Nitrogen-induced plant species shift constrains response of ecosystem productivity to elevated CO_2

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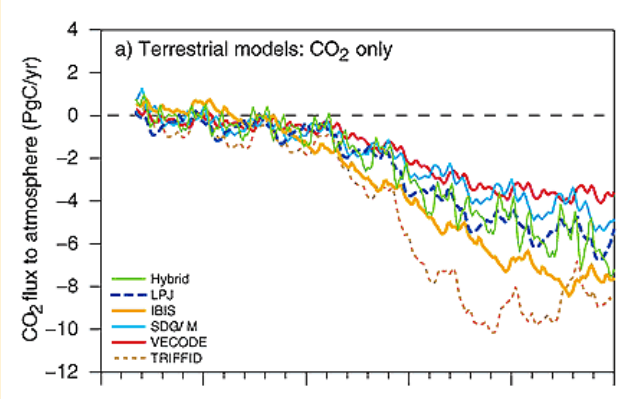
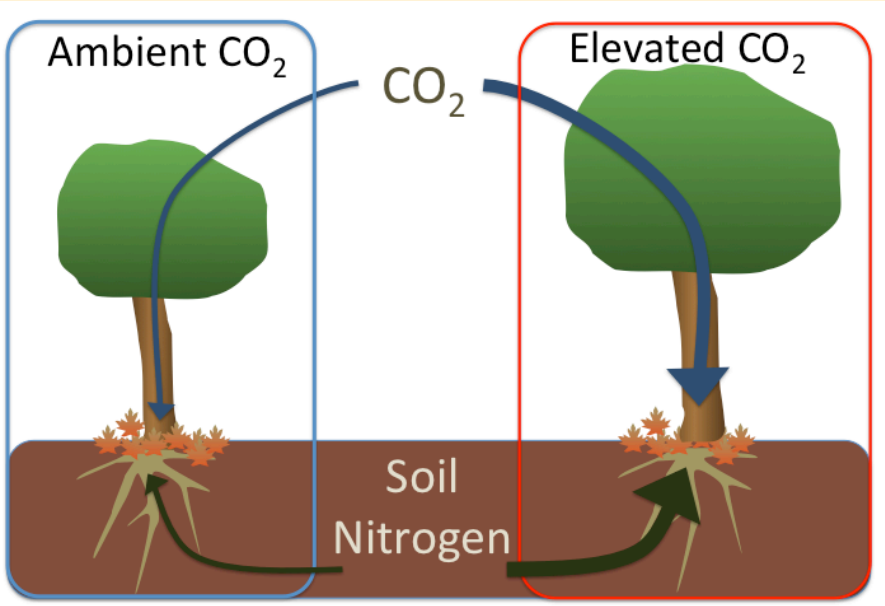
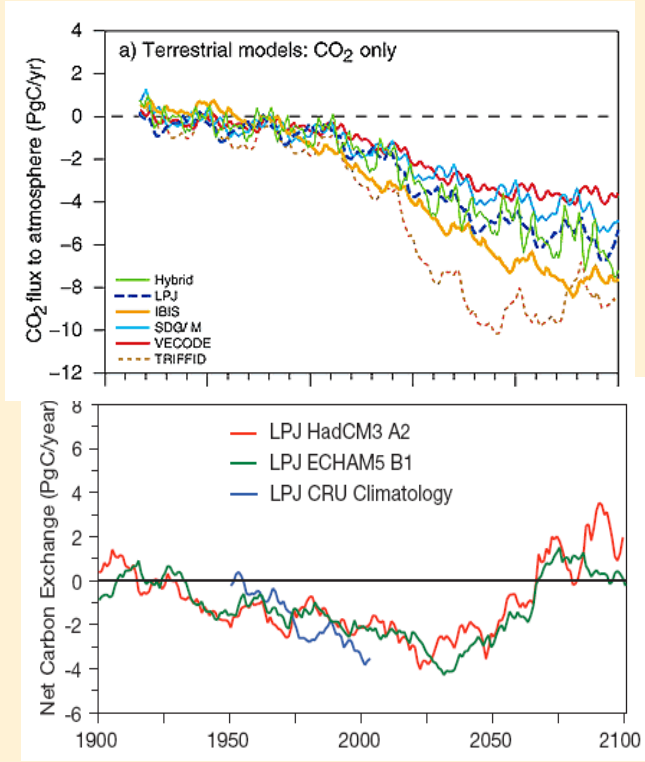


IPCC 2001

Huge carbon sink predicted because of CO_2-fertilization effect on plants

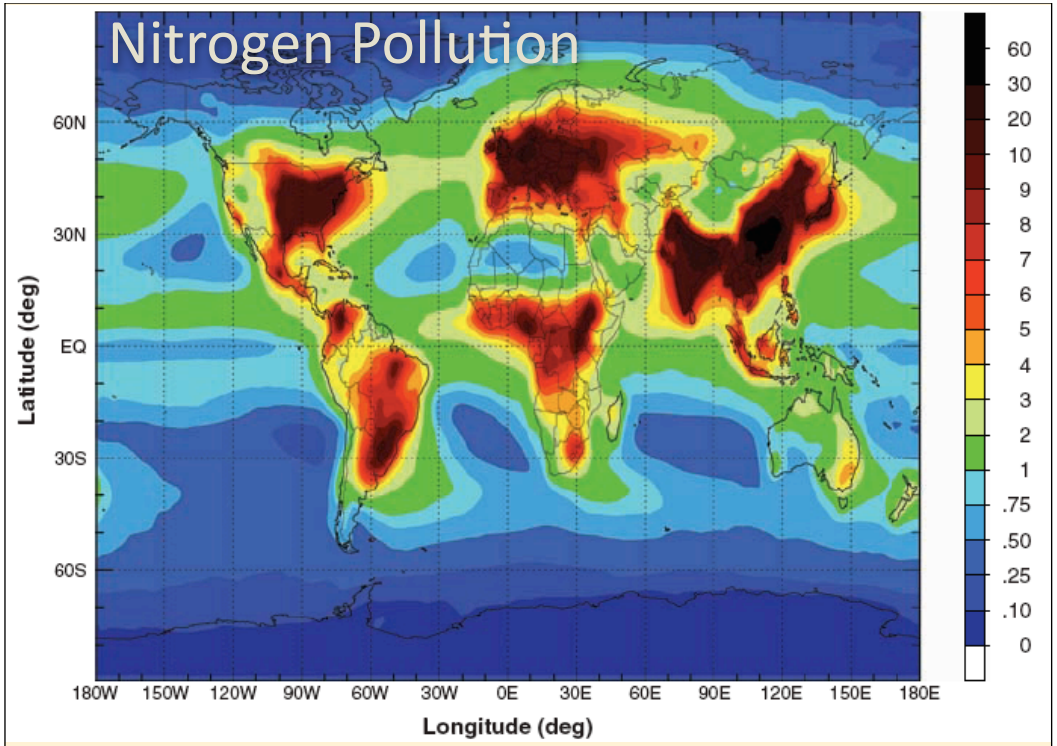
Nitrogen Limitation of the CO_2-Fertilization Effect





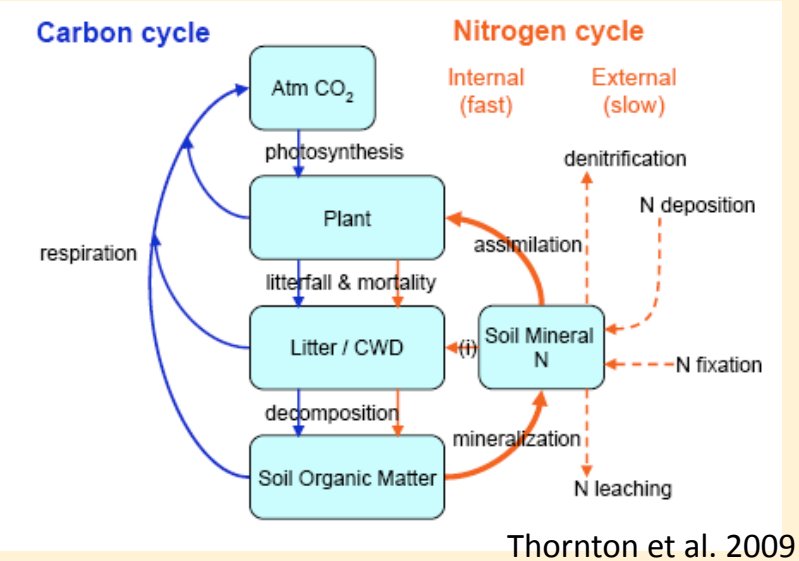
IPCC 2001

Smaller terrestrial carbon sink projected by IPCC in 2007



Dentener et al. 2006, Galloway et al. 2008

Nitrogen limitation incorporated into



Thornton et al. 2009

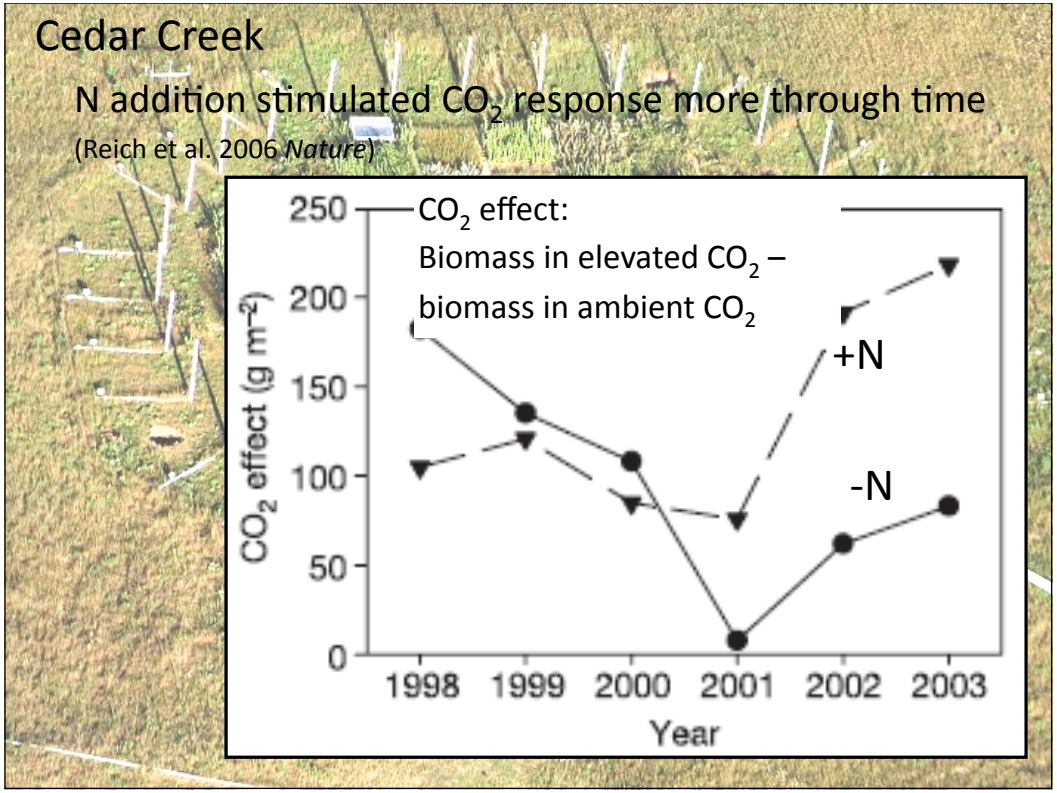
CO_2 X Nitrogen Experiments

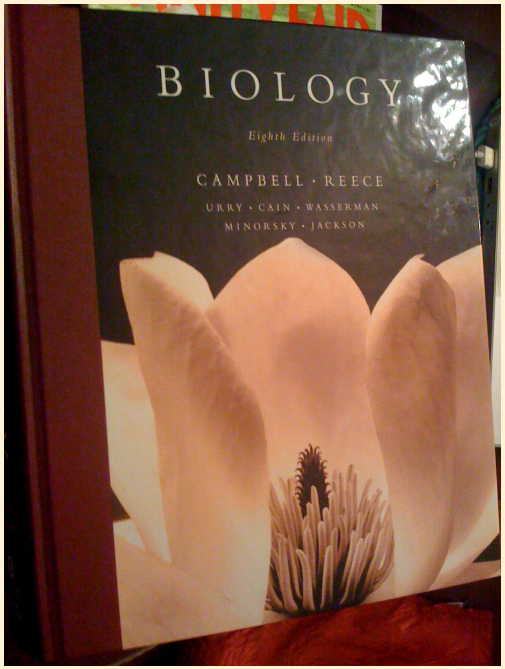
Duke FACE, NC pine forest

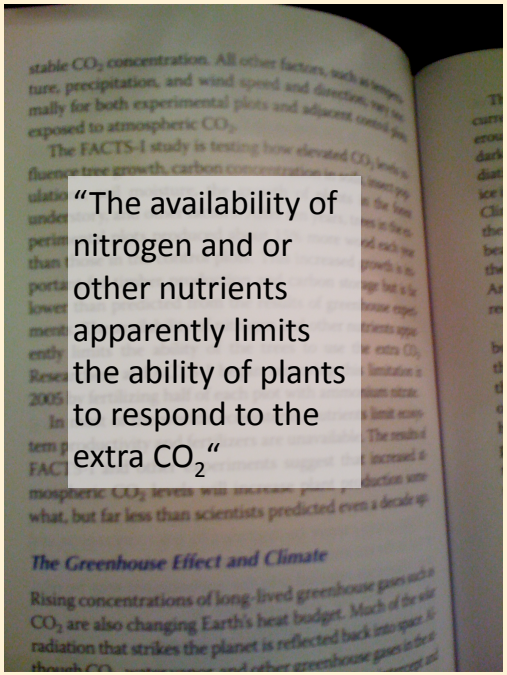
Mixed results of N addition on CO_2response (Oren et al. 2001, McCarthy et al. 2007)

Jasper Ridge, CA grassland

No effect of N on CO_2 response (Shaw et al. 2003)


Cedar Creek
N addition stimulated CO_2 response more through time
(Reich et al. 2006 *Nature*)
CO_2 effect:
Biomass in elevated CO_2 –
biomass in ambient CO_2
+N
-N
CO_2 effect (g m^{-2})
250
200
150
100
50
0
1998
1999
2000
2001
2002
2003
Year





stable CO_2 concentration. All other factors, such as temperature, precipitation, and wind speed and direction, vary normally for both experimental plots and adjacent control plots exposed to atmospheric CO_2.

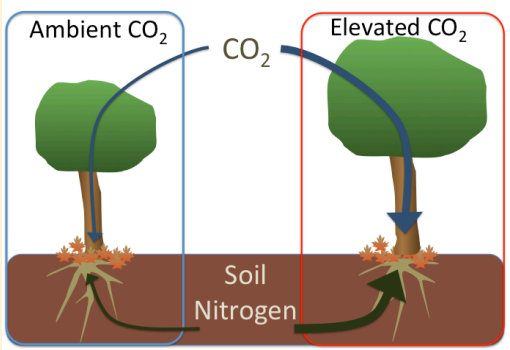
The FACTS-I study is testing how elevated CO_2 levels influence tree growth, carbon concentration in the lower pla-

"The availability of nitrogen and or other nutrients apparently limits the ability of plants to respond to the extra CO_2"

what, but far less than scientists predicted even a decade ago.

The Greenhouse Effect and Climate

Rising concentrations of long-lived greenhouse gases such as CO_2 are also changing Earth's heat budget. Much of the solar radiation that strikes the planet is reflected back into space. Al-

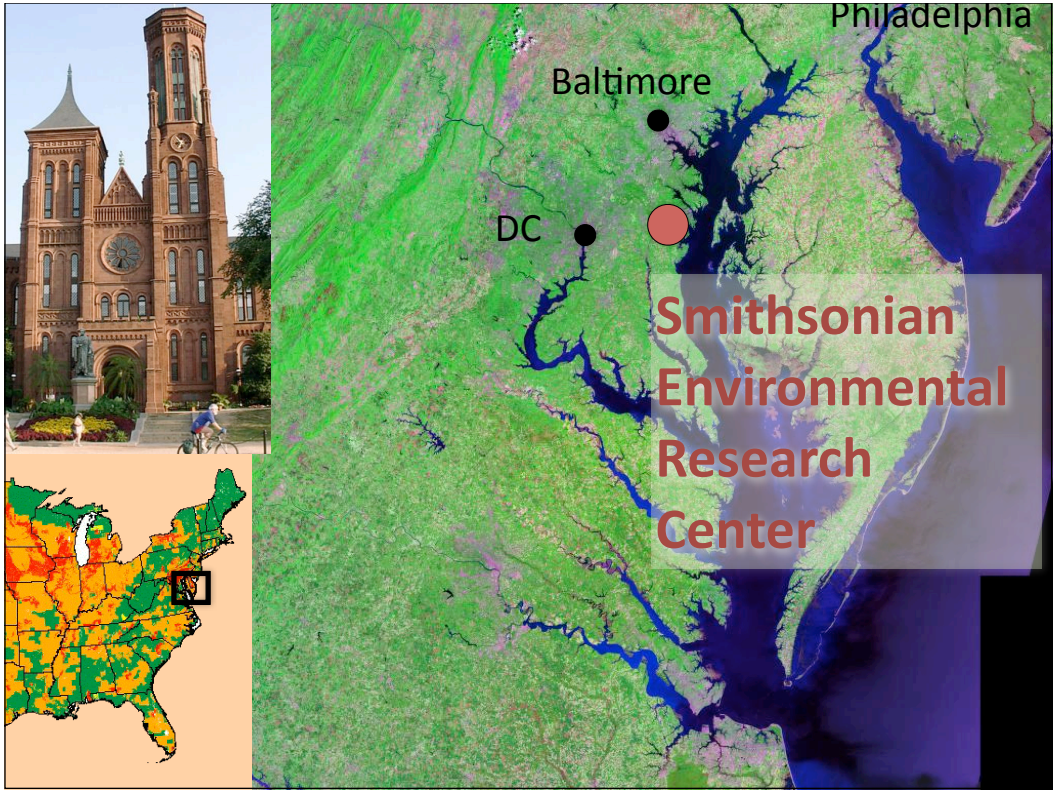


7.3.3.1.3 Nutrient and ozone limitations to carbon sequestration

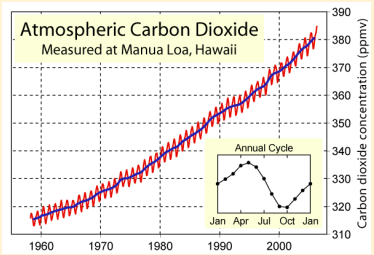
The b[illegible] of [illegible]synthesis implies that stimu[illegible] under high CO_2 concentrat[illegible]ons and be further limited by nutrient availa[illegible]bility (Dukes et [illegible] possible acclimatio[illegible] of plants to high CO_2 levels (Ainsworth and Long, 200[illegible]). Carbon storage by terrestrial plants requires net assimil[illegible], a primary limiting nutrient at [illegible] middle and high latitudes and an important nutrient at lower la[illegible]ngate et al. (2003) argue that 'soil C sequestration under elevated CO_2 is constrained both direct[illegible] N availability [illegible] nutrients needed to support [illegible]de that 'soil N su[illegible]ply is probably an important constraint on global terrestrial r[illegible]iew appears to be consistent with other recent studies (e.g., Finzie et al., 2006; Norby et al [illegible] and [illegible]h at least some of th[illegible] of the current effe[illegible]ts of rising CO_2 on carbon sequestration globally.

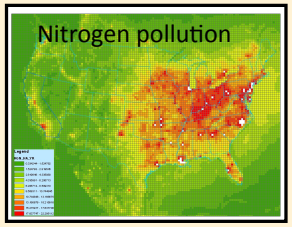
Additio[illegible]sition or direct fertilization can stimulate plant growth (Vitousek, 2004) and in pri[illegible]utrient constraint on CO_2 fertilizatio[illegible] Direct canopy uptake of atmospheric N may be particularly effective (Sievering et al., 2000). Overall, the effectivene[illegible] to be limited by immobilisation and other mechanisms. For example, when labelled nitrogen (^{15}N) was [illegible] over seven years, only a small fraction became available for [illegible] growth (Nadelhoffer et al., 2004). Moreover, atmospheric N deposition is spatially [illegible] including elevated atmospheric ozone. Ozone and other pollutants may have detrimental effects on plant growth, possibly further limiting the stimulation of carbon uptake by anthropogenic N emissions

"Additional N supplied through atmospheric deposition or direct fertilization can stimulate plant growth and in principle could relieve the nutrient constraint on CO_2 fertilization."

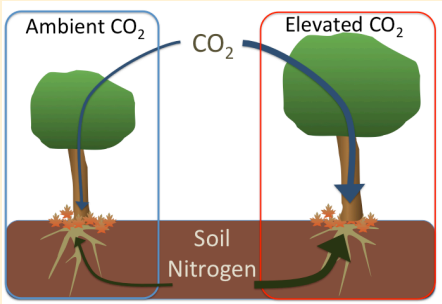

Philadelphia
Baltimore
DC
Smithsonian
Environmental
Research
Center

Smithsonian Global Change Research Wetland



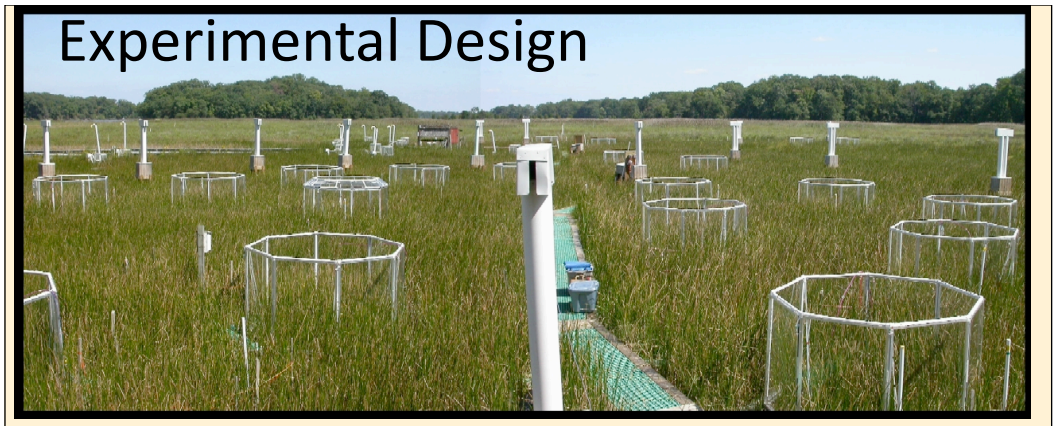


1) Plant growth



Does additional nitrogen enhance the CO_2 fertilization effect on plant growth?

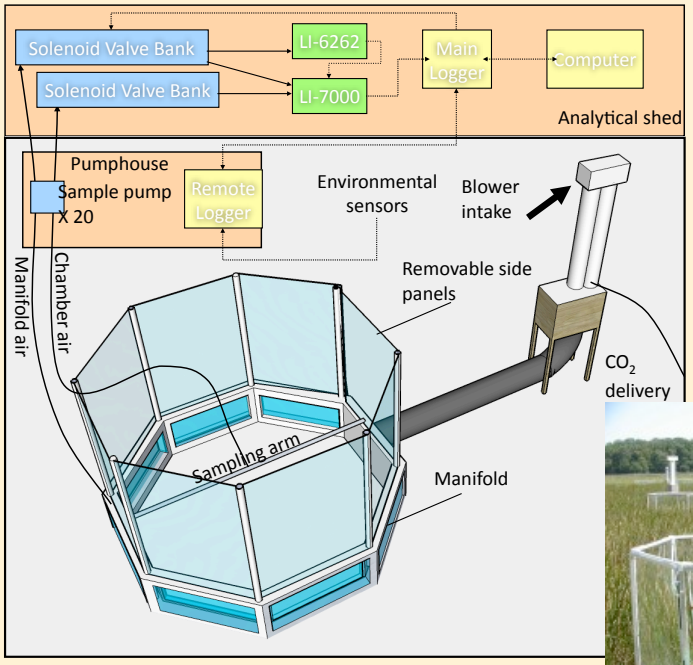
Experimental Design

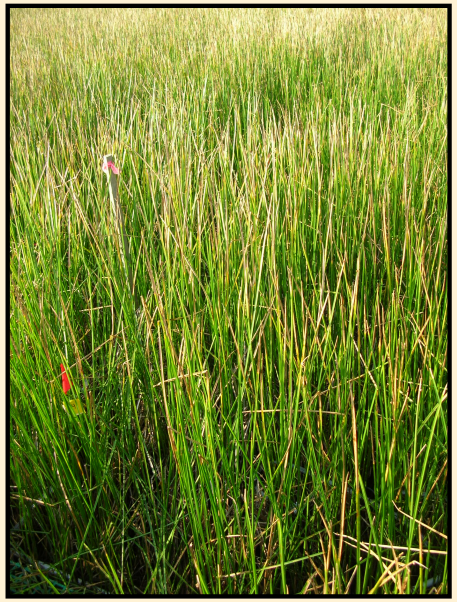


- 20 experimental chambers
- 2 levels of CO_2: ambient (~390 ppm), elevated (~720 ppm)
- 2 levels of Nitrogen: unfertilized or 25 g N m^{-2} y^{-1}

	Ambient CO_2	Elevated CO_2
	Amb	Elev
+Nitrogen	Amb+N	Elev+N

CO_2 and


Solenoid Valve Bank
Solenoid Valve Bank
LI-6262
LI-7000
Main Logger
Computer
Analytical shed
Pumphouse
Sample pump X 20
Remote Logger
Environmental sensors
Blower intake
Removable side panels
Manifold air
Chamber air
CO_2 delivery
Sampling arm
Manifold



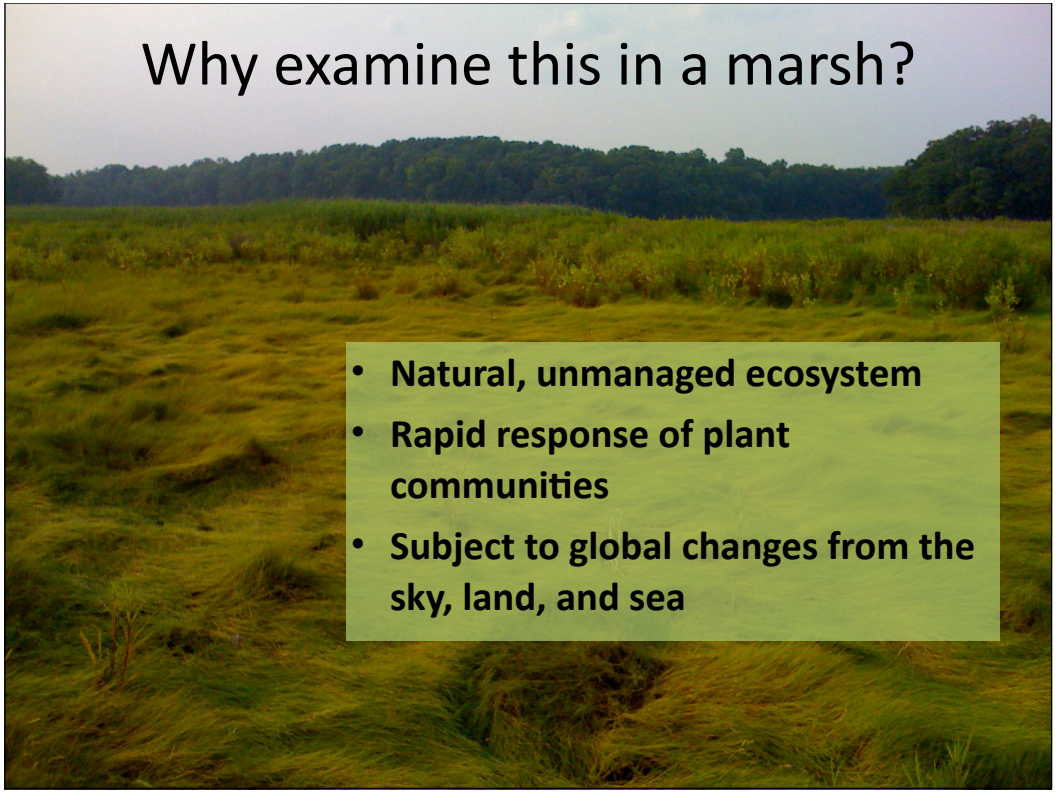
Sedge- C_3 photosynthesis

Schoenoplectus americanus

Grasses- C_4 photosynthesis

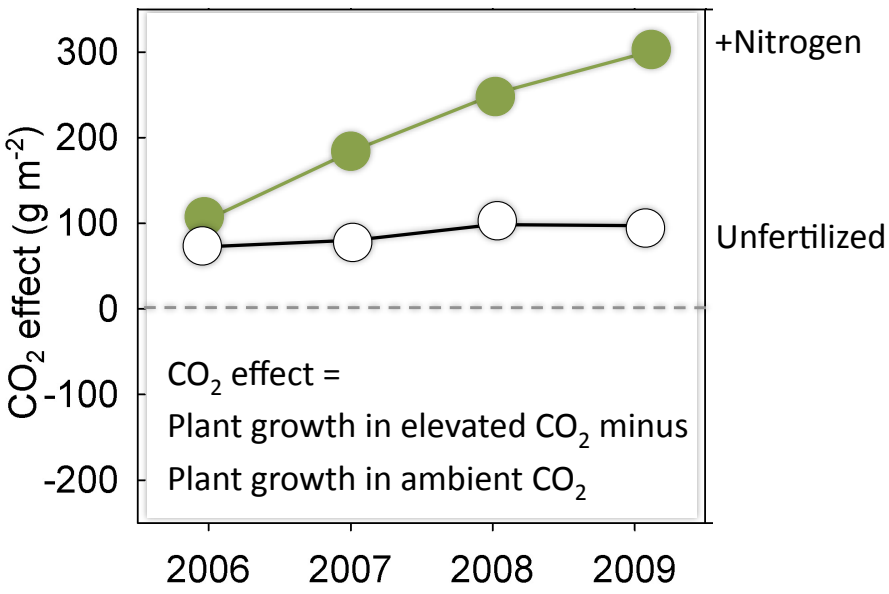
Spartina patens, Distichlis spicata

Why examine this in a marsh?

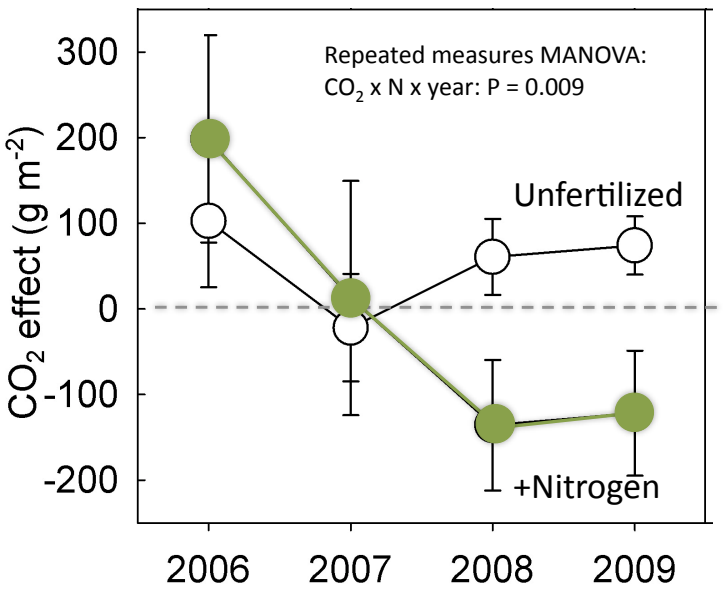


- **Natural, unmanaged ecosystem**
- **Rapid response of plant communities**
- **Subject to global changes from the sky, land, and sea**

Does nitrogen enhance the CO_2 effect?

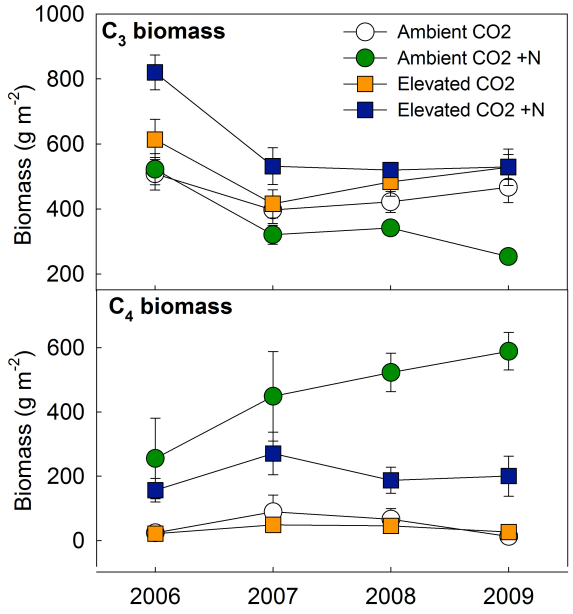


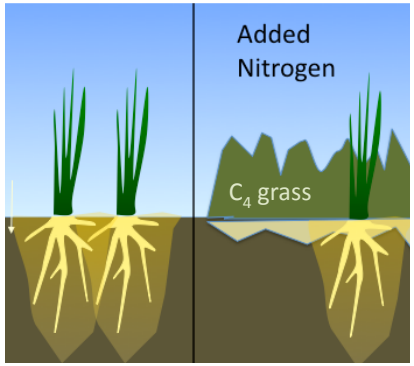
CO_2 fertilization effect through time



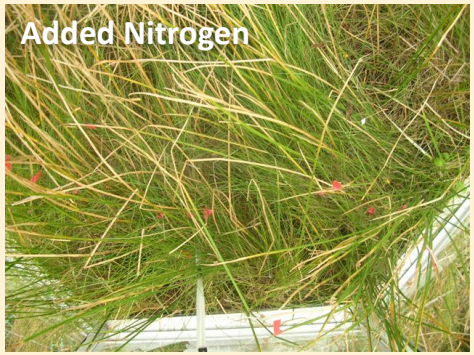
(Langley & Megonigal *Nature* 2010)

Species responses



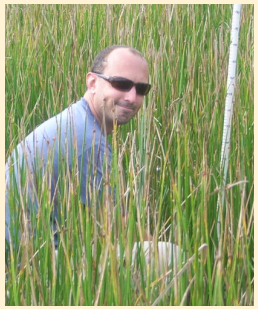


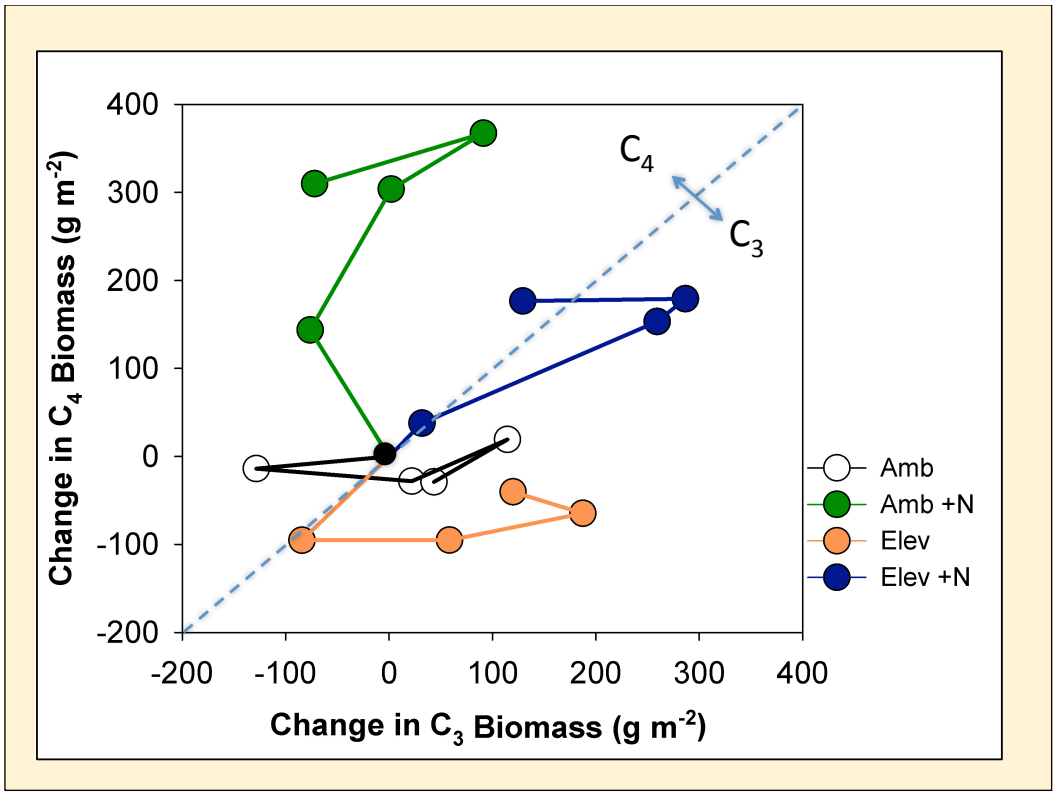
KEVIN WHITE



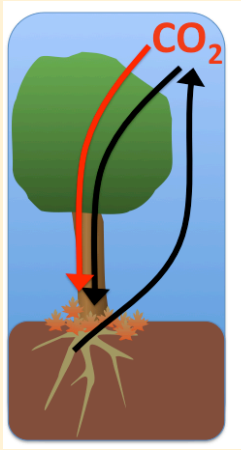
- N promotes C_4 grass encroachment
- Inhibits sedge productivity

Kevin White
U. Penn
"Contrasting C_3 and C_4 root-shoot allocation responses to elevated CO_2 and nitrogen" *In submission*



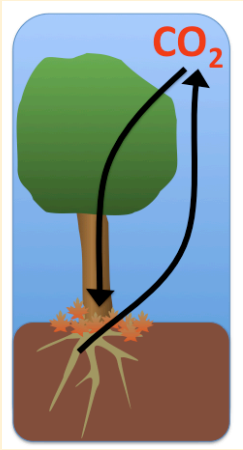

400
300
200
100
0
-100
-200
-200
-100
0
100
200
300
400
Change in C_4 Biomass (g m^{-2})
Change in C_3 Biomass (g m^{-2})
C_4
C_3
Amb
Amb +N
Elev
Elev +N

Elevated CO_2



Plants respond to elevated CO_2 with enhanced productivity

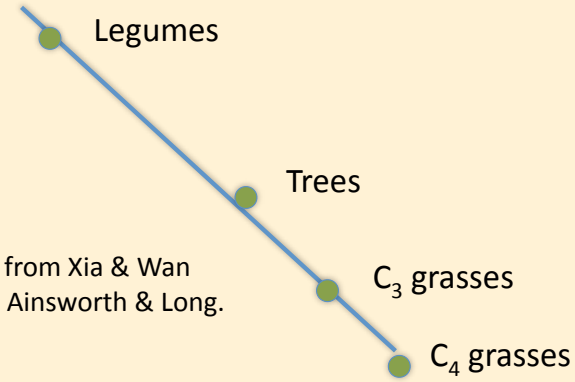
Elevated CO_2 + Nitrogen



Nitrogen addition interrupts the negative feedback loop

Generality of Tradeoffs?

- Plant strategies differ for acquisition of different resources
- Plants may also differ in ability to respond to global

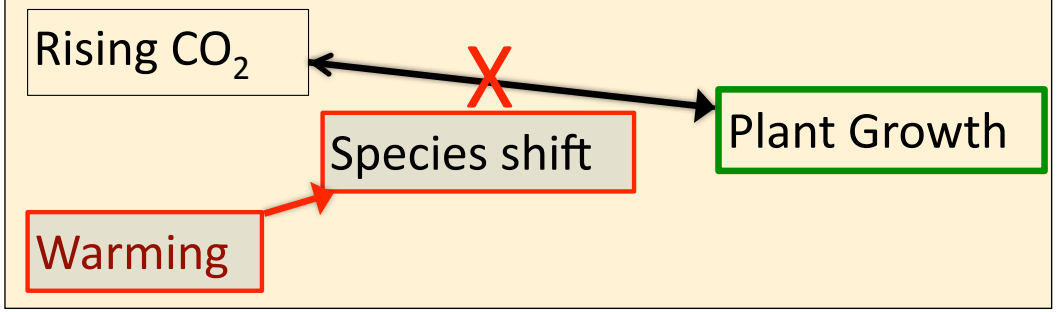


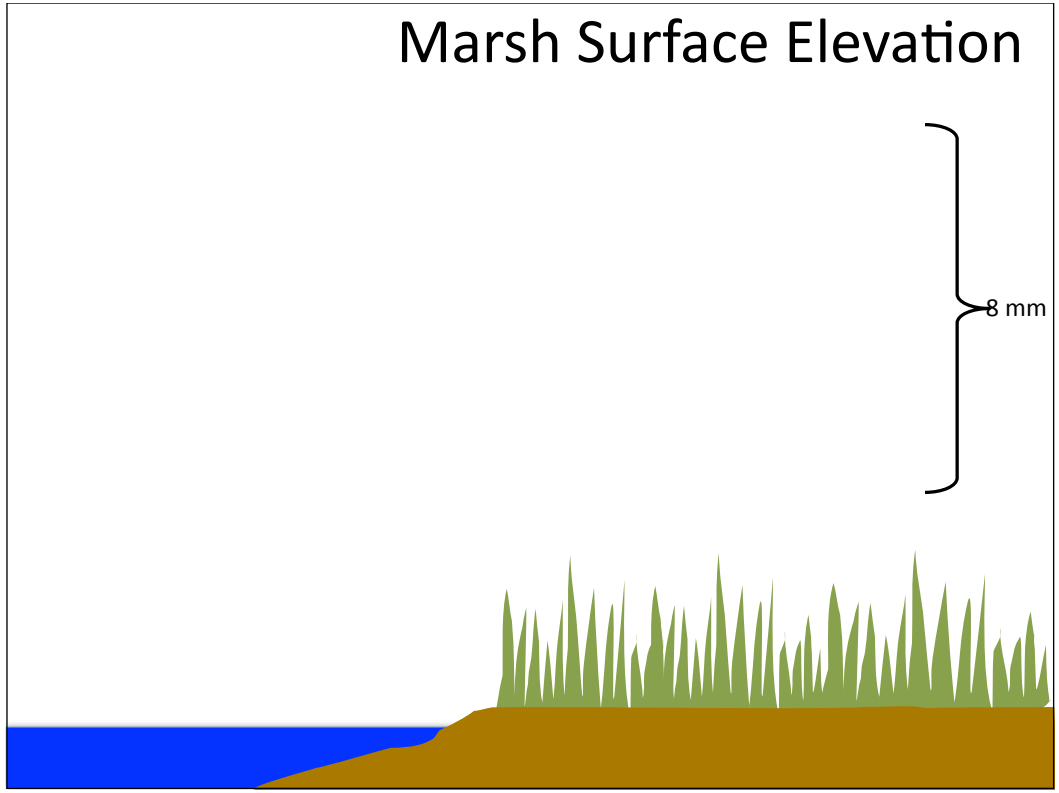
(Data from Xia & Wan 2008, Ainsworth & Long. 2005)

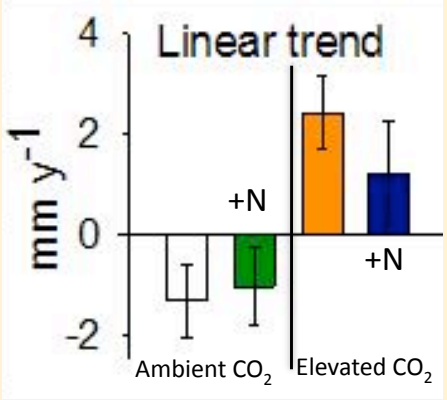
Species?
Genotypes?
Individuals?

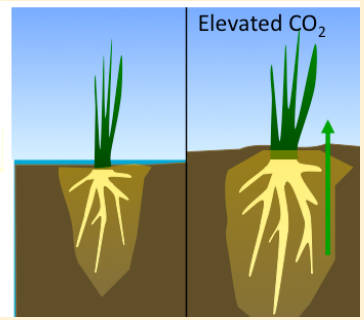
Tradeoffs among other factors?

- Niu et al. 2010. Warming promotes C_4 dominance in tallgrass prairie
- Hovenden et al. 2010. Warming promotes C_4 grass dominance in Tasmanian grassland.




Marsh Surface Elevation
8 mm





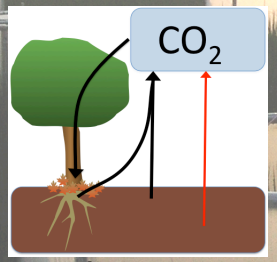
Marsh surface

- Elevated CO_2 boosts marsh surface elevation
- N addition diminishes CO_2 effect.

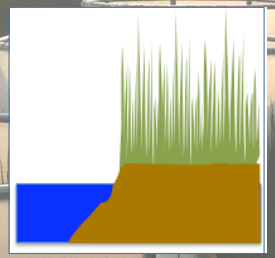
(Langley et al. 2009 *PNAS*)

Main Findings

- Ecosystems respond to one factor, elevated CO_2, by dampening its negative effects.
- Adding a second factor, nitrogen, diminishes the buffering capacity of the ecosystem.
- We could be underestimating the negative effects of multi-factored global change.



Atmospheric CO_2 rise



Sea-level rise

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•Thank You!