Nitrogen uptake and net primary productivity in four forest FACE experiments

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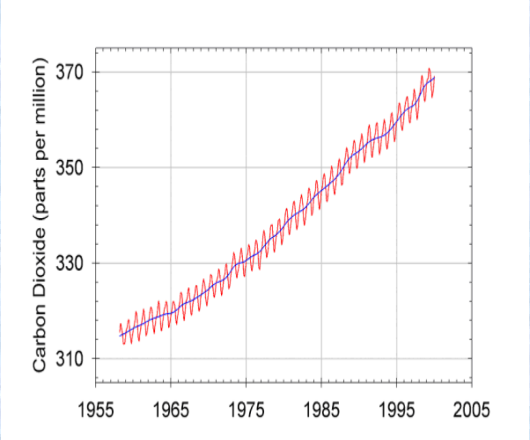
FACE experiments provide valuable data for projecting future global carbon cycling

- Forests account for a large fraction of the exchange of C between the atmosphere and the terrestrial biosphere
- Net primary productivity of forests is expected to increase as the atmospheric [CO_2] rises ("CO_2 fertilization")
- Ecosystem and coupled carbon-climate models require an accurate representation of the CO_2 fertilization effect
- Free-air CO_2 enrichment (FACE) experiments are the best source of data to inform models



Forest FACE Synthesis Project

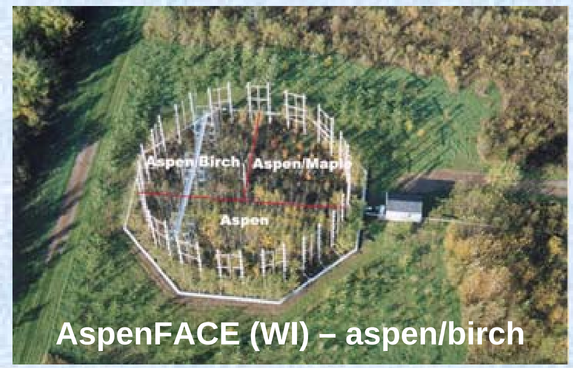
Objectives:

- Quantify CO_2 effect on NPP in a manner that will inform ecosystem and global models
- Quantify N uptake, N-use efficiency, and related expressions of C-N interaction
- Look for general patterns of response that apply across diverse sites

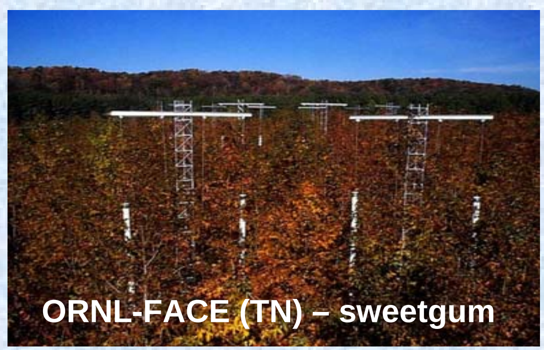
Four experiments in which forest stands exposed to ~550 ppm CO_2 for 3-8 years

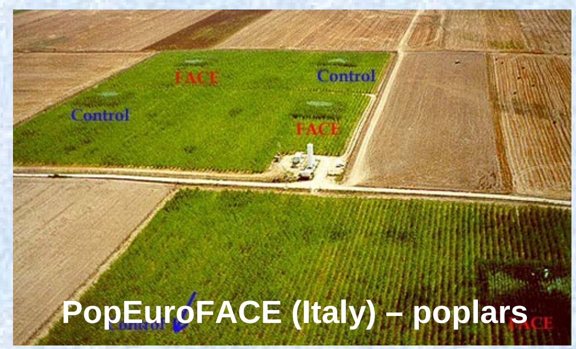
Closed-canopy | **Developing stands**


DukeFACE (NC) – loblolly pine



AspenFACE (WI) – aspen/birch


ORNL-FACE (TN) – sweetgum



PopEuroFACE (Italy) – poplars

Calculation of NPP

NPP = woody increment + leaf litter + fine-root production

Wood increment

Allometry : DM = f(BA, H, taper, density)

Harvest

Leaf

Litter traps

Fine root

Minirhizotrons and in-growth cores

Sequential coring

NPP calculated for all plots and years after canopy development was complete

Calculation of N Uptake

N uptake = N content of current year wood
+ N content in live canopy – amount resorbed from previous year
+ amount used in fine-root production

Peak N content = amount in all wood
+ N content of canopy at peak mass
+ N content of fine roots at peak mass

Data

Concentration of N in green leaves, leaf litter, fine roots, and wood

[N] combined with biomass data to calculate N content

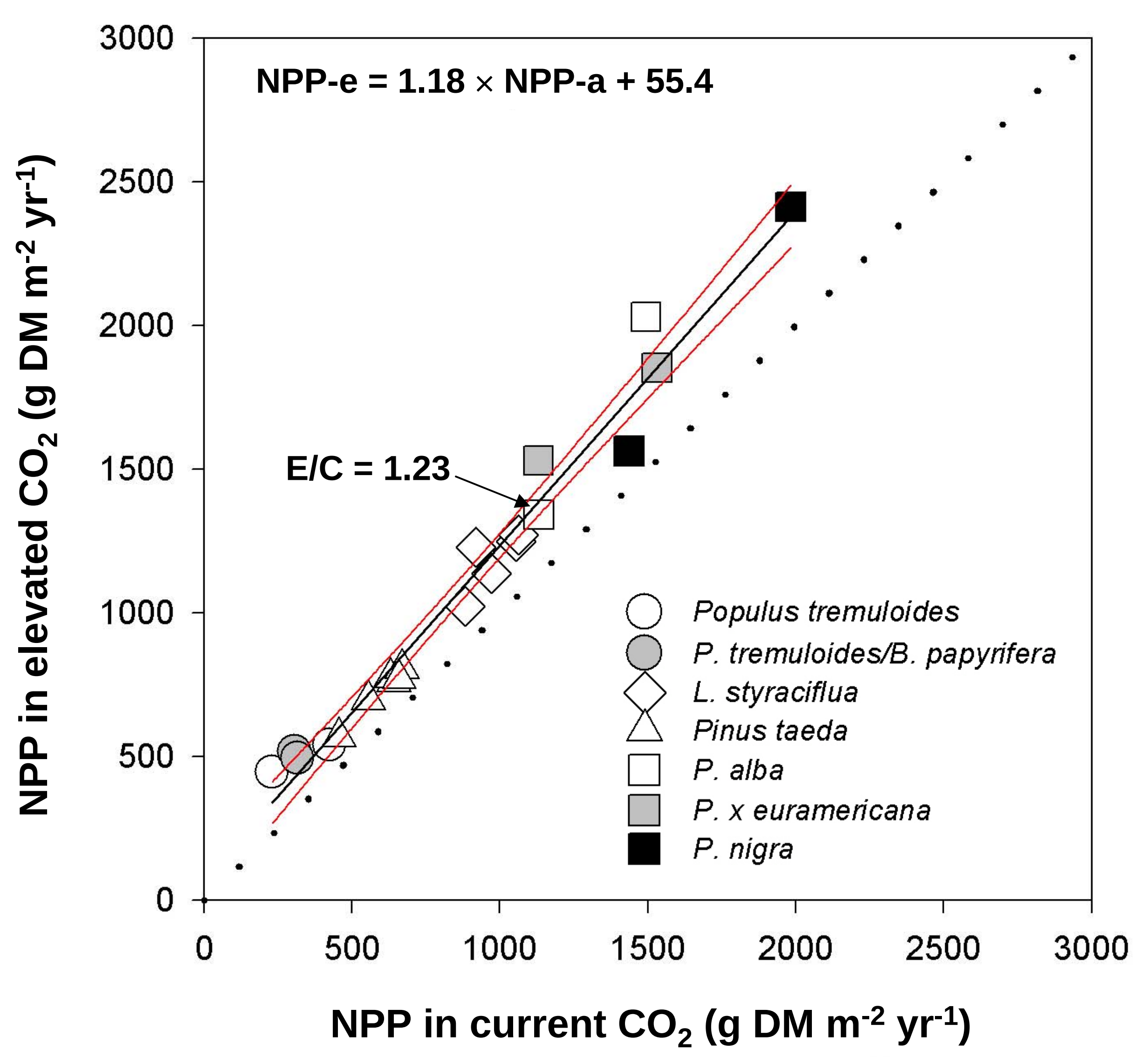
NUE = NPP / N uptake

N productivity = NPP / N content

MRT = N content / N uptake

NUE = Nprod × MRT

NPP increased in elevated CO_2 across a wide range of NPP



- **Regression is significantly different from 1:1 line**
- **Regression defines a median response of 23% enhancement**
- **Basis of response was increased light absorption at low LAI and increased light-use efficiency at high LAI**

Norby et al. (2005) *PNAS* 102: 1805

This analysis does not resolve all issues about forests in a CO_2-rich world

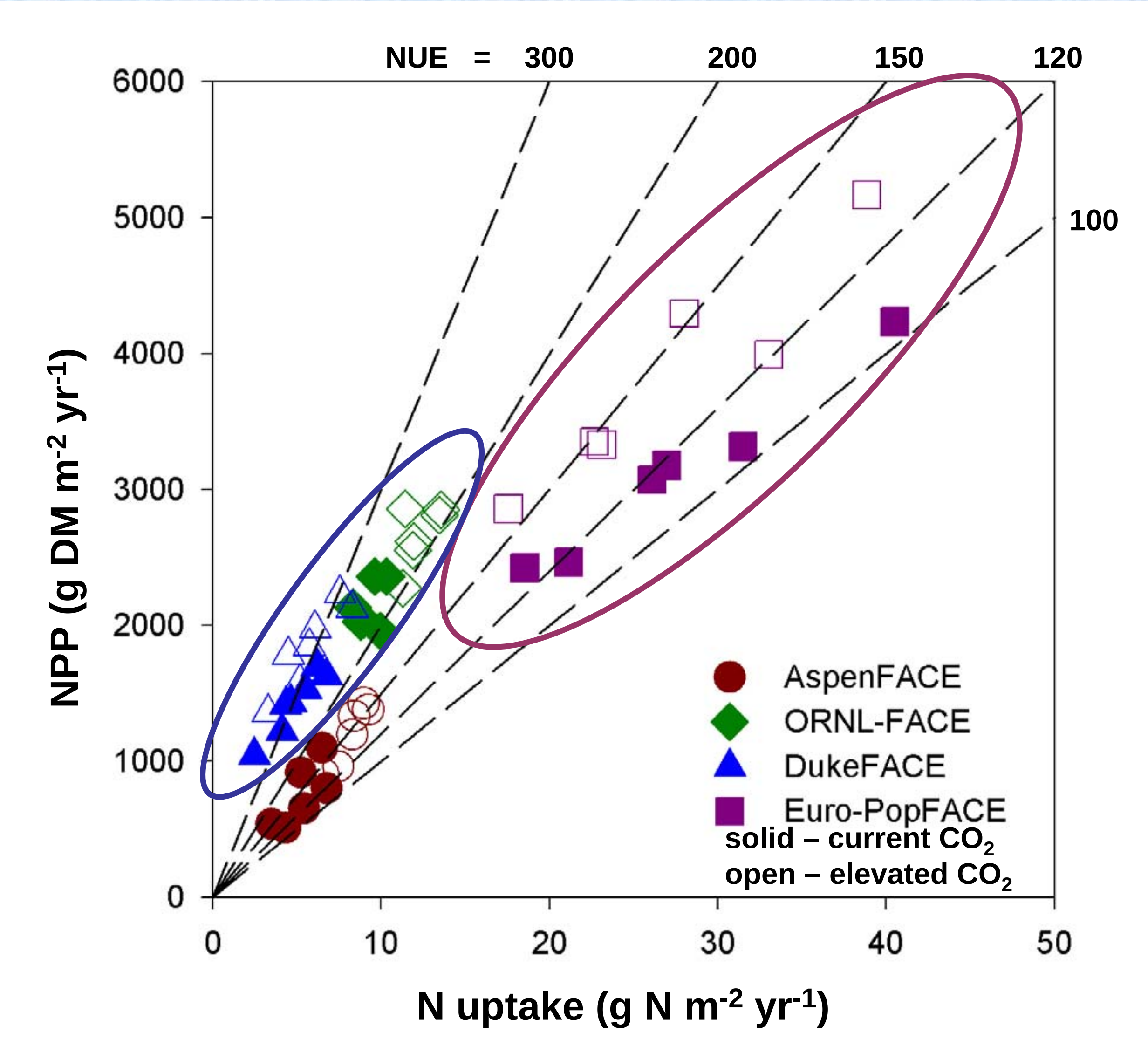
- The median response masks spatial and temporal variability
- Interactions with other global change factors may be significant
- The analysis did not include tropical or boreal forests
- C partitioning patterns may determine the ultimate fate of the additional C
- Will responses persist in more mature forests?
- N feedbacks might limit response over the long term

It’s time to look below ground!

To support increased NPP, the trees must either take up more N from soil or use N more efficiently

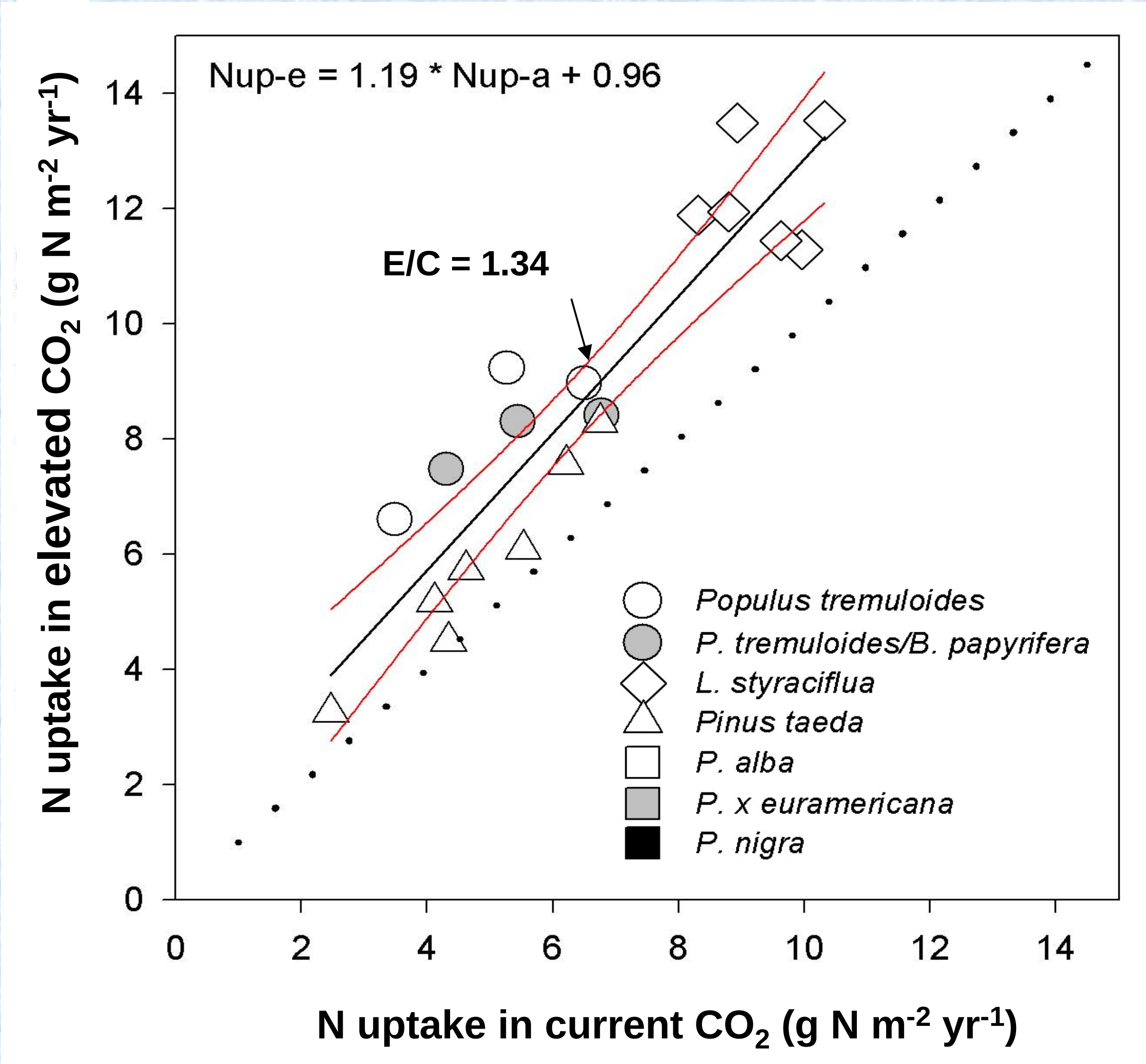
- Increased N uptake
  - Availability in soil
  - Root exploration
  - Sustainable?
- Increased efficiency
  - Biochemical
  - Allocation and retranslocation
  - Tissue quality feedbacks?

Nitrogen-use efficiency describes the relationship between NPP and N uptake



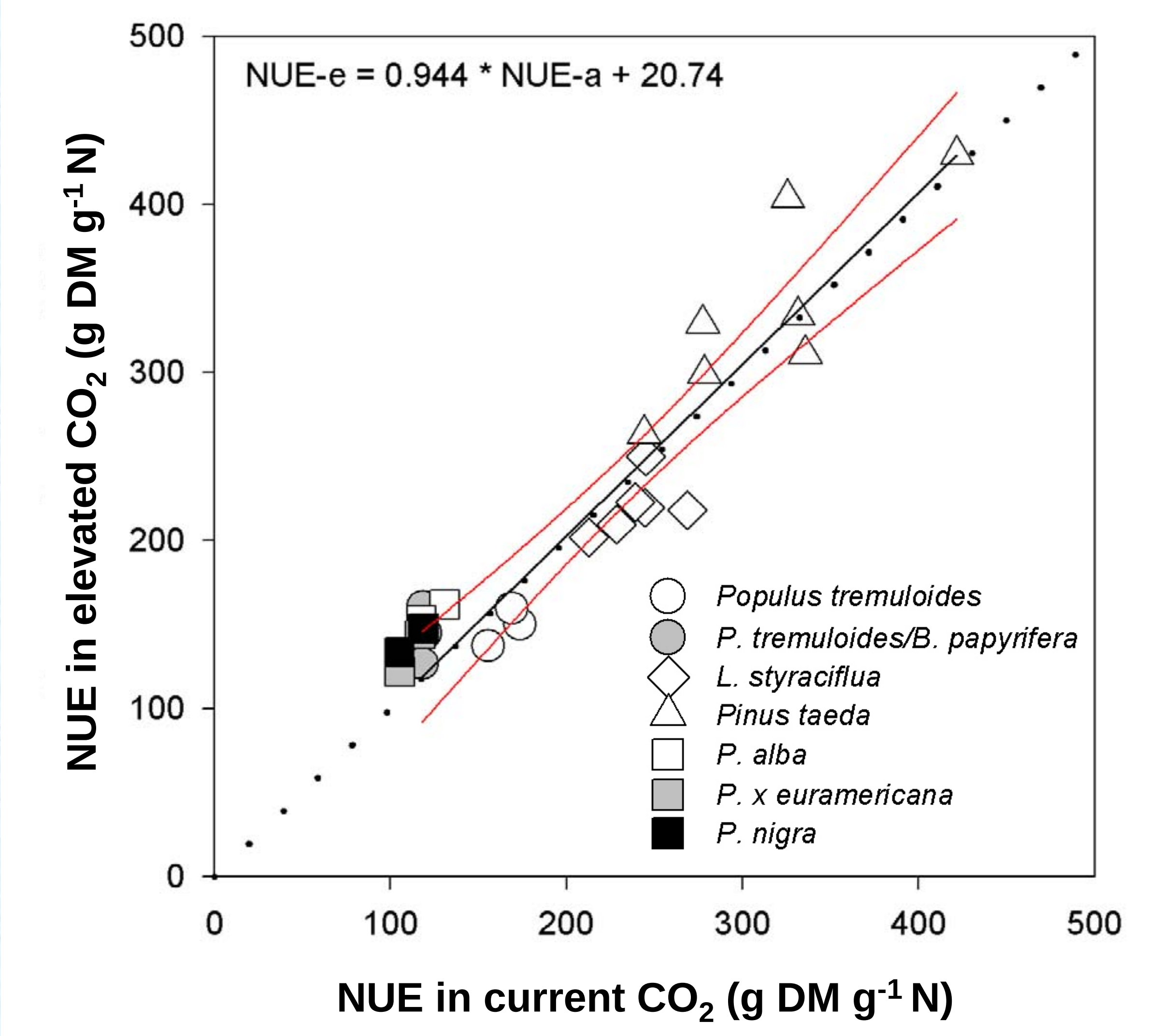
- Within a site, both NPP and N uptake are generally higher in in elevated CO_2
- Exception: N uptake was not increased in the irrigated, fast-growing Euro-PopFACE experiment
- Within a site, data generally align along a constant NUE isopleth
- NUE is greater in the older stands

Nitrogen uptake is the first point of interaction between soil N and plant N



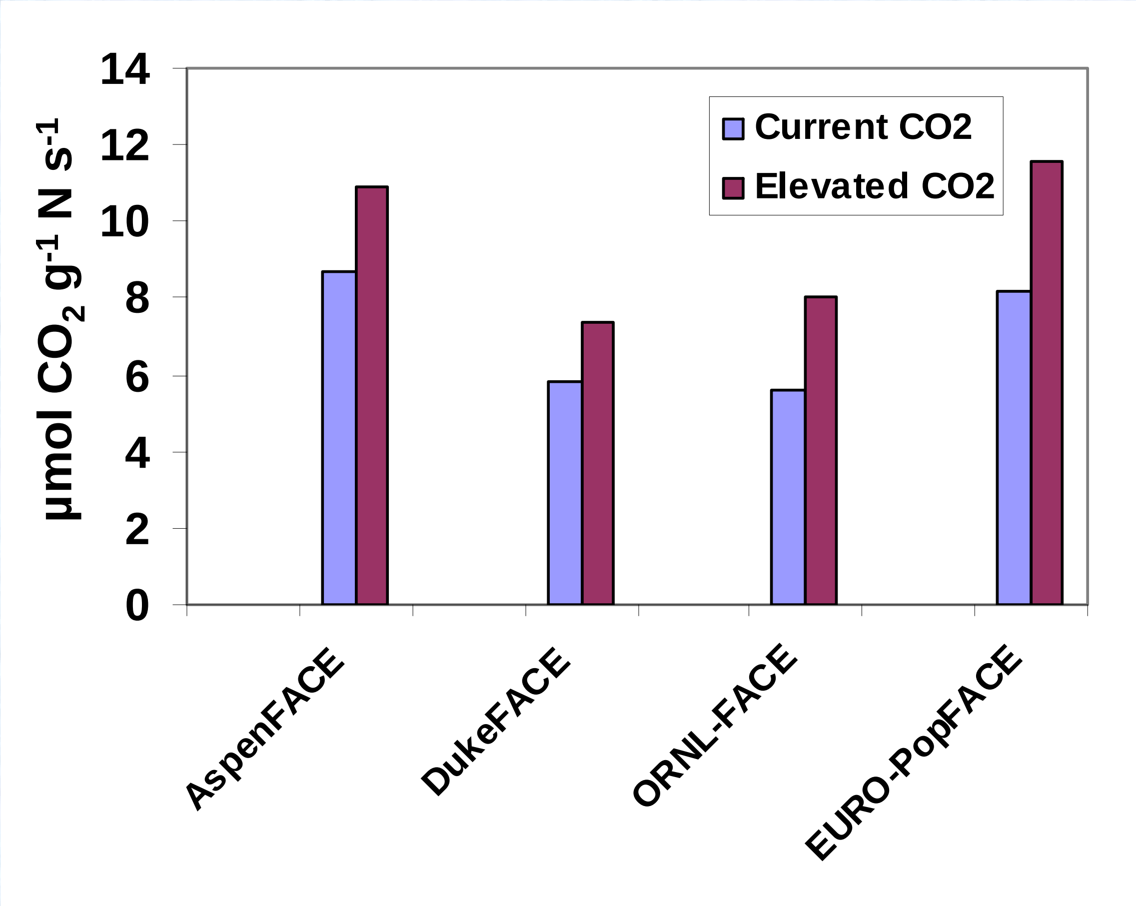
- **N uptake increased significantly in elevated CO_2**
- **Increased uptake was not associated with any measured effect on microbial N metabolism**
- **Increased root exploration is indicated**

Nitrogen-use efficiency is often assumed to increase in elevated CO_2 -- *not supported by our data*



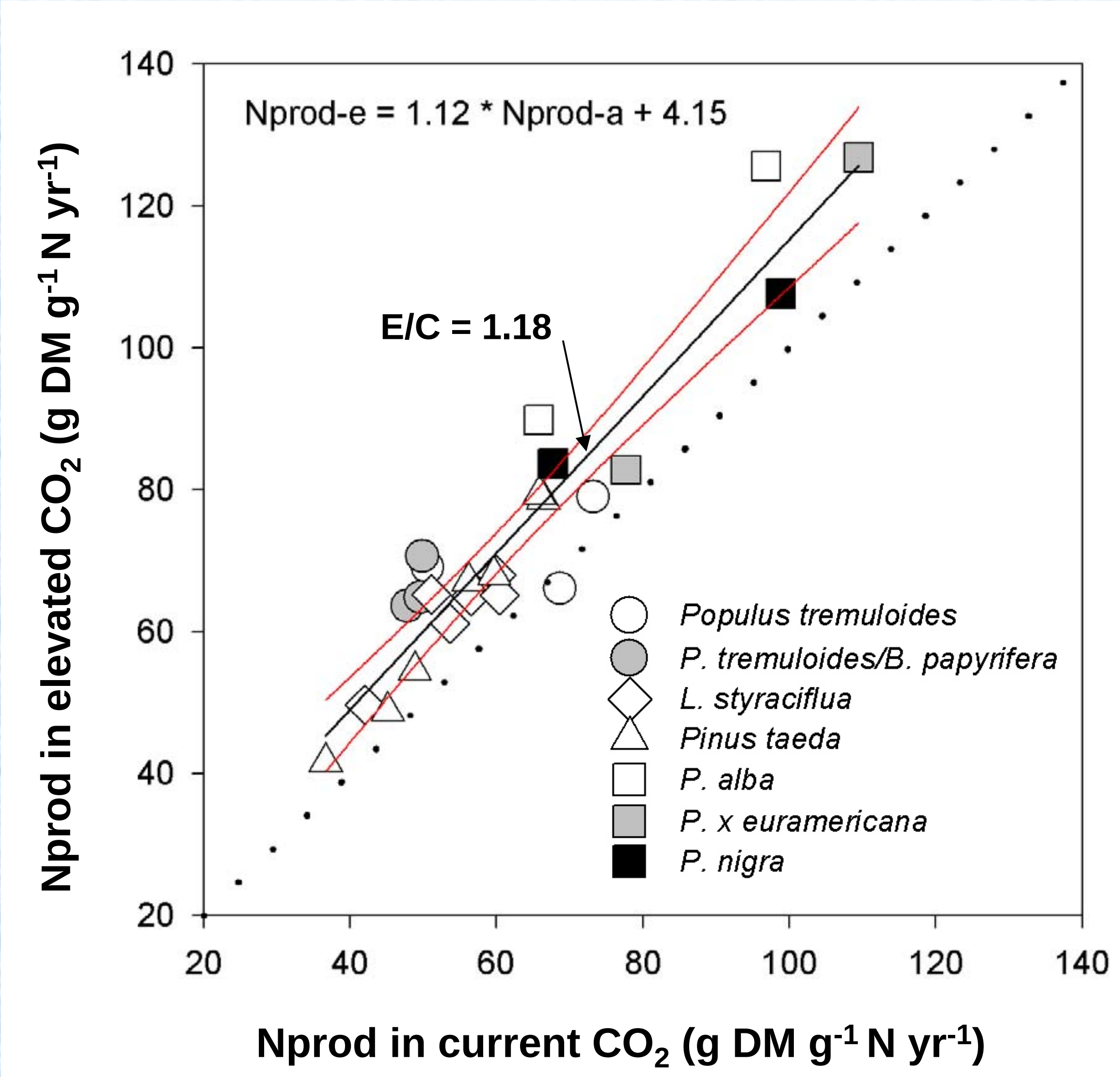
- There was no response of NUE to elevated CO_2
- Understanding and predicting N uptake should be a key objective for modeling NPP response to elevated CO_2

Photosynthetic N-use efficiency *did* increase in elevated CO_2



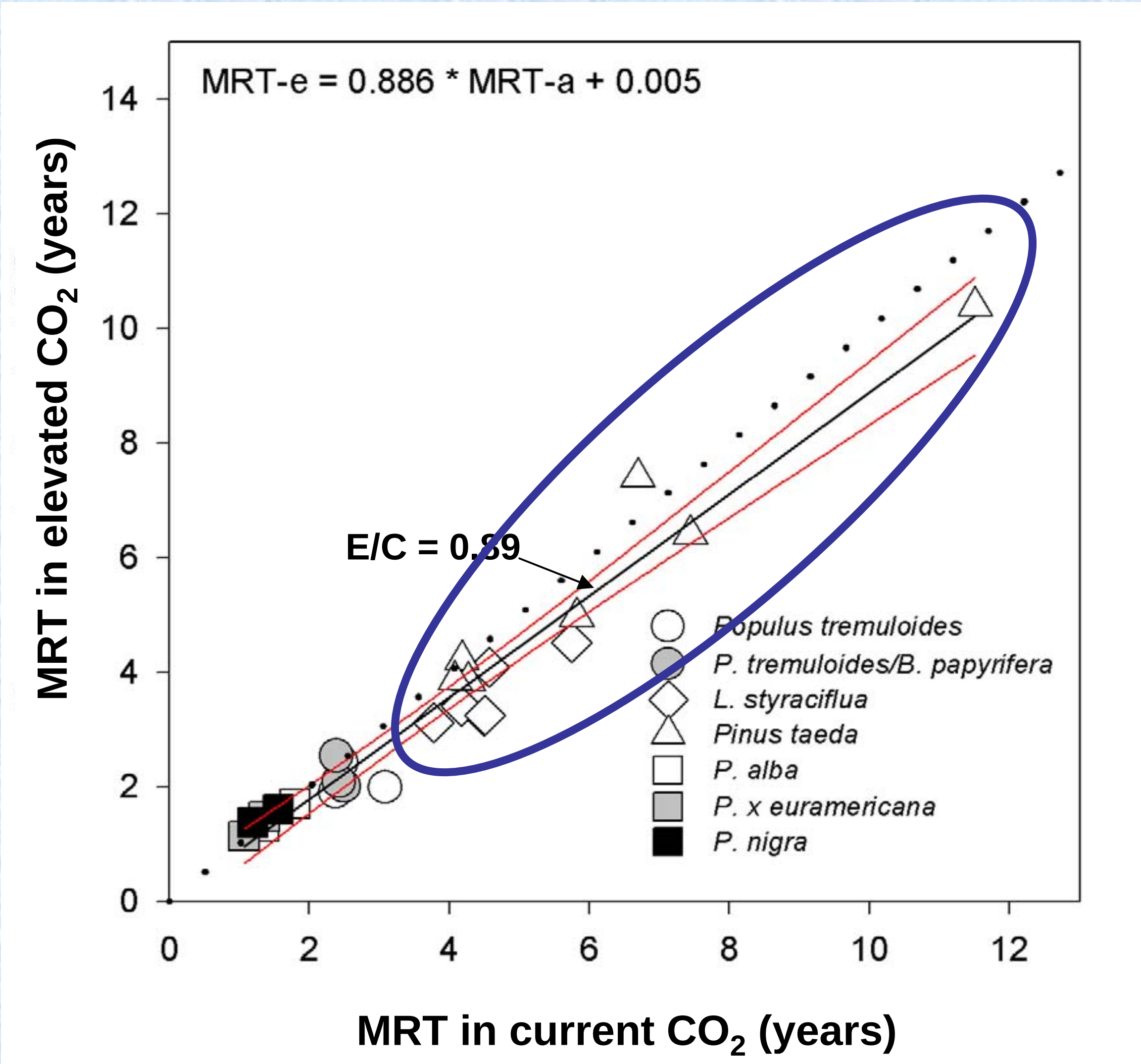
- **Stimulation ranged from 26 to 44%**
- **Leaf-level PNUE at the whole-tree scale is N productivity**

Nitrogen productivity describes the relationship between NPP and peak N content



- **N productivity increased significantly and consistently**
- **N productivity is not often used in models**
- **Discrepancy between NUE and N productivity is explained by MRT**

Mean residence time describes relationship between content and uptake



- MRT is a function of partitioning, organ longevity, and retranslocation
- MRT was reduced in elevated CO_2 in the more mature forests that are more dependent on recycling of N
- Lower MRT reflected increased partitioning of N to fine roots
- Partitioning to fine roots necessary for increased uptake

Conclusions….

- The response of forest NPP to ~550 ppm CO_2 was highly conserved across a broad range of productivity, with a stimulation at the median of 23%
- The surprising consistency of response across diverse sites is providing a benchmark to evaluate predictions of ecosystem and global models
- Increased NPP was usually associated with increased N uptake rather than increased N-use efficiency
- Increased N productivity reflected increased leaf-level photosynthetic N-use efficiency
- Reduced MRT offset increased N productivity
- A “cost” associated with increased foraging for N is partitioning of N to fine roots
- These results emphasize the continuing importance of unresolved questions about C and N partitioning, and controls on N uptake from soil

Good fellowship….

….good science