Nitrogen and the global carbon cycle: Insights from experimental N additions and N deposition gradients

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Two Nitrogen-Carbon Datasets

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Increased tree carbon storage in response to nitrogen deposition in the US

R. Quinn Thomas[1*], Charles D. Canham[2], Kathleen C. Weathers[2] and Christine L. Goodale[1]

Nitrogen Deposition and Forest Carbon Sequestration: a Quantitative Review from Plot to Global Scales

In Revision for Global Change Biology

Christine L. Goodale, R. Quinn Thomas, Frank Dentener, Mary Beth Adams, Jill S. Baron, Richard D. Bowden, D. Bryan Dail, Bridget A. Emmett, Christopher D. Evans, Ivan J. Fernandez, Per Gundersen, Frank Hagedorn, Andrew Kulmatiski, Gary M. Lovett, Steven G. McNulty, April M. Melvin, Filip Moldan, Scott V. Ollinger, Patrick Schleppi, Lucy J. Sheppard, Marissa S. Weiss

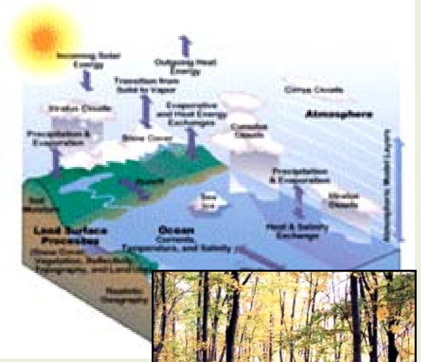
Models show that N influences the land C sink

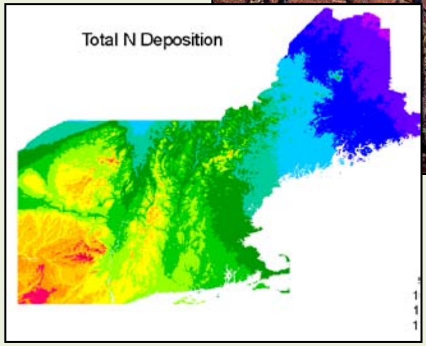
- N limits growth enhancement from CO_2 fertilization
- Elevated N availability from increased decomposition increases growth
- N deposition increases growth
- The C-N interactions in the models need to be compared to observations

Randerson et al. 2009; Thornton et al. 2007, 2009

Carbon sequestration response to increasing nitrogen inputs

1. <u>Global Models</u>
   - + Integrative
   - – Many processes still poorly known



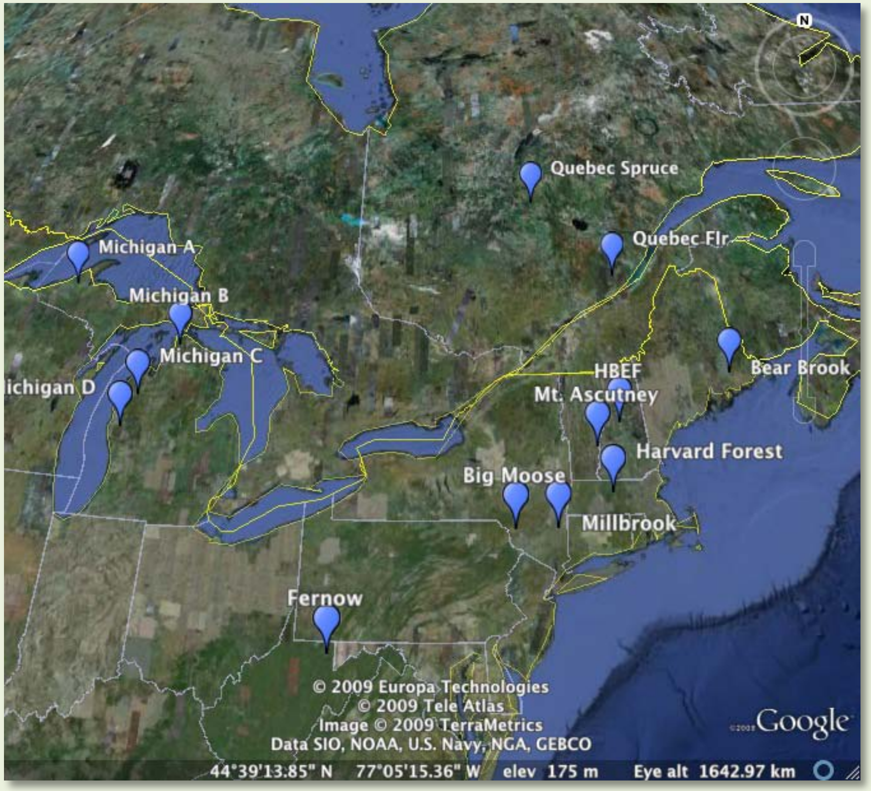


2. <u>Plot N-Addition Experiments</u>
   - + Controlled study response to N
   - – Typically high rates of N addition
   - – Step-change manipulation

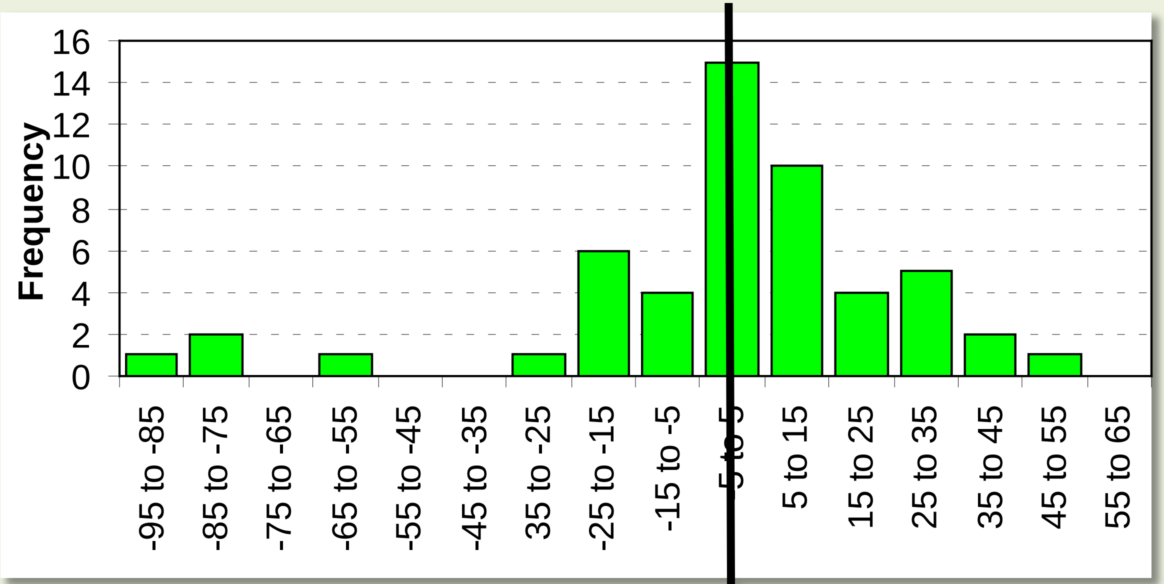
3. <u>N Deposition Gradients</u>
   - + Represents real-world responses
   - – Need MANY sites to sort out N deposition from other factors of site-to-site variation

Plot N-Addition Experiments

53 experiments across the globe

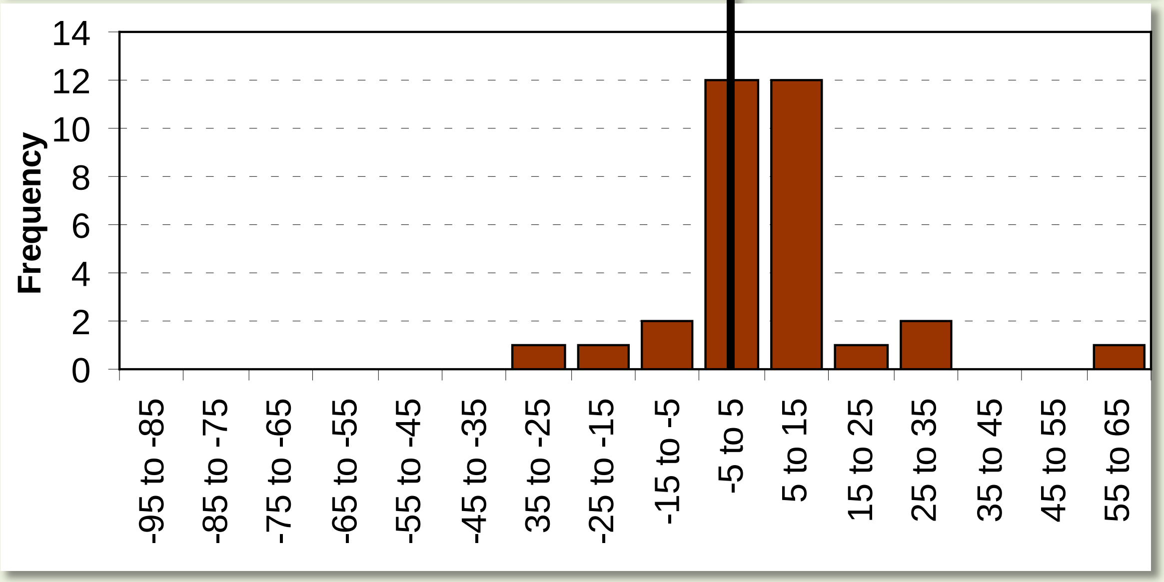


Multi-year N Addition Studies
53 Temperate & Boreal Forests



Median

dC_{tree}/dN_{fert} = 2

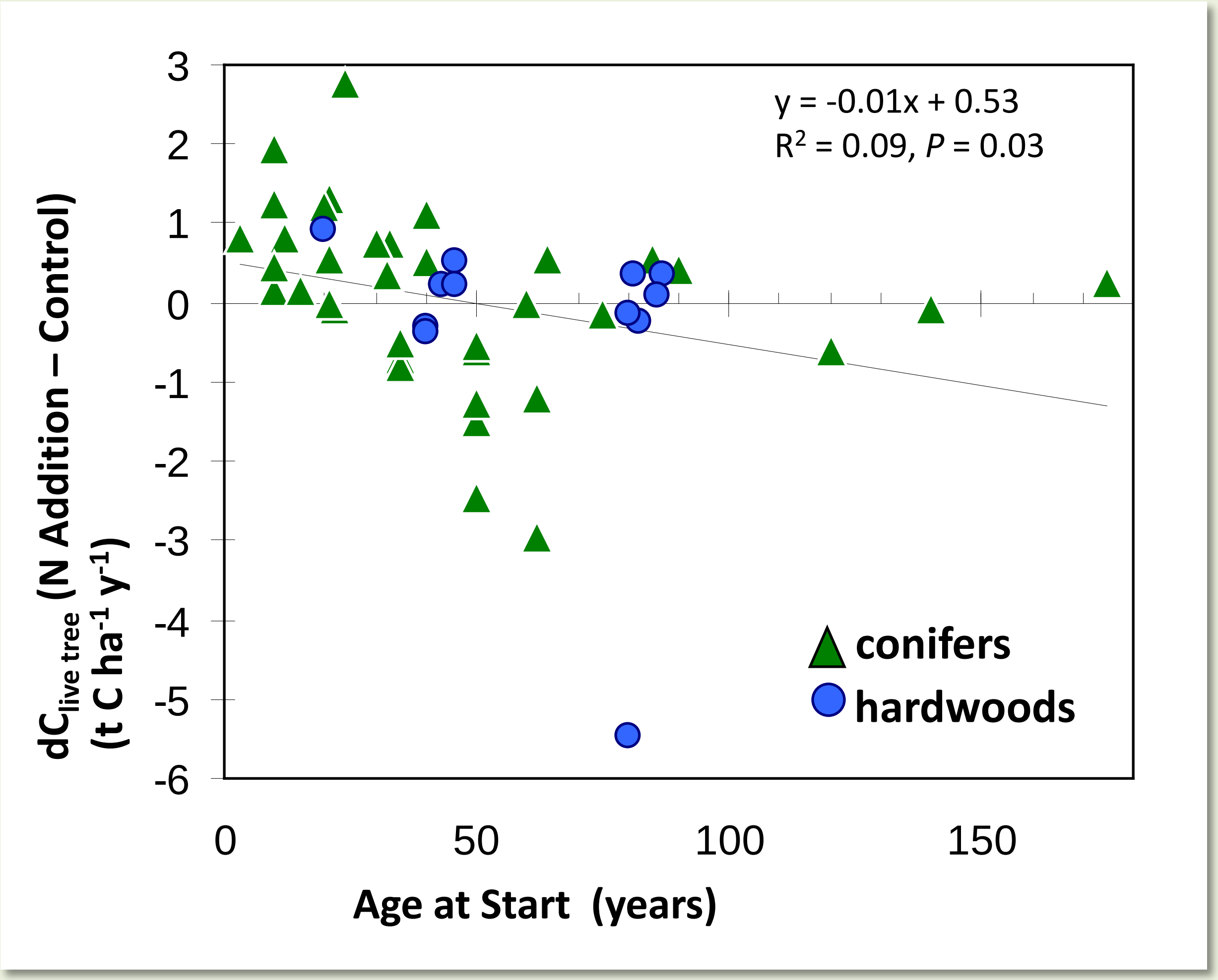


Median

dC_{soil}/dN_{fert} = 5

N Addition Experiments

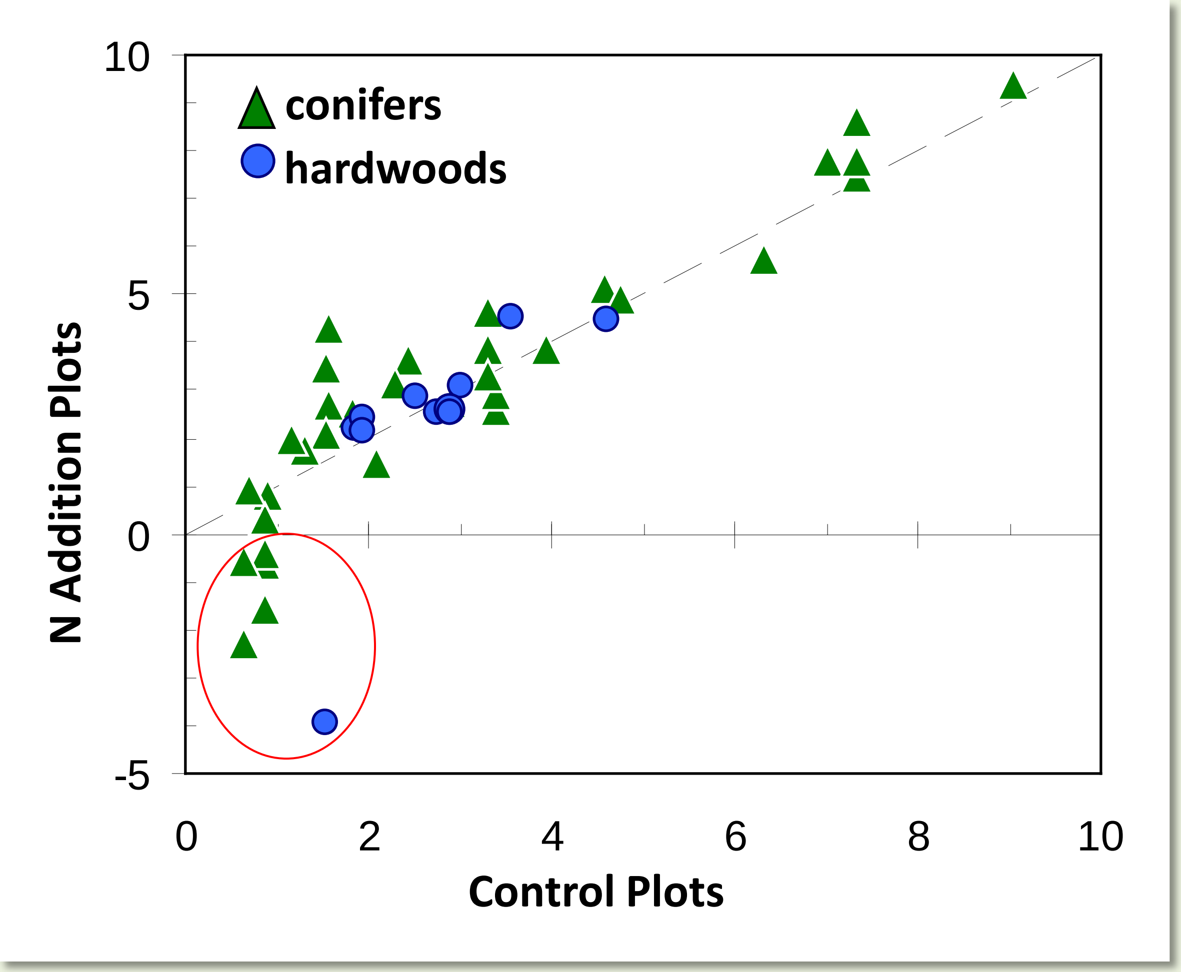
Tree C response depends on stand age



N Addition Experiments

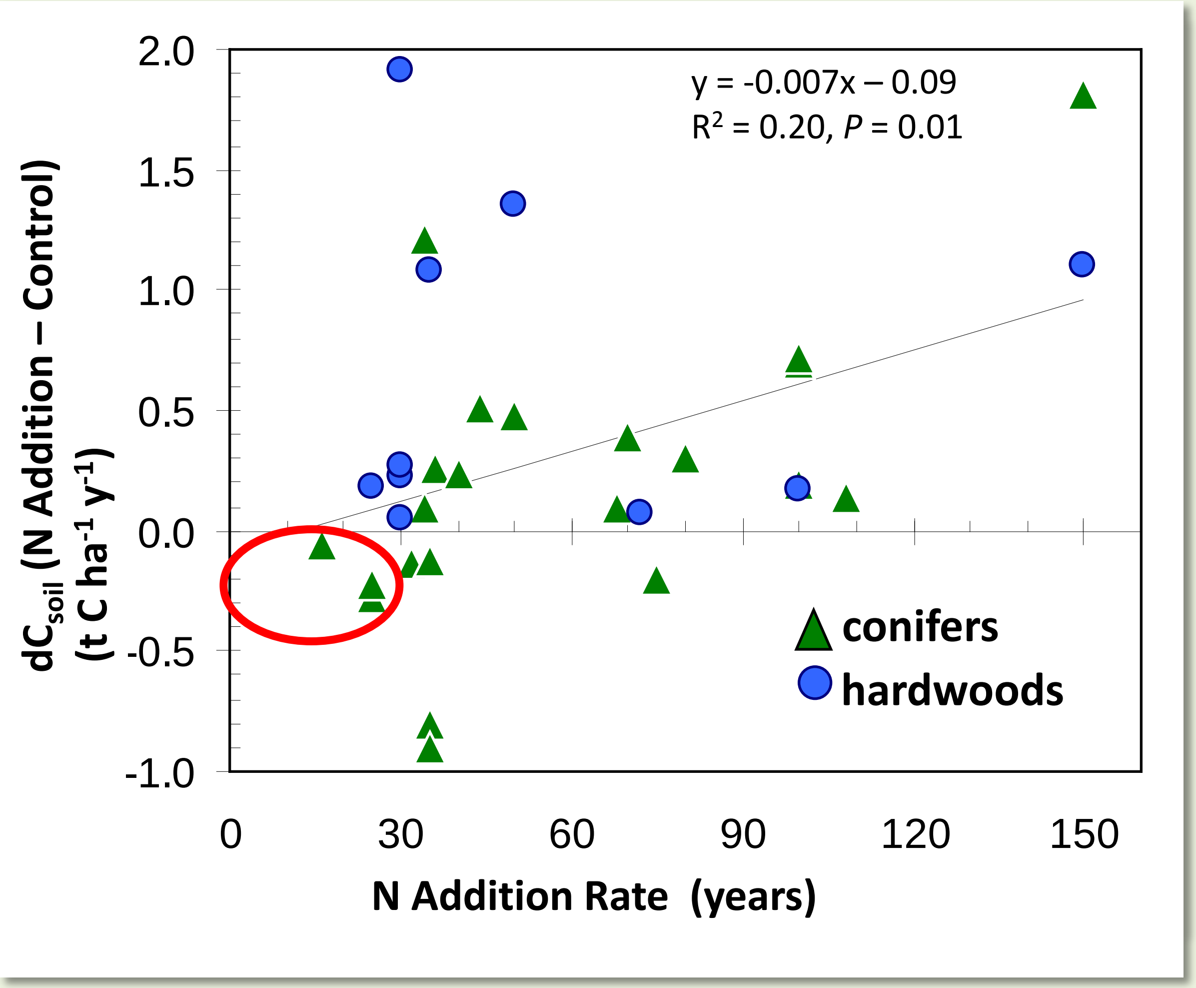
Tree C declines when rates of C accumulation are low

Live Tree C Gain over study (t C ha^{-1} y^{-1})



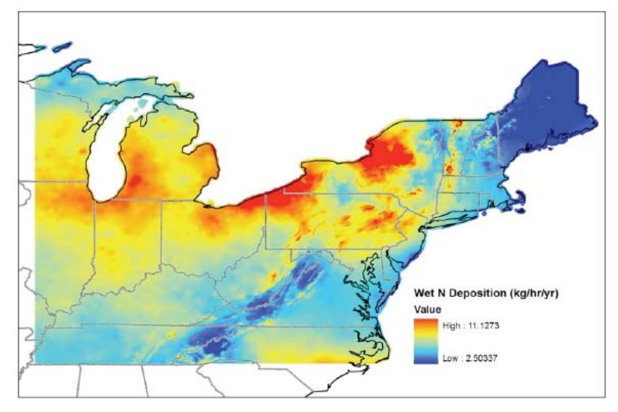
N Addition Experiments

<u>Soil C</u> response depends on stand N addition rate.



A Northeast US Gradient

Tree growth v. N dep, after considering climate variation



U.S. Forest Inventory & Analysis (FIA)

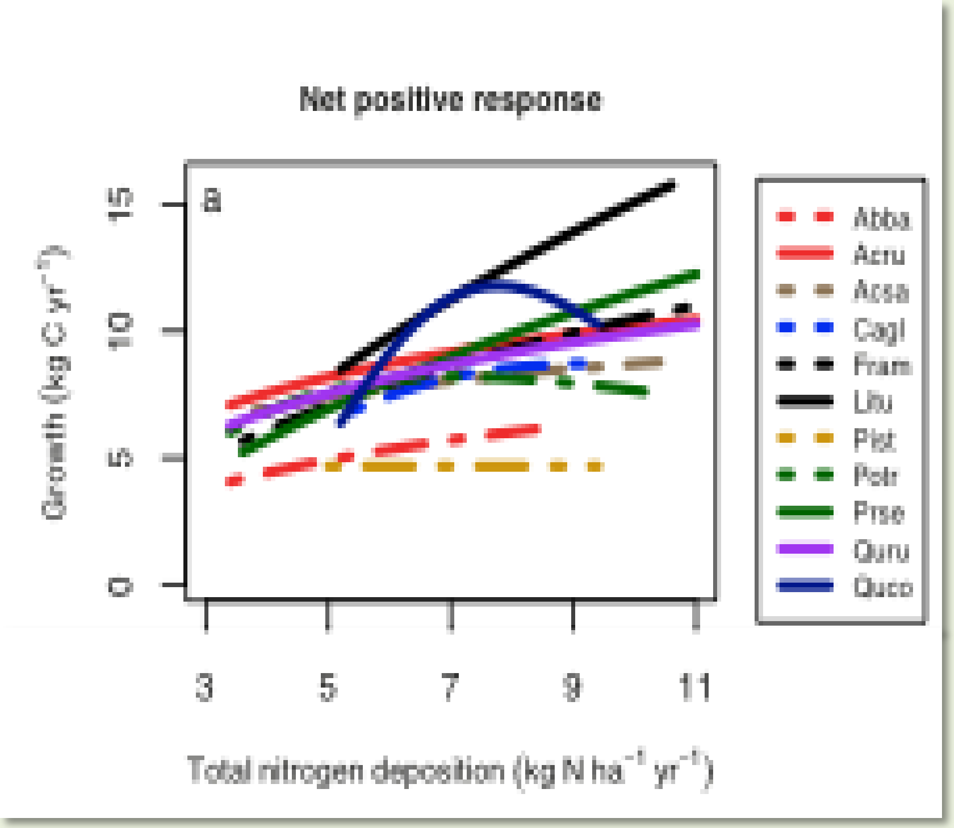
- Tree-level analysis: Growth & survival
  - 24 most common tree species
  - 20,067 plots
- Stand-level analysis: Net C increment (trees)
  - 4,778 plots

- Climate: MAT, Precip.
- N Deposition: 3-11 kg N ha^{-1} yr^{-1}

Thomas *et al.* 2010 *Nature Geoscience*

Growth response to N deposition

N dep. <u>enhanced</u> growth for 11 of 24 species

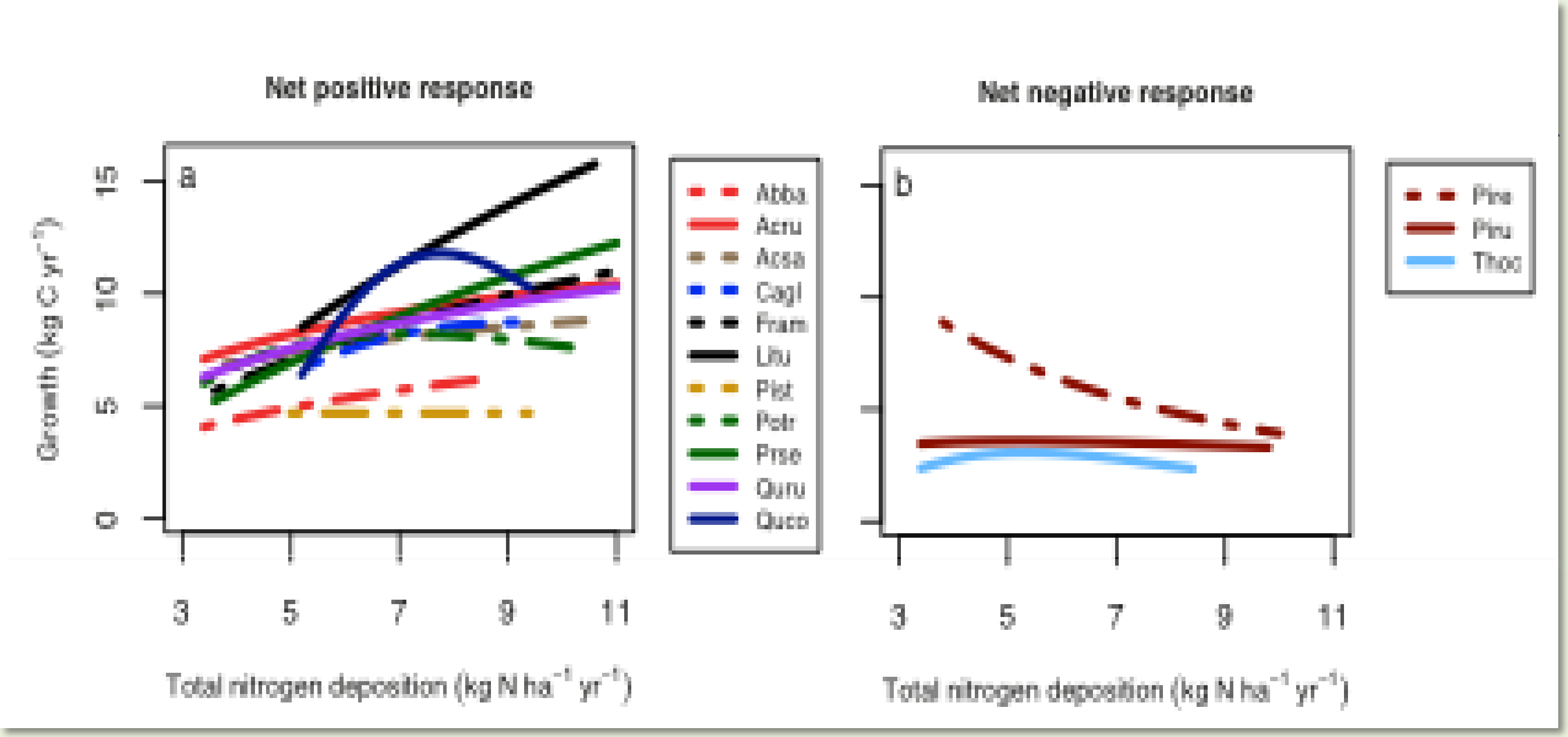


Balsam fir
Red maple
Sugar maple
Pignut hickory
White ash
Tulip tree
White pine
Quaking aspen
Black cherry
Red oak
Scarlet oak

Thomas *et al*. 2010 *Nature Geoscience*

Growth response to N deposition

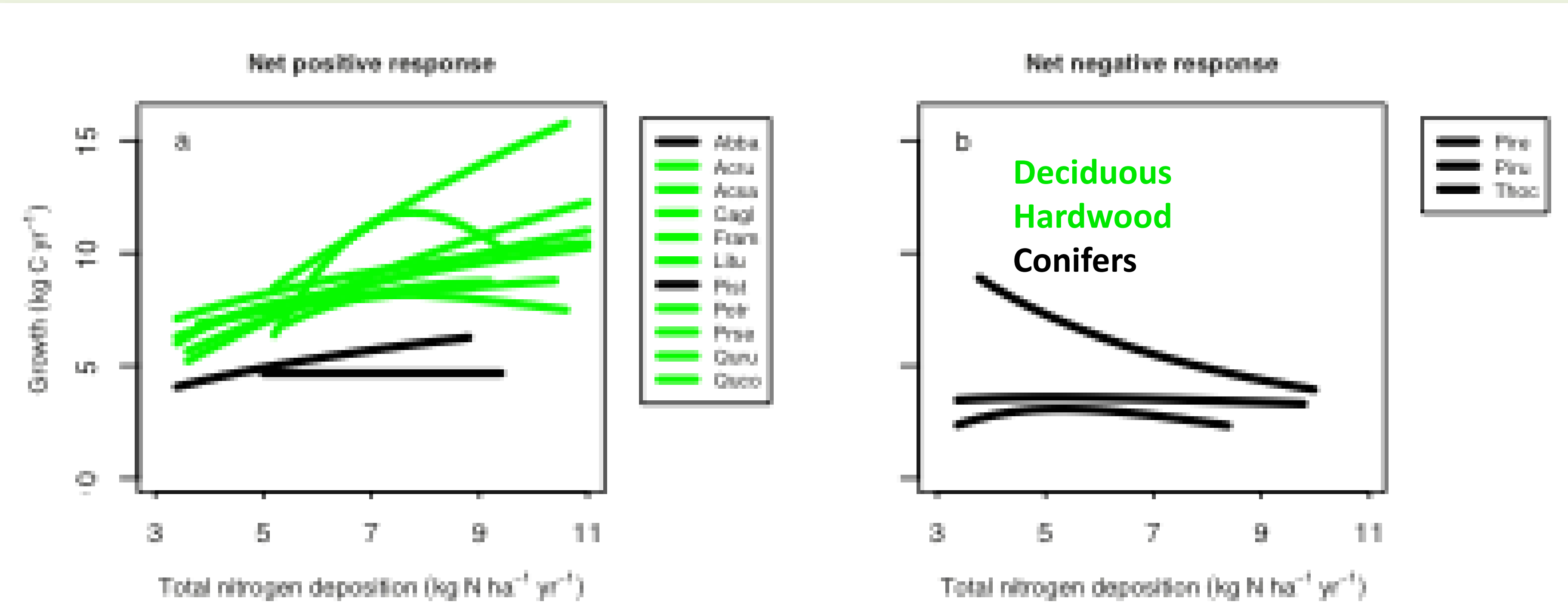
N dep. <u>depressed</u> growth for 3 of 24 species



Thomas et al. 2010 *Nature Geoscience*

Relation to plant functional types?

Conifer vs. deciduous important



Non-responders include 9 hardwoods and 1 conifer

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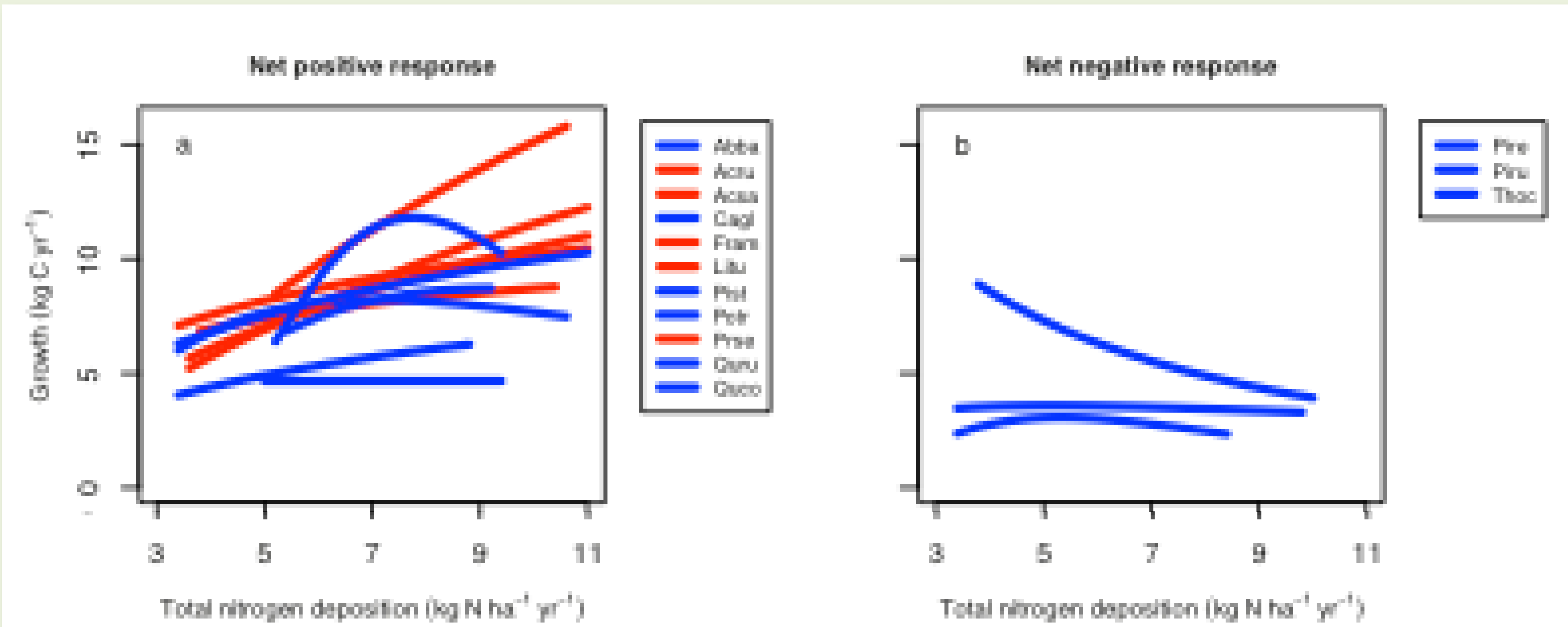
Relation to plant functional types?

Root-fungi associations are important



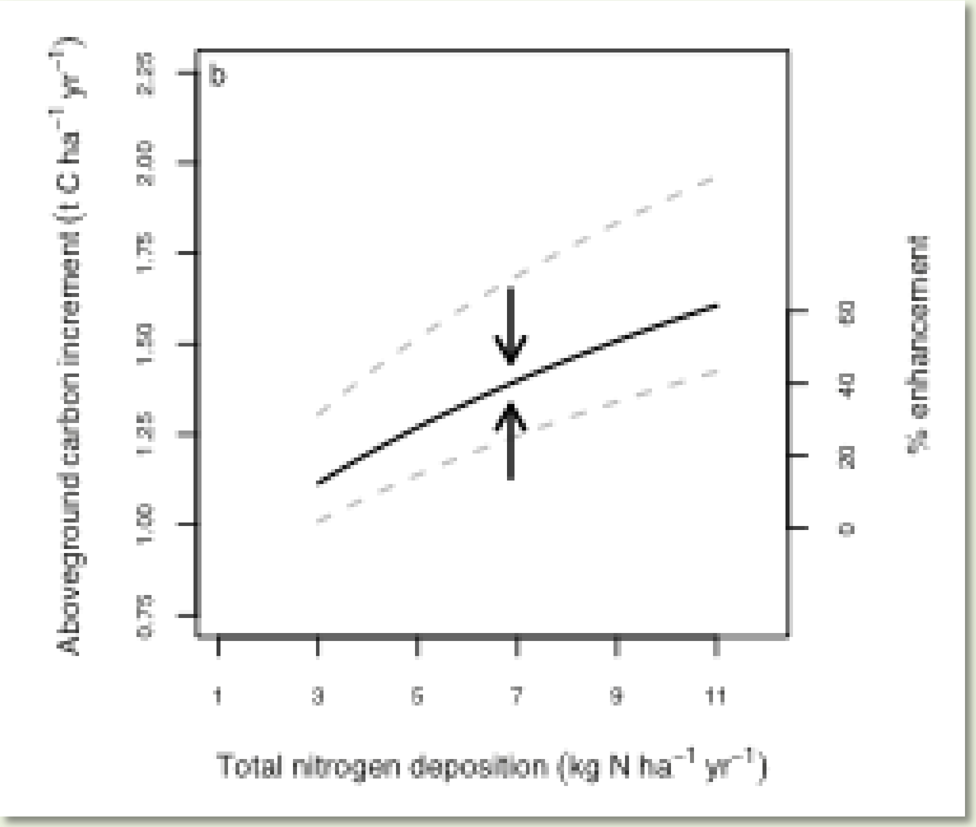
All non-responders are ectomycorrhiza

Thomas *et al.* 2010 *Nature Geoscience*

Stand-level Response: Tree C Balance

Slope: dC_{tree}:dN_{dep} = 61 (51-82) kg C per kg N_{dep}

Slope: 5.5% increase in net C accum. kg N_{dep}

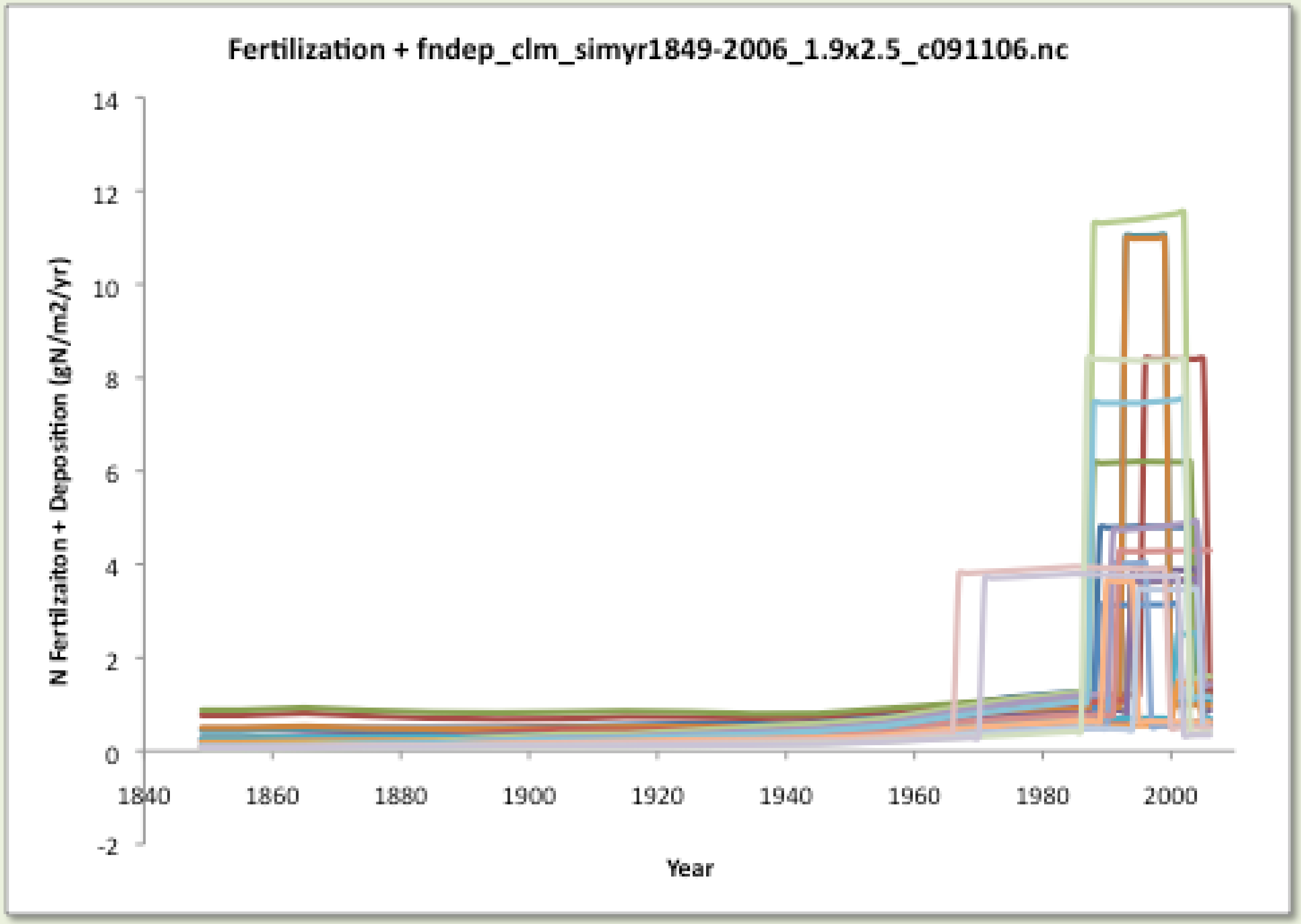


Thomas *et al.* 2010 *Nature Geoscience*

Model-Data Comparison

- Simulate the fertilization experiments in CLM-CN
  - Plant functional type
  - Land-use history
  - N inputs
  - Tropical sites

Model-Data Comparison



Model-Data Comparison

- Compare carbon cycling across N deposition gradients in CLM-CN
  - Must include land-use history
  - Two other gradient studies (Magnani *et al.* 2007 and Solberg *et al.* 2009)

Future model developments

- Processes that cause slower growth at high levels of N deposition
- Processes that allow for reduced decomposition at higher N inputs
- Plant functional types based on root-fungi associations

QUESTIONS?

Feed back on the model-data comparison is greatly appreciated