be required to maintain soil N availability and sustain crop yield.
- The extra N could come from increased rates of fertilizer N application, or greater use of legume intercropping and legume cover crops.
- P supply for pulses/legumes will determine the severity of N limitation.
- Higher agricultural greenhouse gas emissions may offset some of the benefit of added C sequestration.
- Grain micronutrient concentration declines – likely related to protein.



Yield impact (% change per decade)
2
0
–2
–4
–6
(19)
(27)
(18)
(10)
(13)
(12)
90th percentile
75th percentile
Median
25th percentile
10th percentile
Tropical
Temperate
Wheat
Soy
Rice
Maize
Region
Crop type

Muchas gracias……

*…..*por su atención

Gracias AACS por la invitación.

& al Dr Garcia IPNI

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