Response of Forest Carbon and Nitrogen Cycles to Decreasing Acidification

NYSERDA-EMEP Biennial Conference

November 15, 2011

Christine L. Goodale
April M. Melvin
Department of Ecology & Evolutionary Biology
Cornell University

Acid Deposition **Atmospheric CO_2 Conc.**

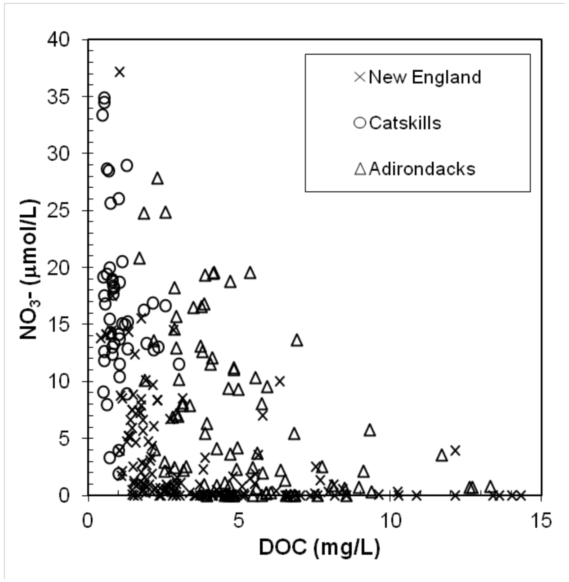
DOC Release Calcium Depletion

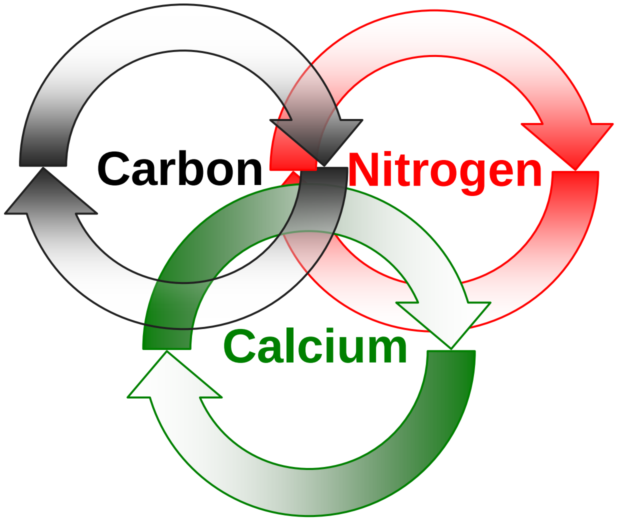
Nitrate Loss? *Forest C Storage?*

Outline

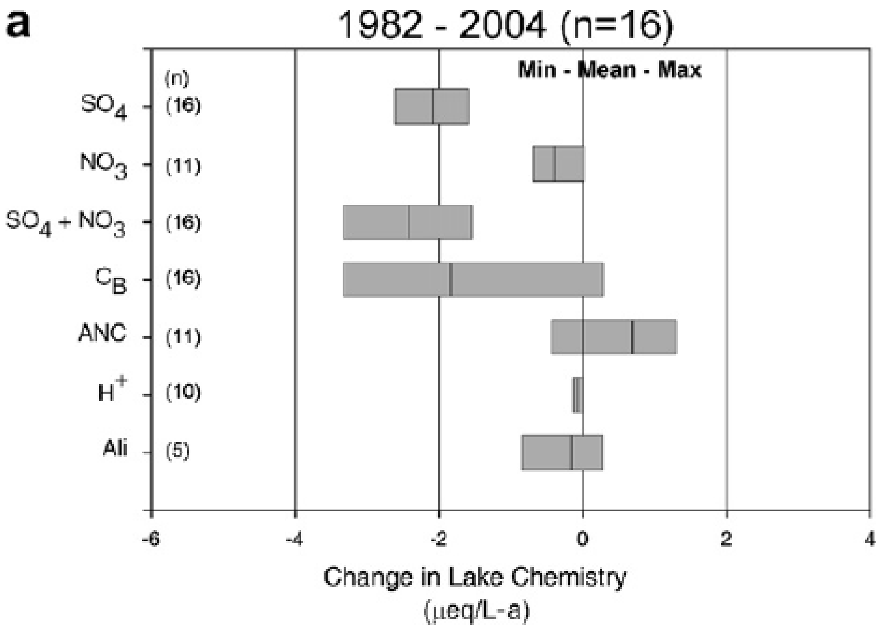
1. Deacidification, DOC and Nitrate Export

2. Interactions Among Carbon, Nitrogen, and Calcium Cycles in an Adirondack Forest

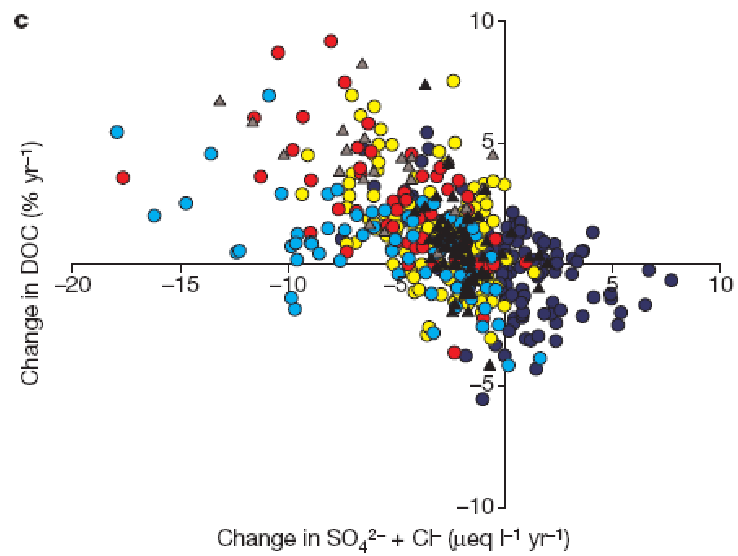




Trends and Interactions: Sulfate, DOC and Nitrate

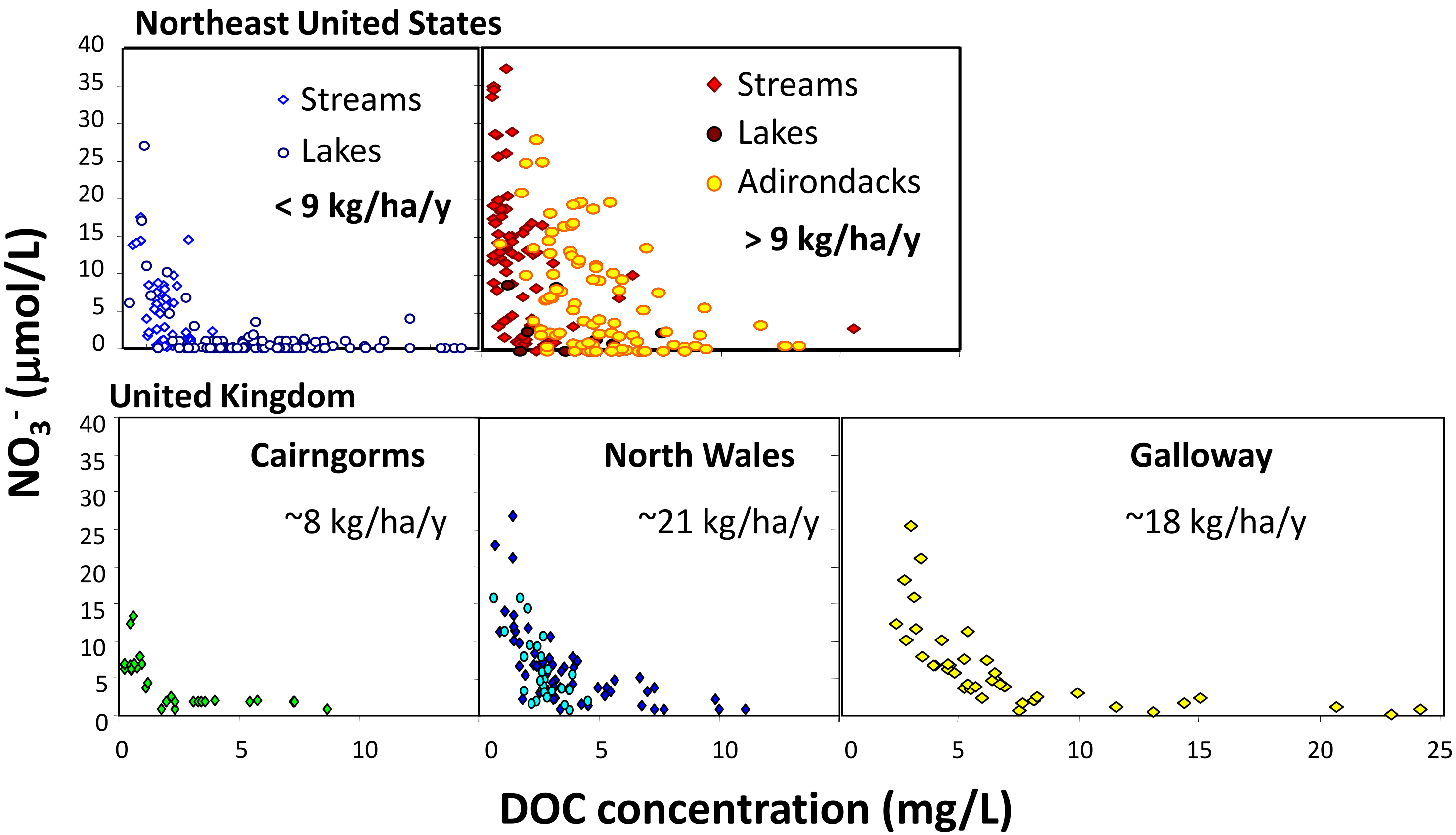


Driscoll et al. 2007, *Applied Geochem.*



Monteith et al. 2007, *Nature*

N Retention, DOC, and De-Acidification



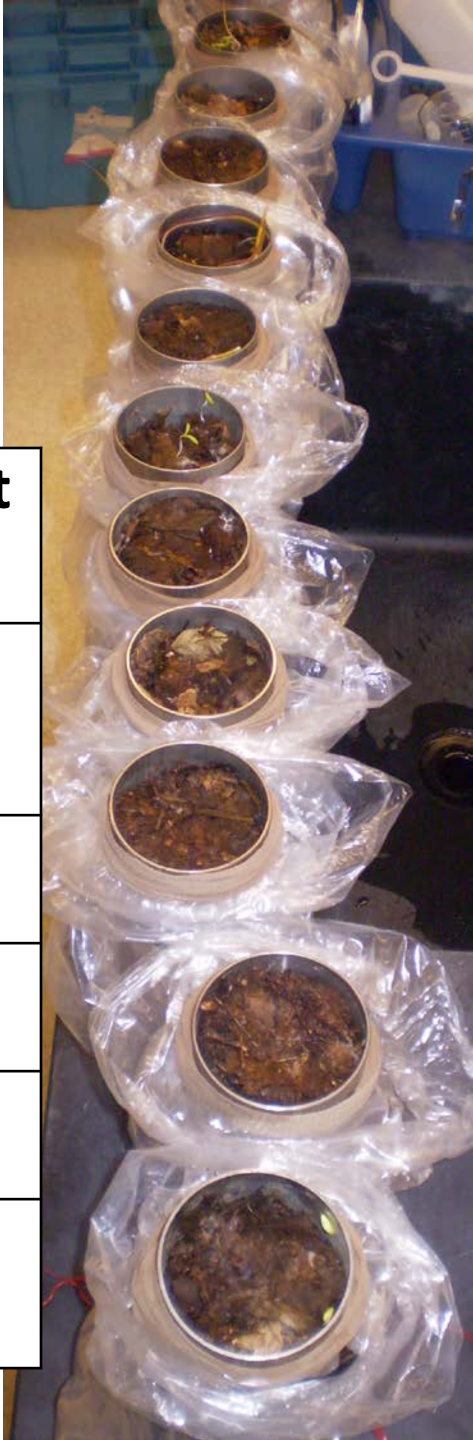
- Driven by variation in catchment soils?
- Response to changes in acidification?

Goodale, CL, JD Aber, PM Vitousek, and WH McDowell. 2005. Long-term decreases in stream nitrate: successional causes unlikely; possible links to DOC? *Ecosystems* 8:334-337.

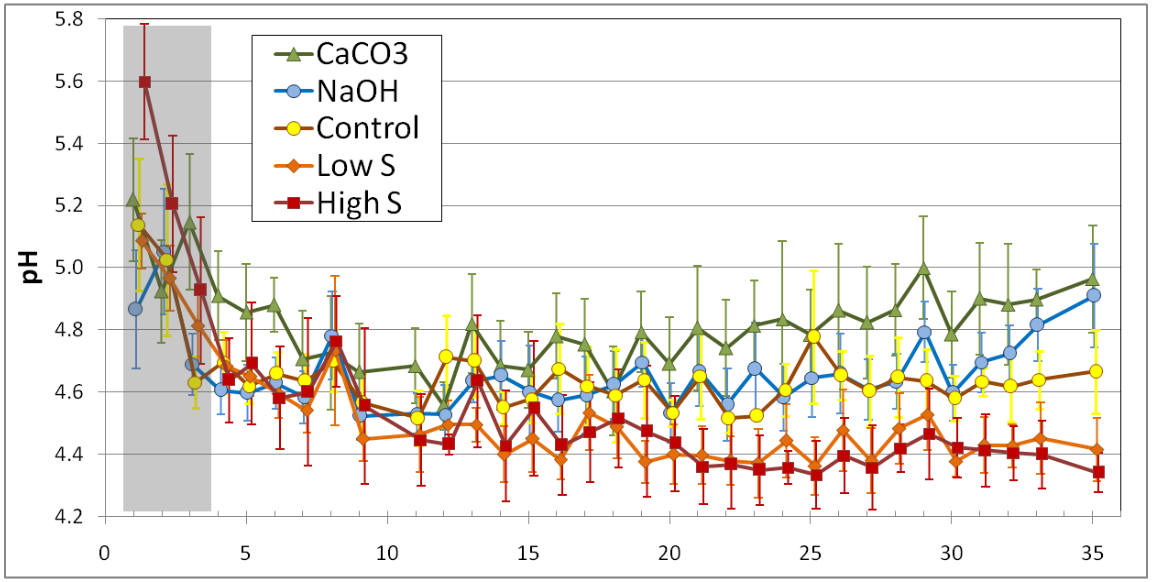
Evans, CD, B Reynolds, A Jenkins, RC Helliwell, CJ Curtis, CL Goodale, RC Ferrier, BA Emmett, M Pilkington, SJM Caporn, JA Carroll, D Norriss, J Davies, and MC Coull. 2006. Soil carbon pool determines susceptibility of semi-natural ecosystems to nitrogen saturation. *Ecosystems* 9:453-462.

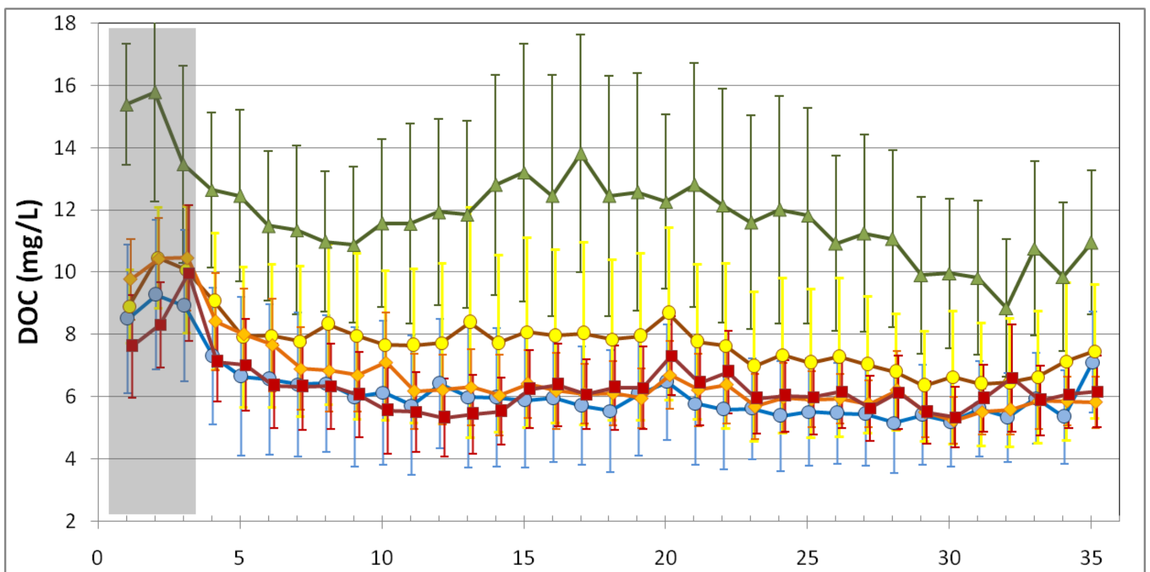
DOC and NO_3^- *Affected by changing acidification?*

	Description	SO_4^{2-} (μeq/L)	Target pH
Control	Simulated current ADK precipitation; based on Moss Lake NADP site (2004-07)	21	4.6
Low S	Mean H_2SO_4 for ADKs during the 1970s	75	4.0
High S	+3X the H_2SO_4 load of the low S treatment	225	3.6
NaOH	+NaOH, equimolar to high S treatment	21	7.0
$CaCO_3$	+$CaCO_3$, equimolar to high S treatment	21	7.0



Soil Core Response to Weekly Leaching





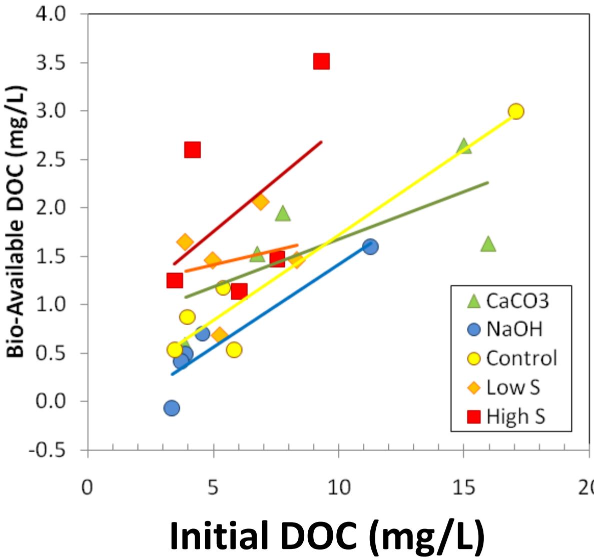
Week of extraction

Leaching shifted core pH – eventually.

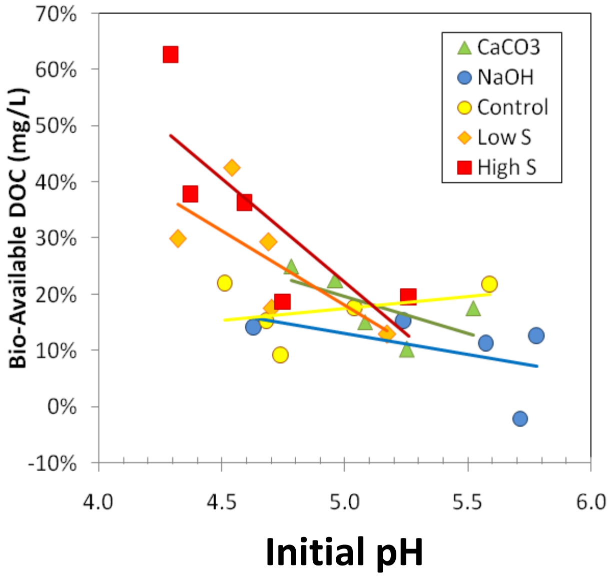
No significant effect on (variable) DOC concentrations

Acidification increases DOC bioavailability (week 34)

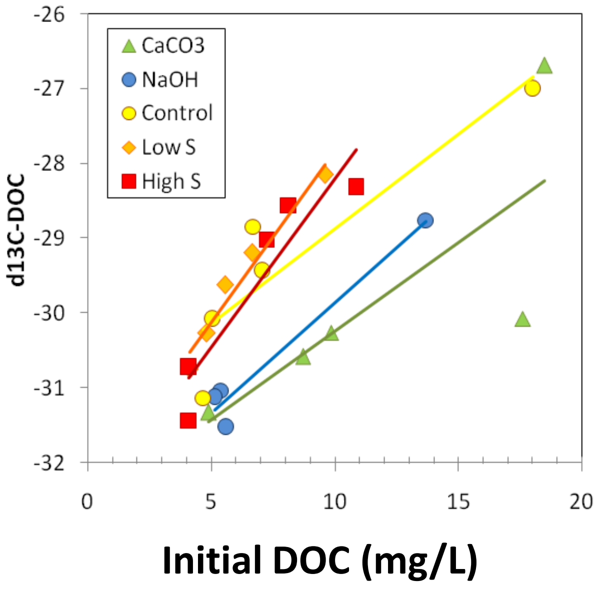
bDOC (mg/L)



bDOC (% of DOC)



$\delta^{13}C$-DOC



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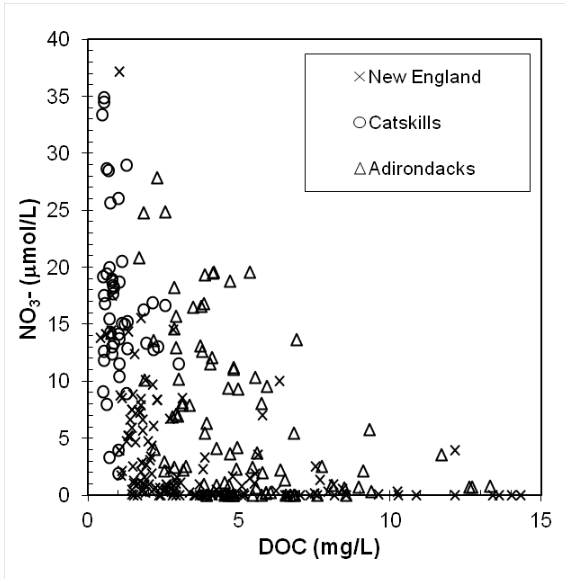
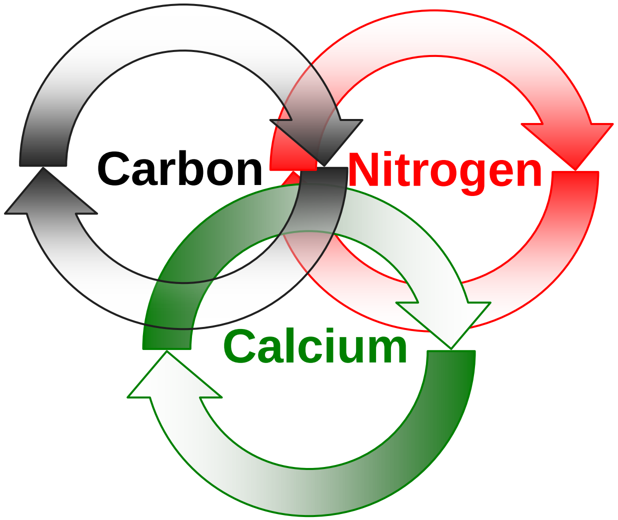


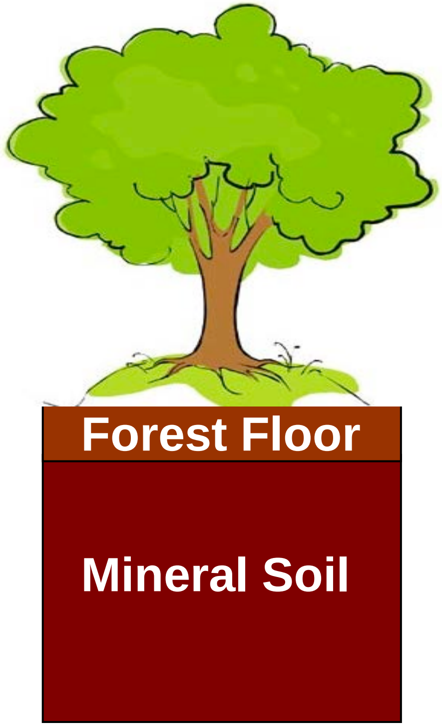


Hypotheses

Increased Ca availability alters C and N cycling

Tree Response

- Increased tree growth
- Increased litter production
- Increased root production

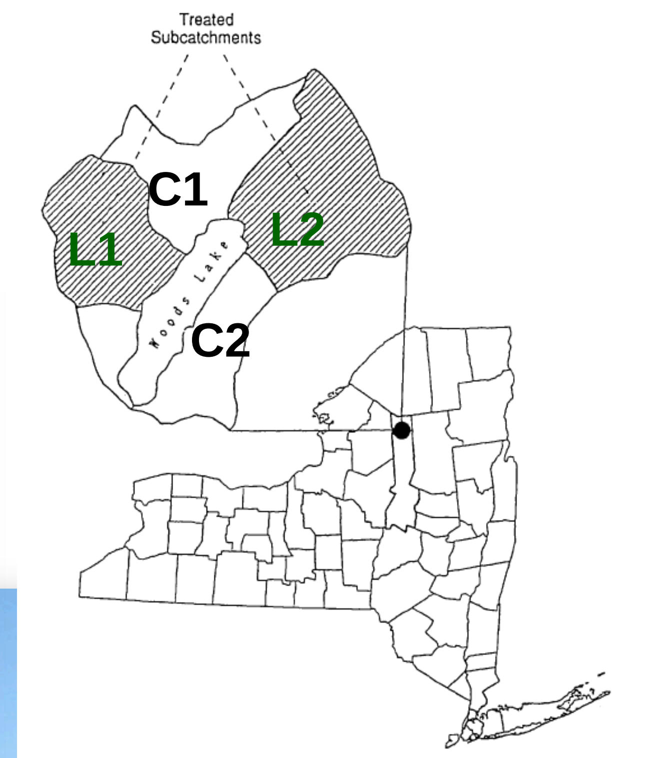


Soil Response

- Forest Floor:
  - Enhanced decomposition and N mineralization
  - Reduced C and N stocks
- Mineral soil
  - Physical stabilization of organic matter
  - Increased C and N stocks

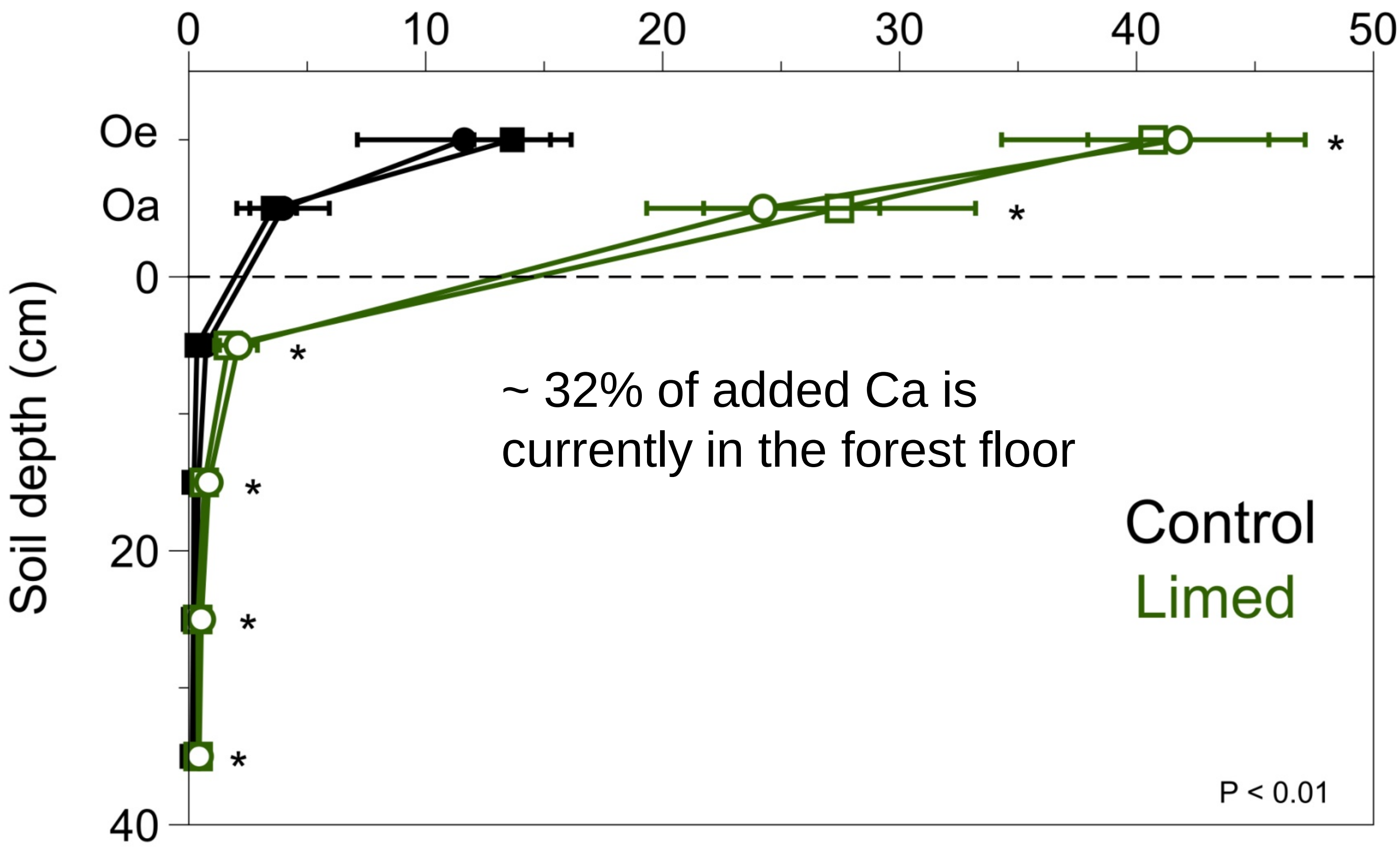
Woods Lake Watershed

Adirondack Park, New York

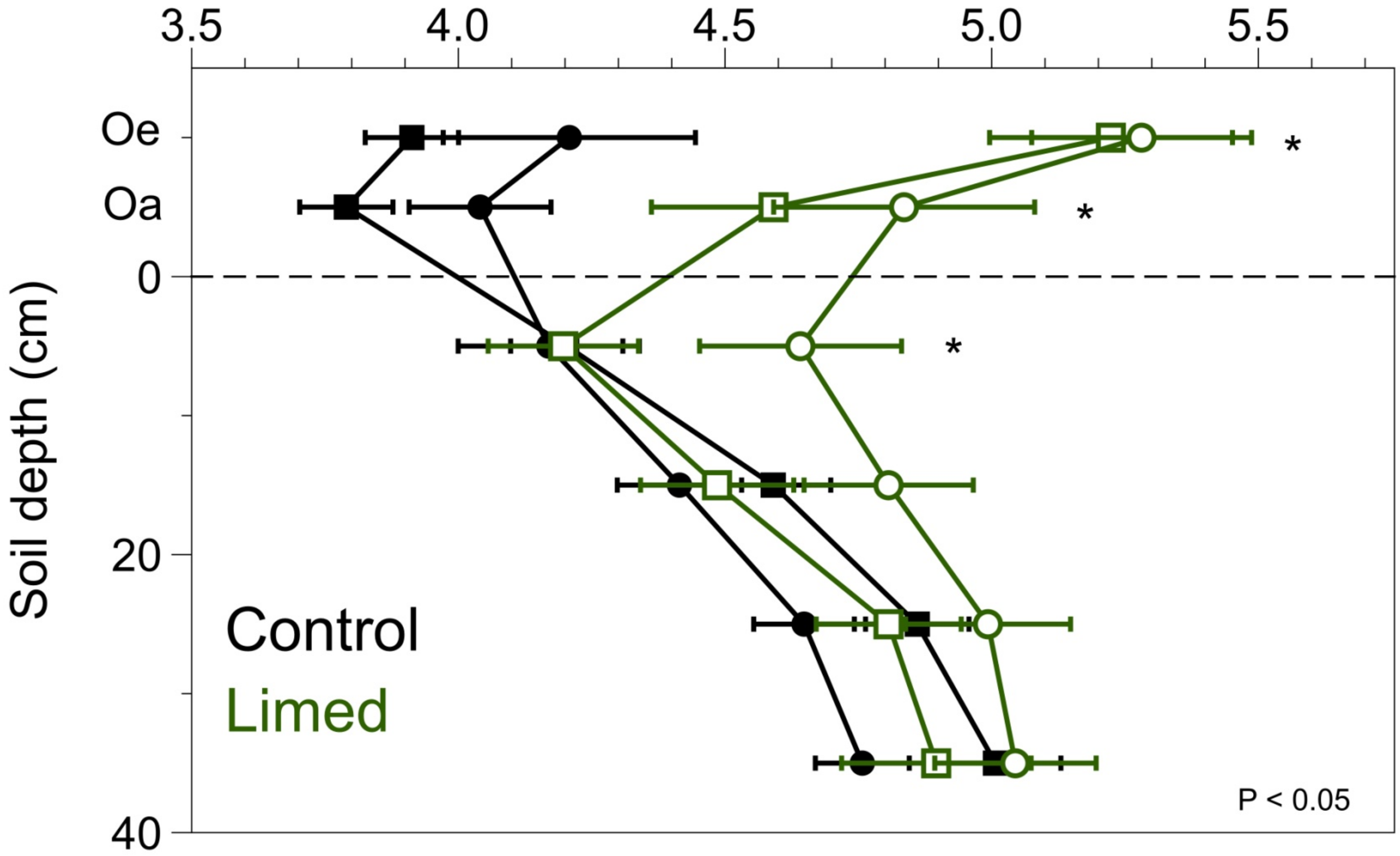


Photos courtesy of Doug Burns

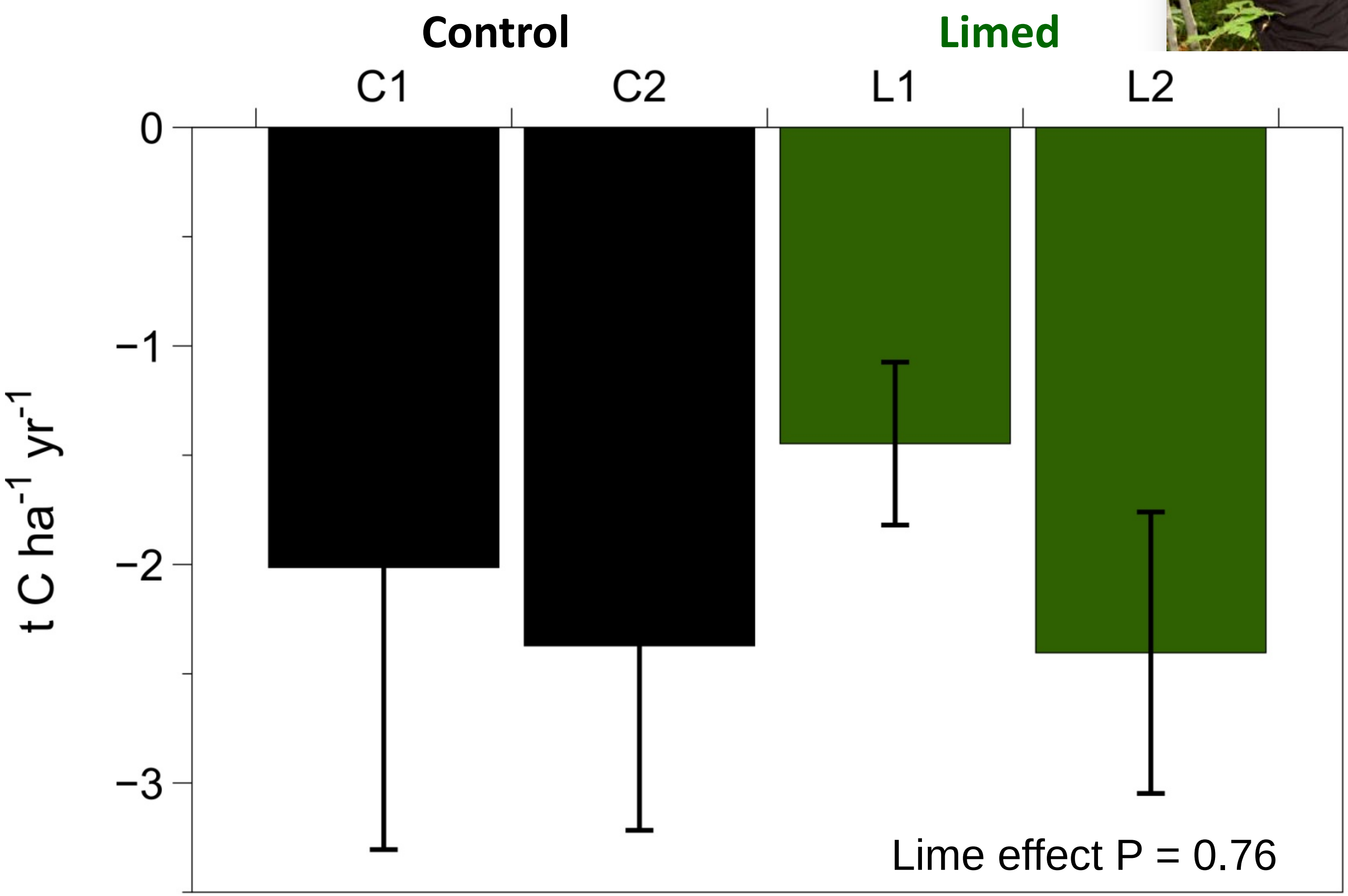
Liming increased soil exchangeable Ca ($cmol_c\ kg_{soil}^{-1}$).



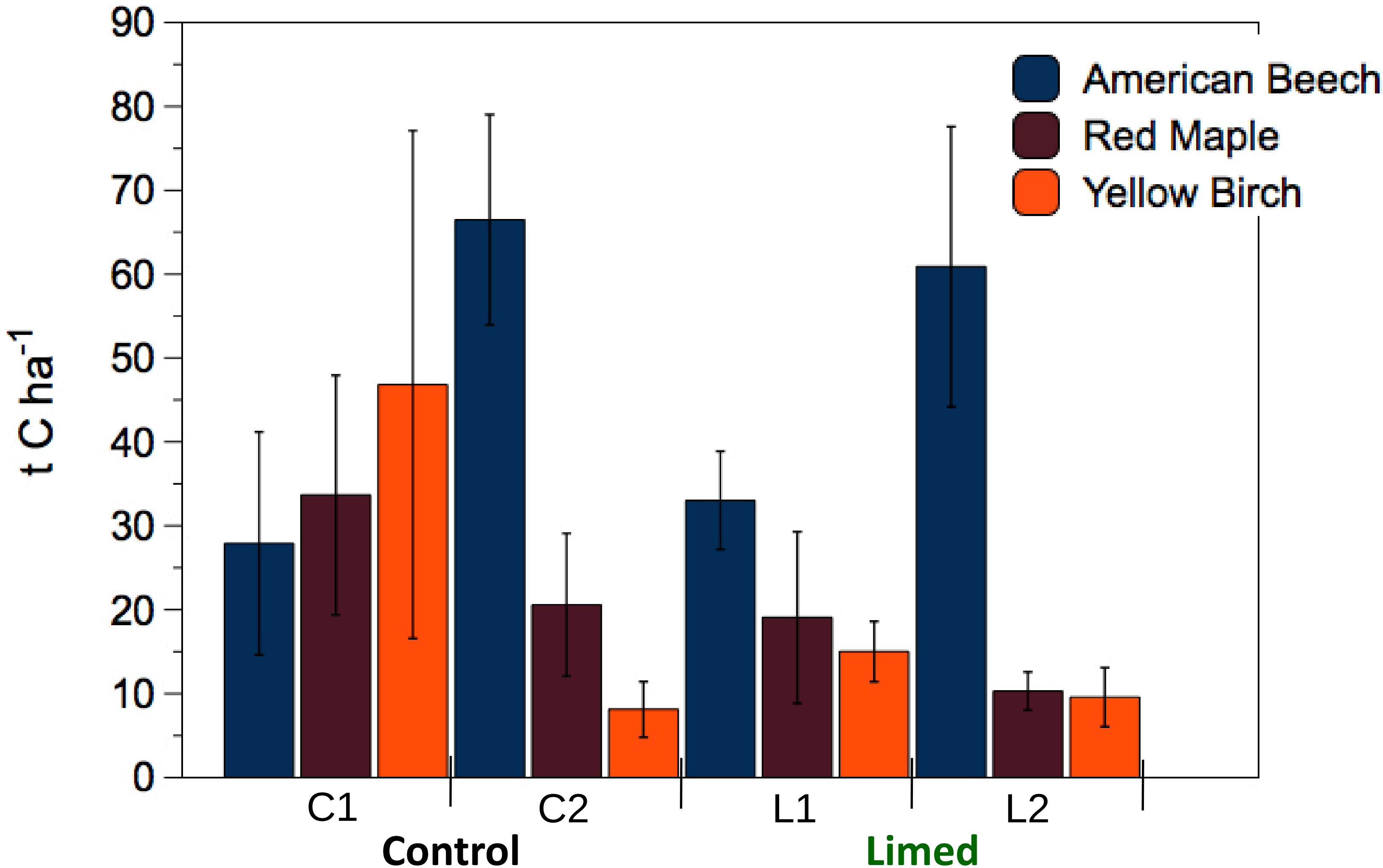
Liming increased surface soil pH.



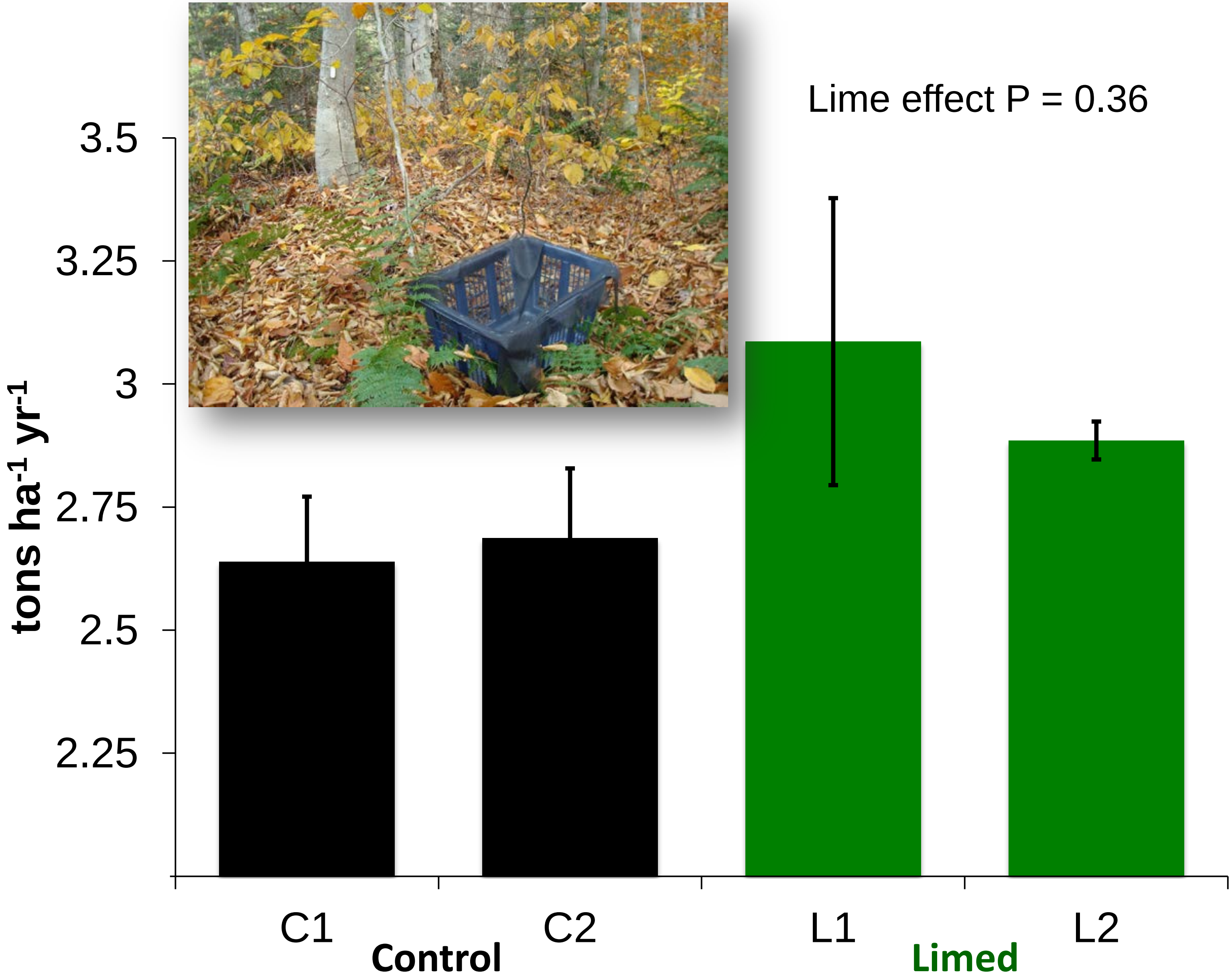
Live tree biomass decreased but was unaffected by liming.



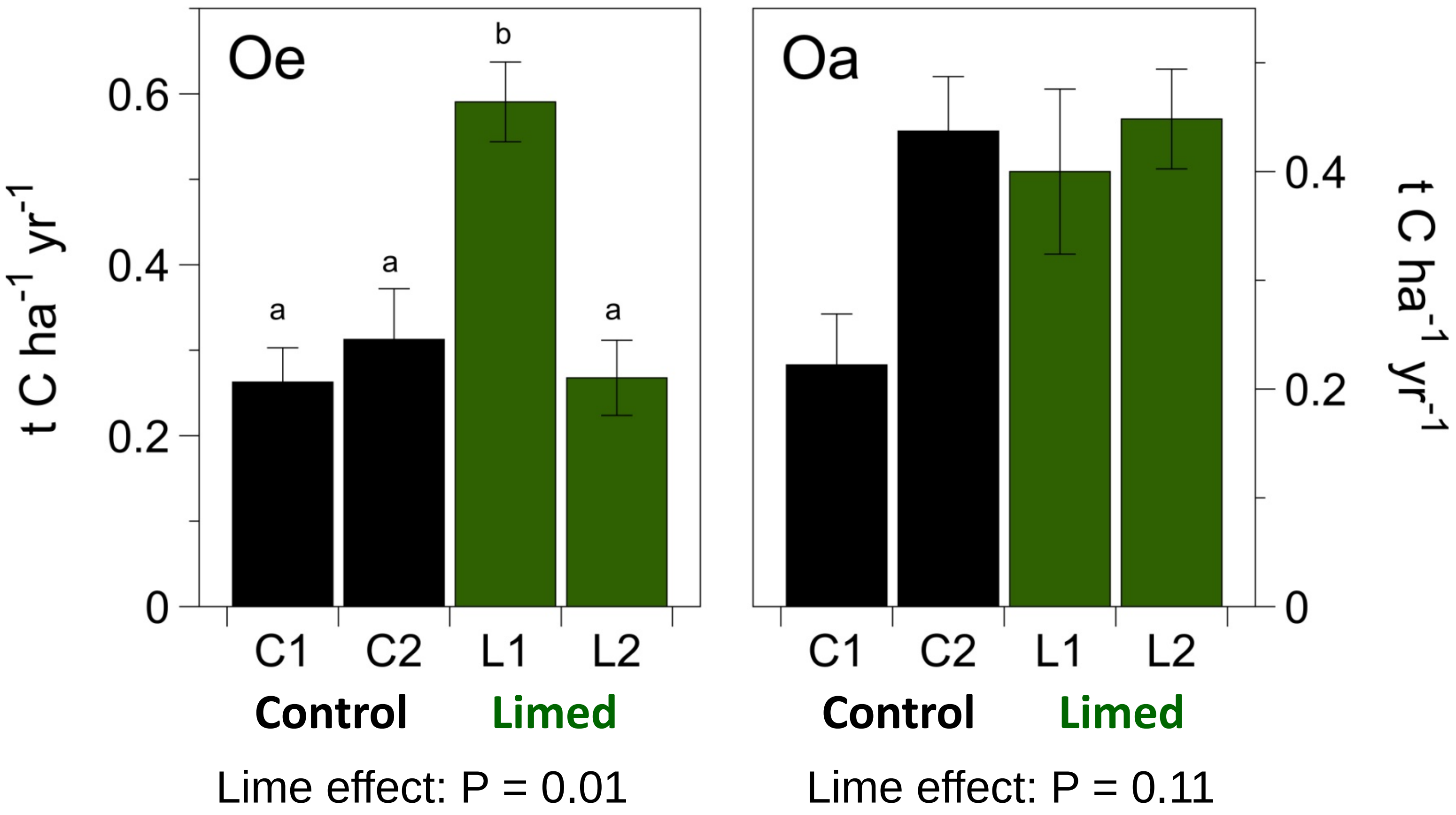
Stand mortality driven by beech decline and was unaffected by liming.



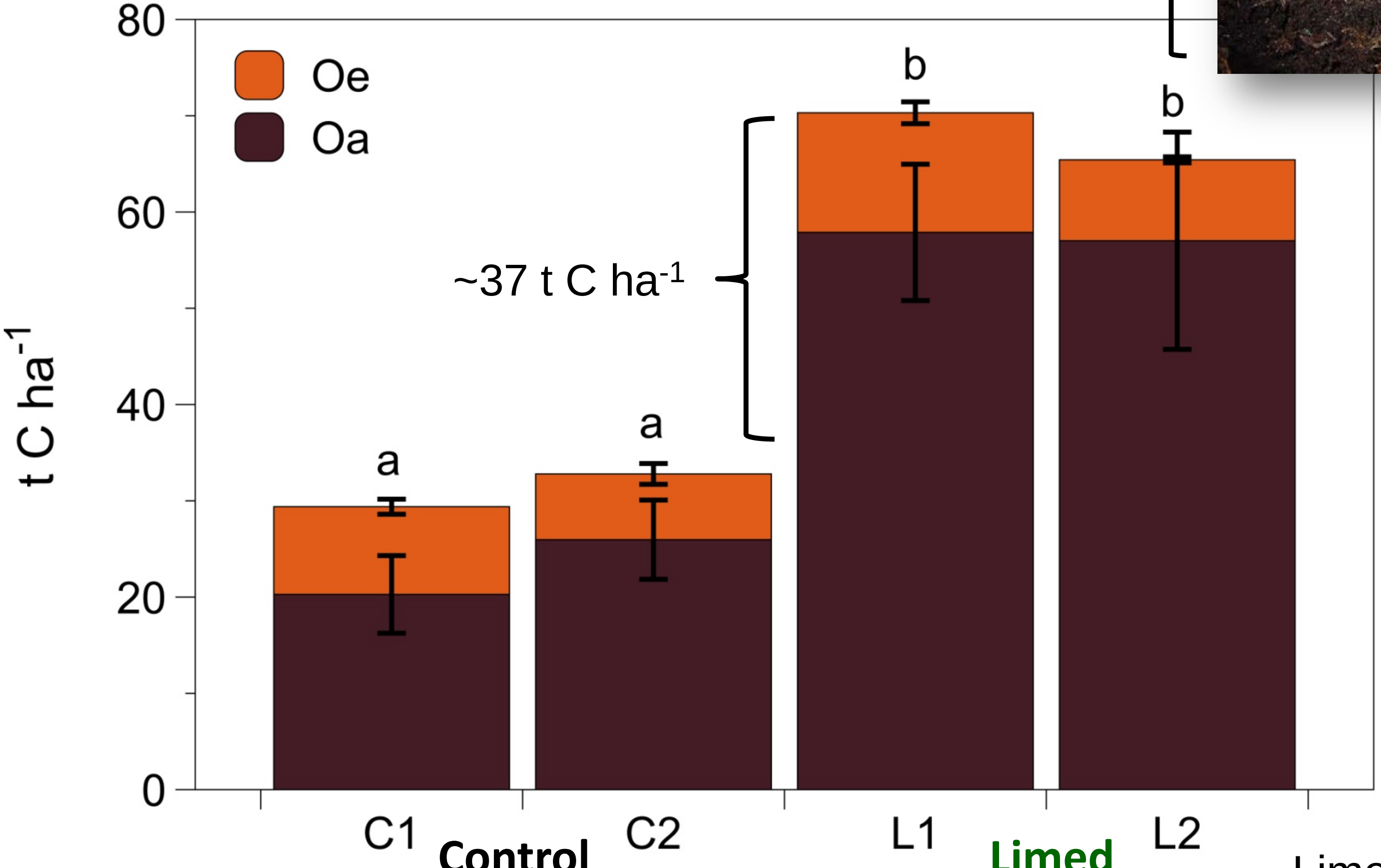
No effect of liming on litter production.



Liming increased fine roots, but only in the Oe in one subcatchment.

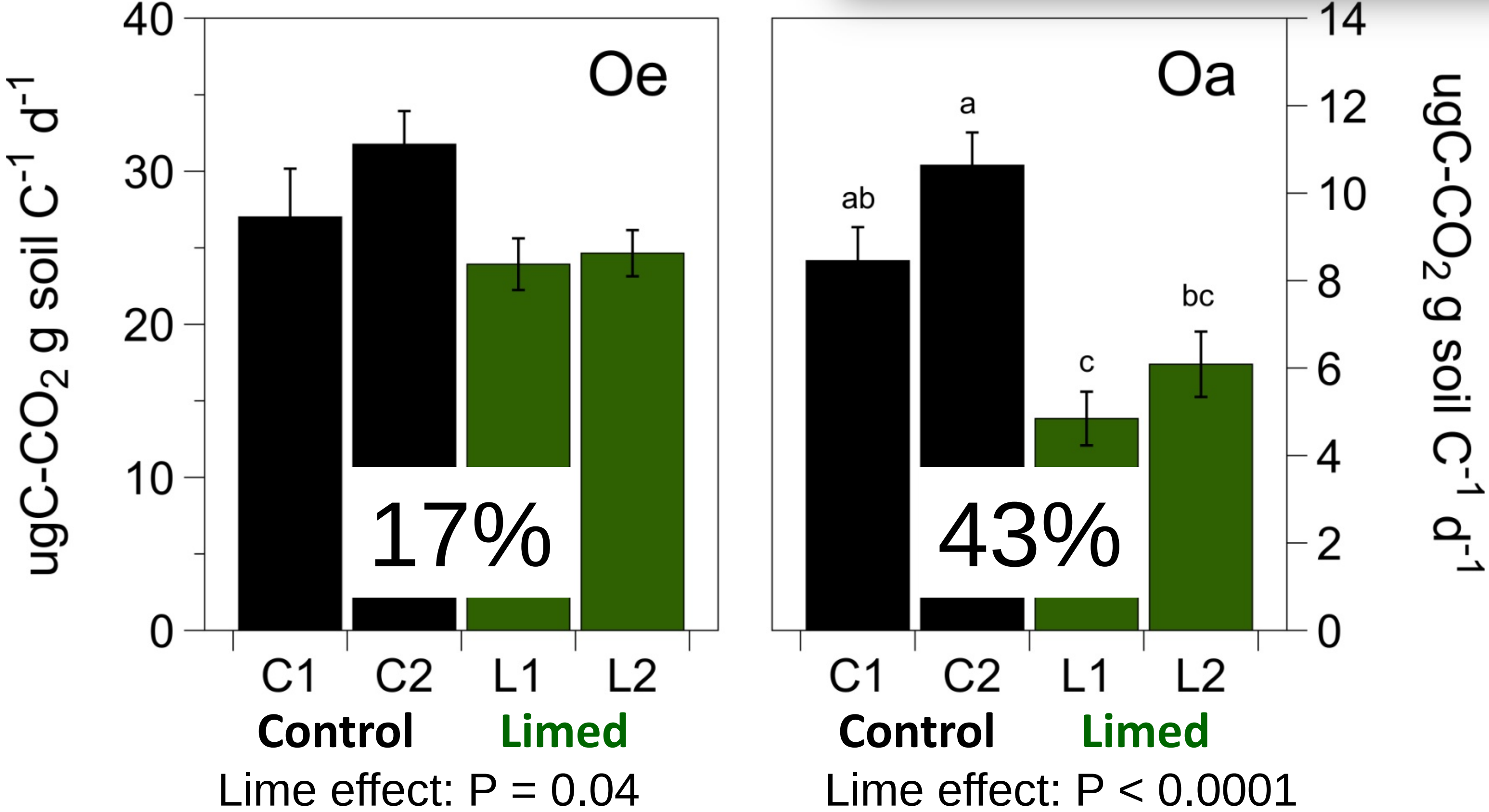


Liming increased forest floor C stocks.



Lime effect: $P < 0.0001$

Liming suppressed soil basal respiration.

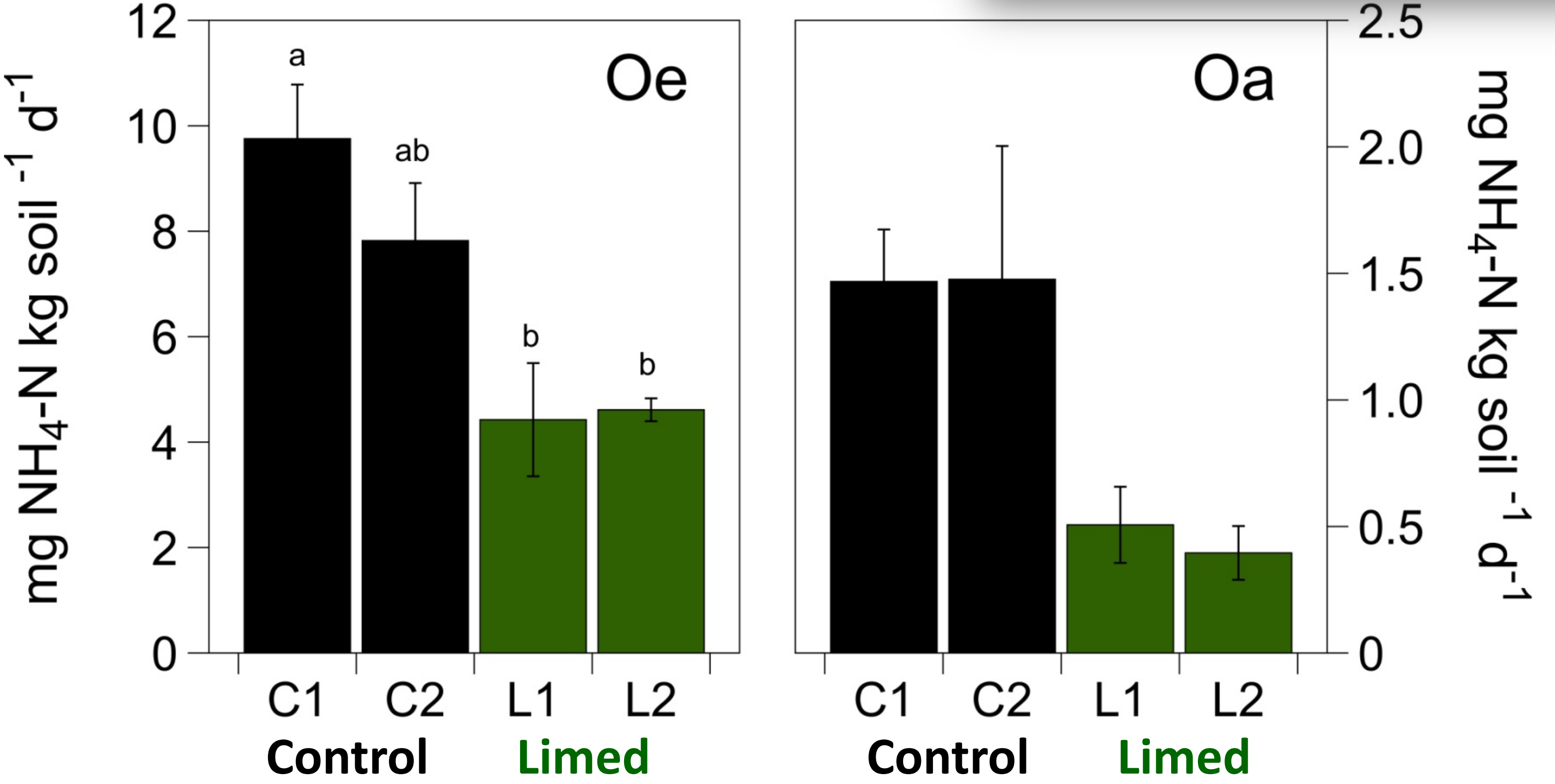


Why has respiration decreased?

Hypotheses

- Increased chemical recalcitrance?
- Change in the microbial community?
- Increased physical stabilization?

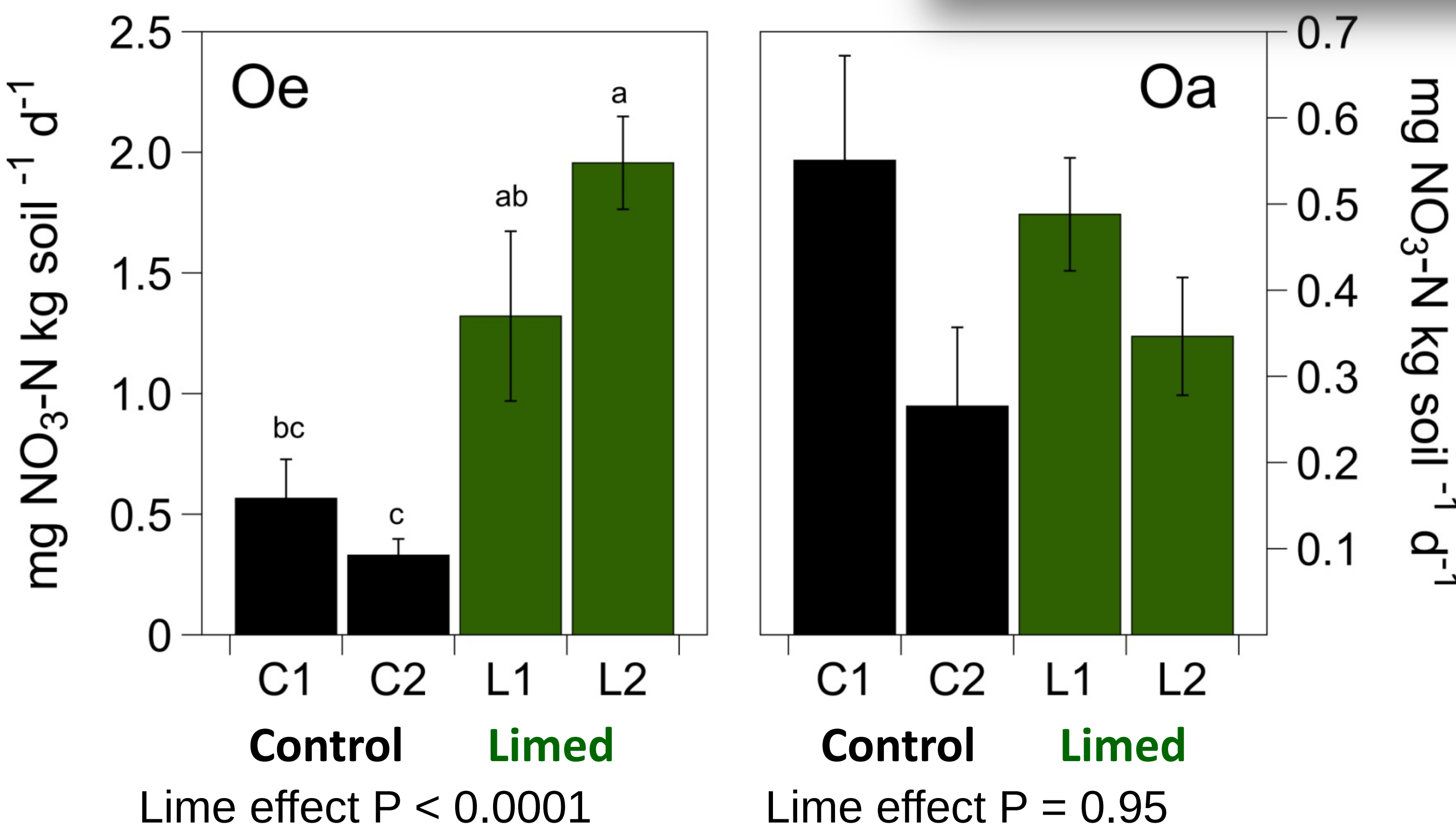
Liming suppressed net N mineralization.



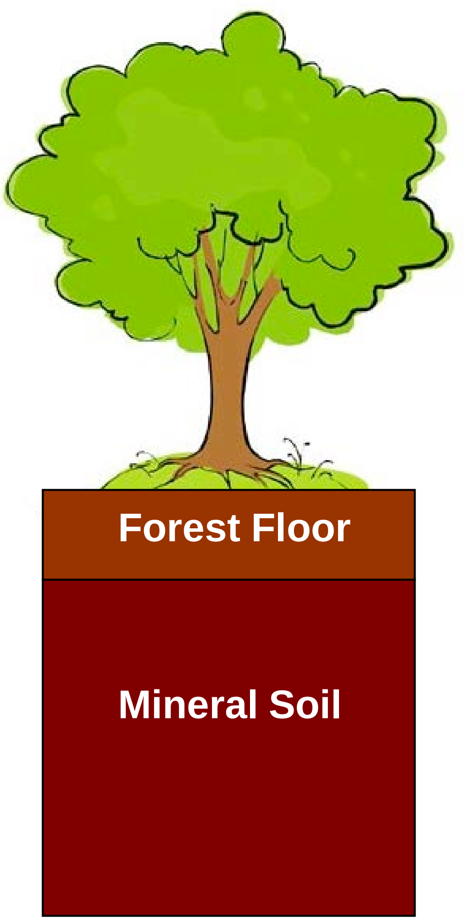
Lime effect $P = 0.0003$

Lime effect $P = 0.0032$

Liming stimulated net nitrification.



Increased Ca availability alters C and N cycling



Tree Response

- Wood production	NO LIME EFFECT
- Leaf litter production	NO LIME EFFECT
- Root production	INCREASED

Forest Floor

- Respiration	DECREASED
- N Mineralization	DECREASED
- Nitrification	INCREASED
- C and N stocks	INCREASED

-**Mineral Soil**

- C and N stocks	NO LIME EFFECT

Net C balance

Source of C flux	Increase in C stocks in limed soils (t C ha^{-1} yr^{-1})	20 - year enhancement in C stocks due to liming (t C ha^{-1})
Foliar litter nsd	0.32	6.4
Non - foliar litter nsd	-0.20	-4.0
< 2 mm roots*	0.07	1.4
Heterotrophic respiration*	0.95	19
Observed increase in forest floor C stocks	1.85	37
Net C balance of measured fluxes	1.14	22.8

Some Conclusions

- (De-)acidification directly and indirectly affects multiple forest C processes and pools
  - Increases release of bio-available DOC.
    - Implications for catchment NO_3^- export?
  - Decreases decomposition rates and yields additional C storage in some forest soils.
    - Exact mechanism and persistence uncertain.

Thank-you!

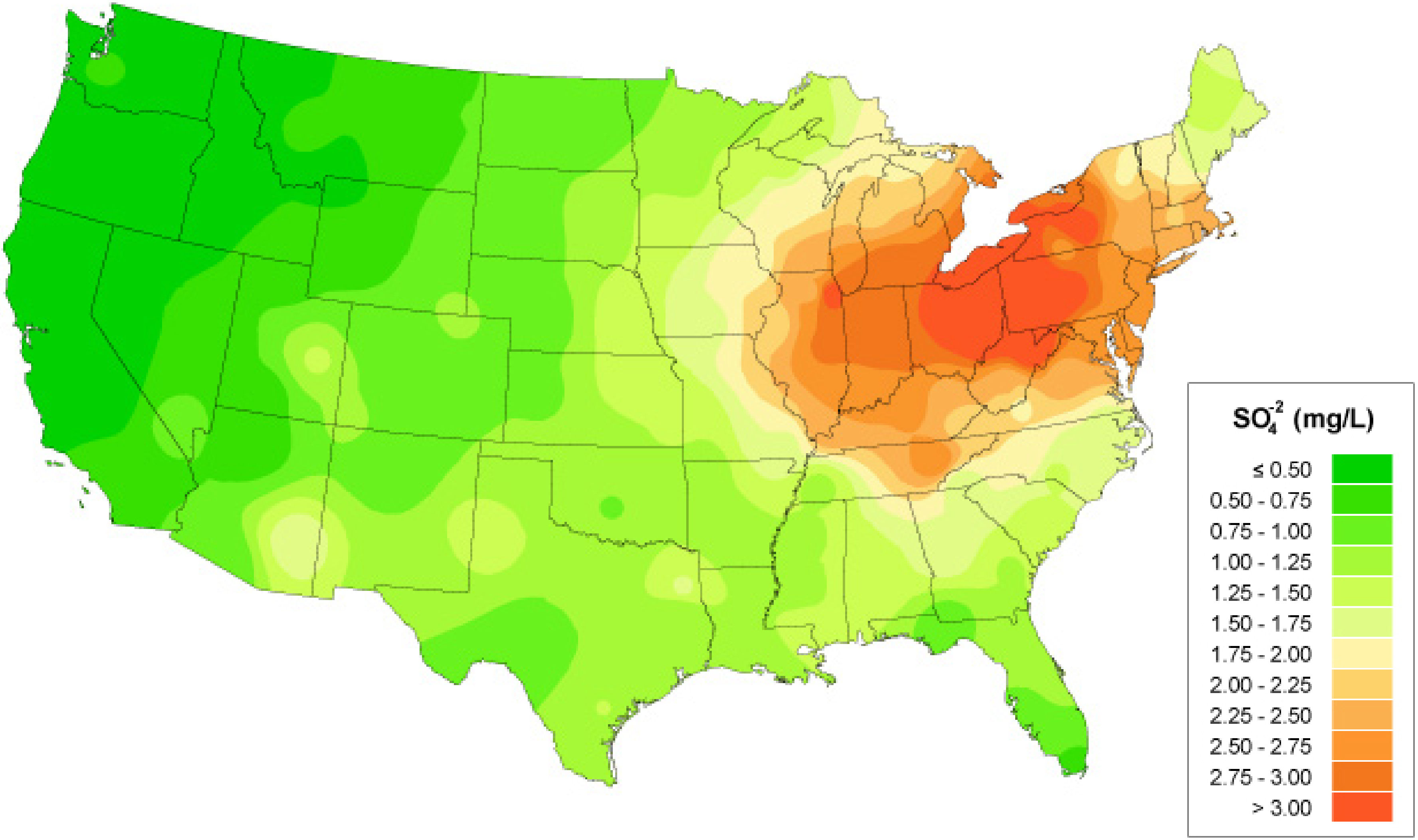
Guin Fredriksen
Max Kraft
Chris Johnson
Multiple undergrads
The Woods Lake Co.

NSF IGERT
NSF CAREER

NYSERDA-EMEP Program
& Grad. Student Fellowship

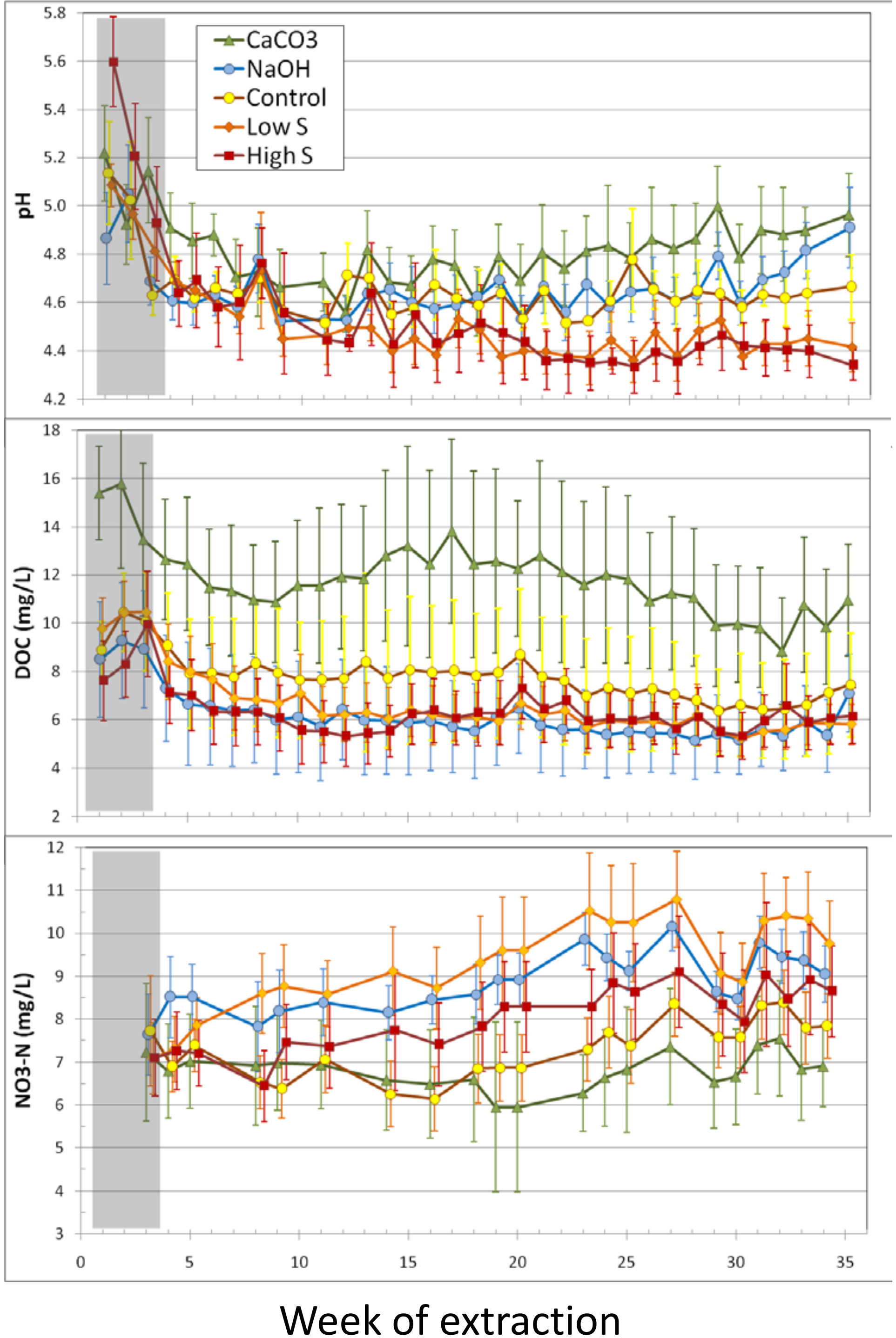
Spare Slides

Sulfate Deposition



Sulfate Ion Concentrations 1986

NADP

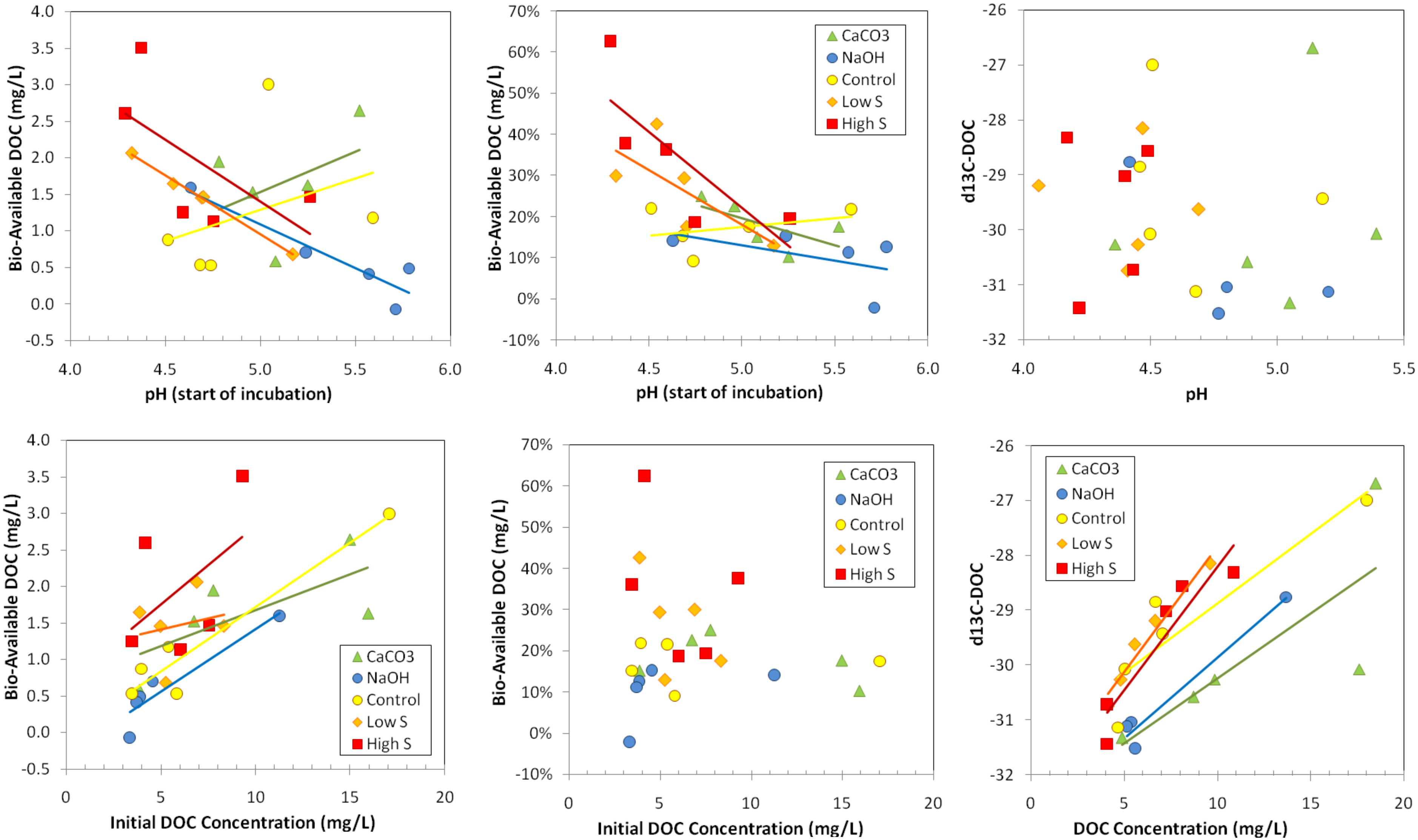


Leaching shifted core pH

No effect on DOC

Nitrate increase in acidified samples

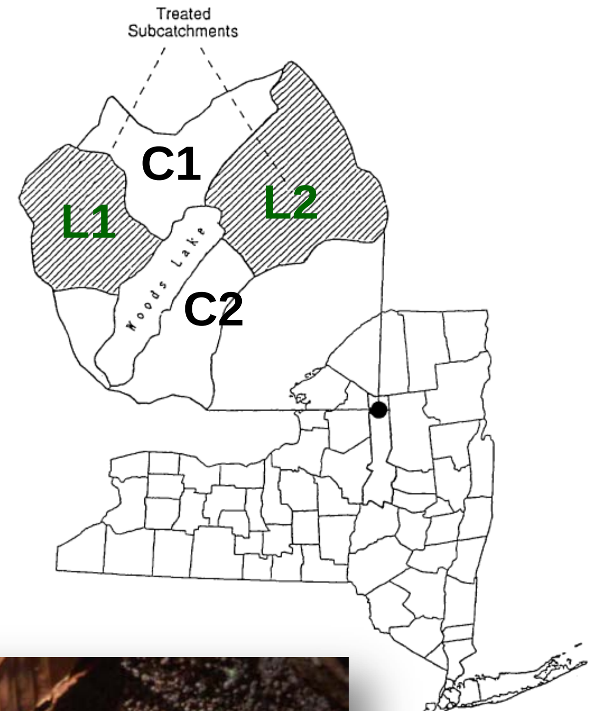
Acidification increases DOC bioavailability (week 34)



Why calcium?

- Biologically important
- Abiotic soil interactions

Woods Lake Watershed
Adirondack Park, New York

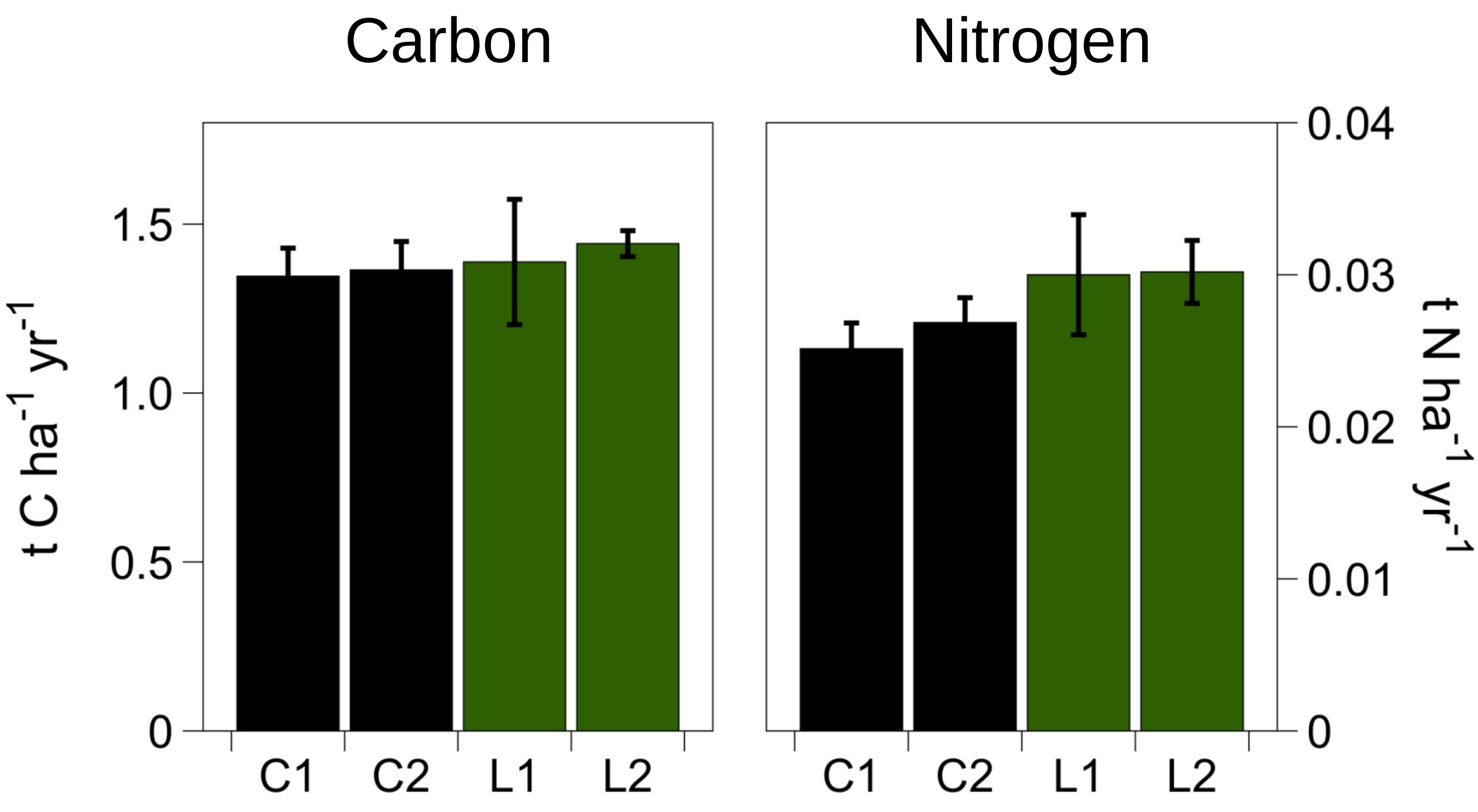


Photos courtesy of Doug Burns

Tree response

Annual litter production

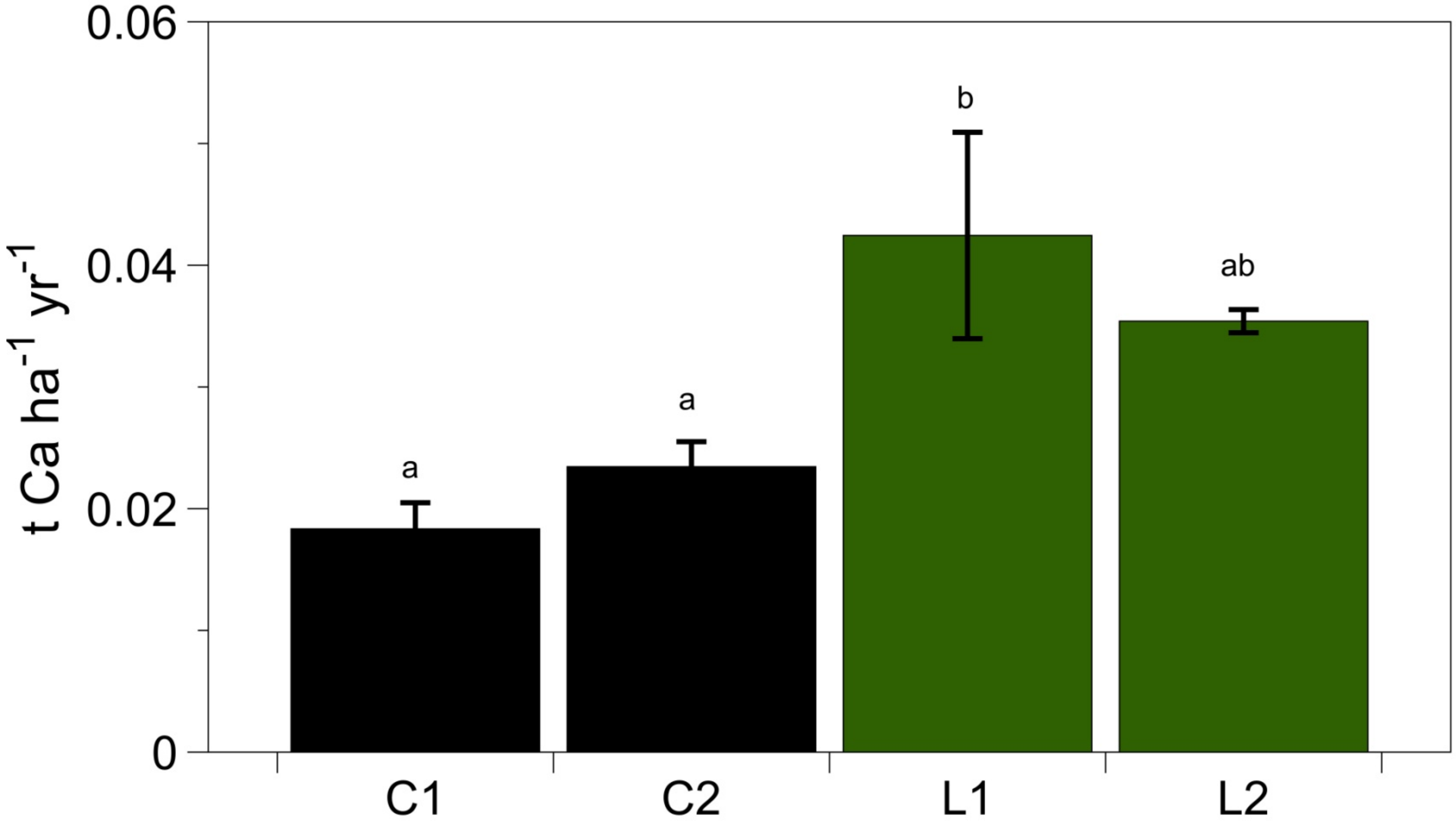
Litter C and N inputs



Lime effect: $P = 0.60$

Lime effect: $P = 0.12$

Litter Ca inputs



Lime effect P = 0.001

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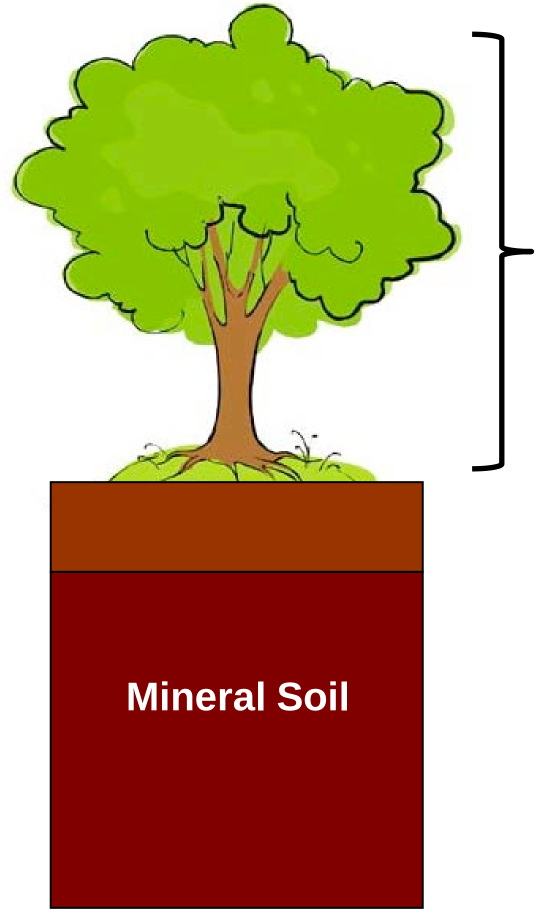

Tree response

Increased:

- tree growth: NO LIME EFFECT
- leaf litter production: NO LIME EFFECT
- root production: INCREASED

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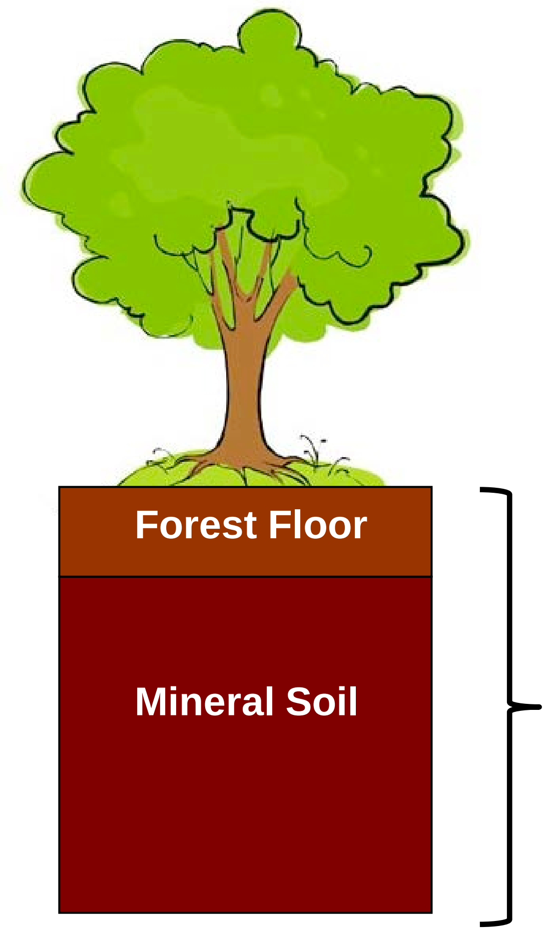
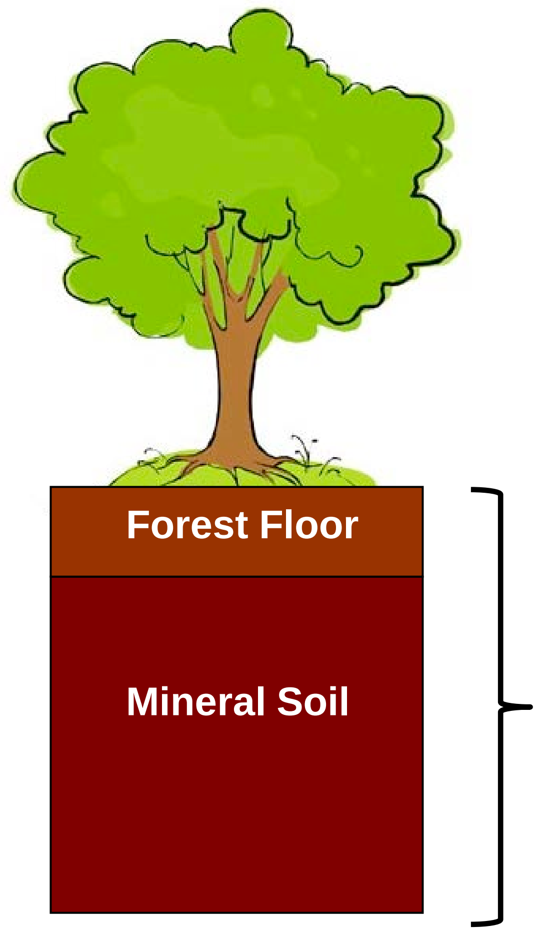


Soil response

- Forest floor:
    - increased decomposition and net N mineralization DECREASED
    - decreased C and N stocks INCREASED
- Mineral soil:
    - increased C and N stocks NO EFFECT

Increased Ca availability alters C and N cycling



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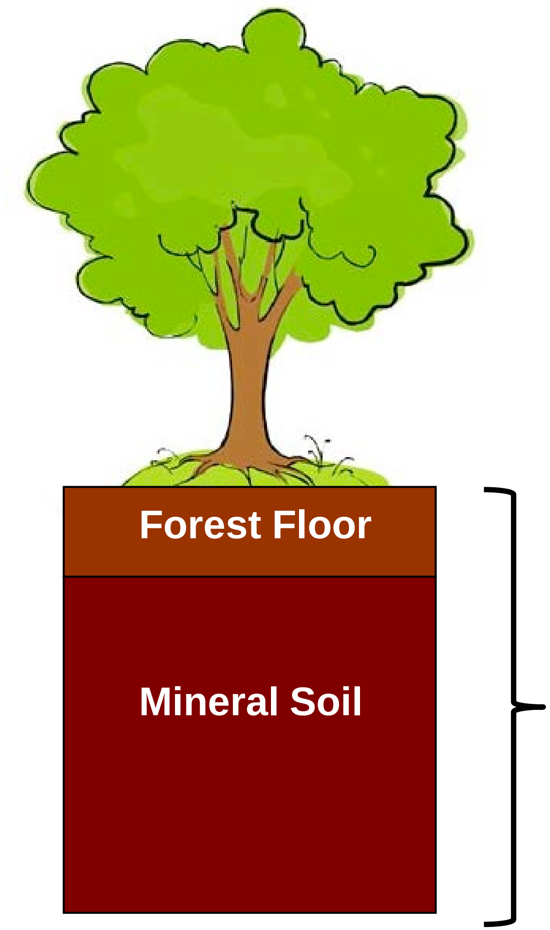

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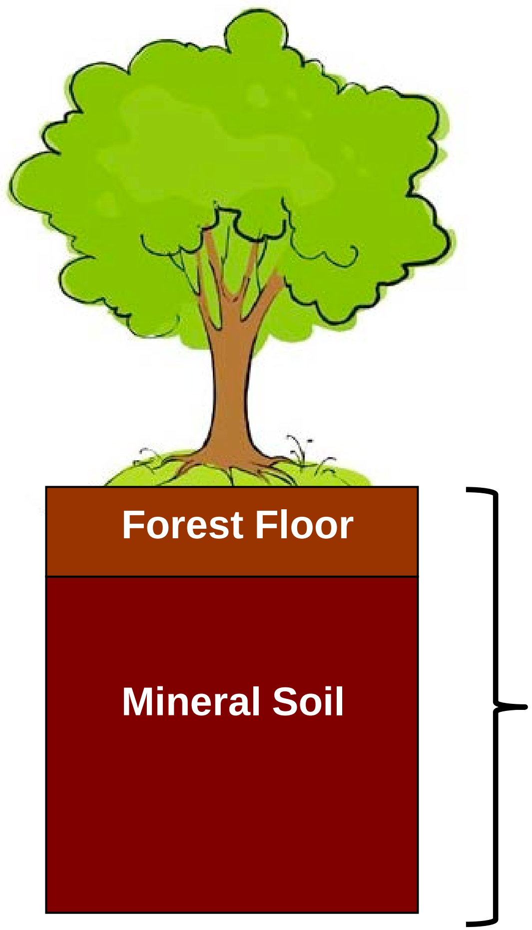

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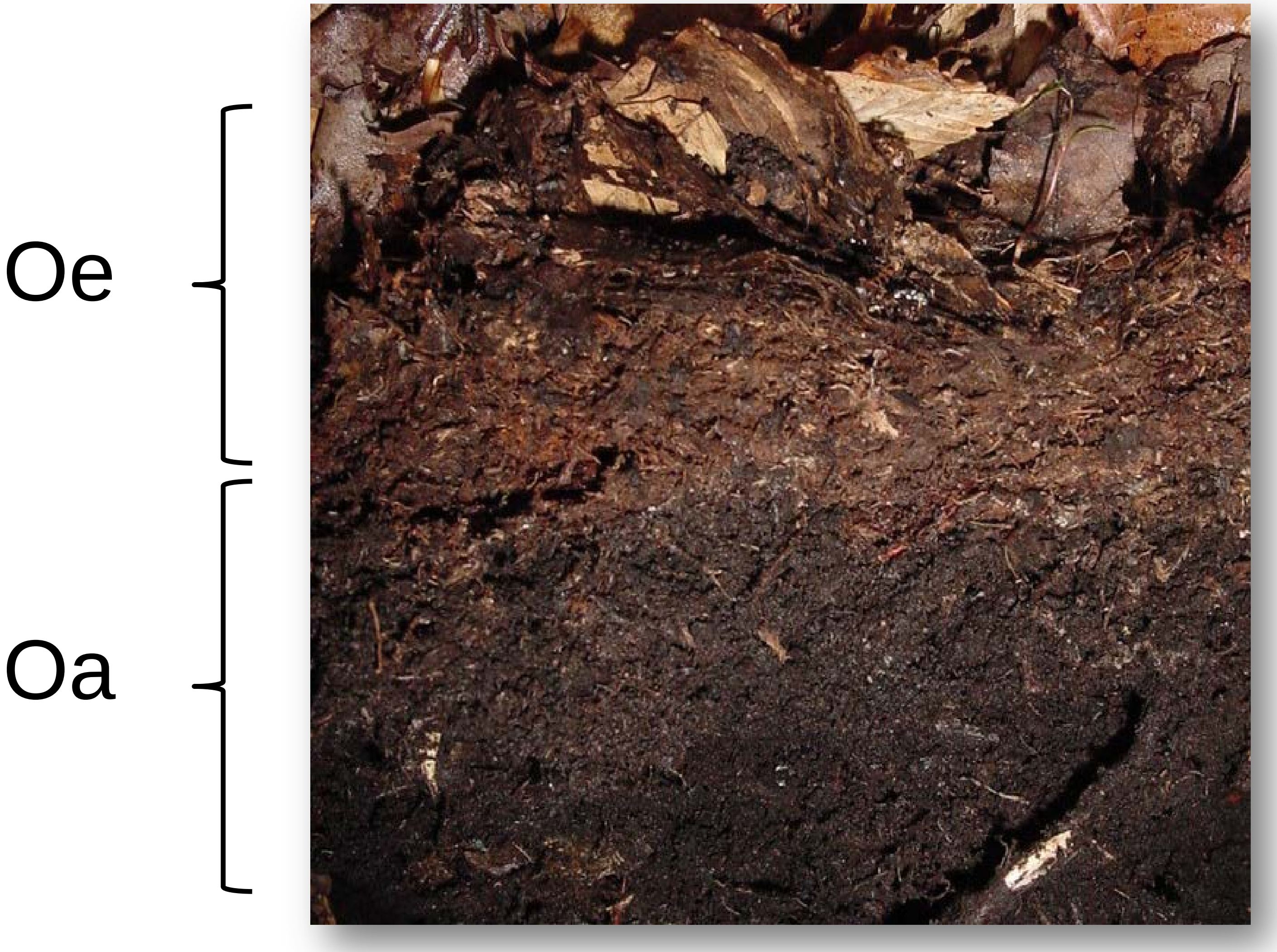
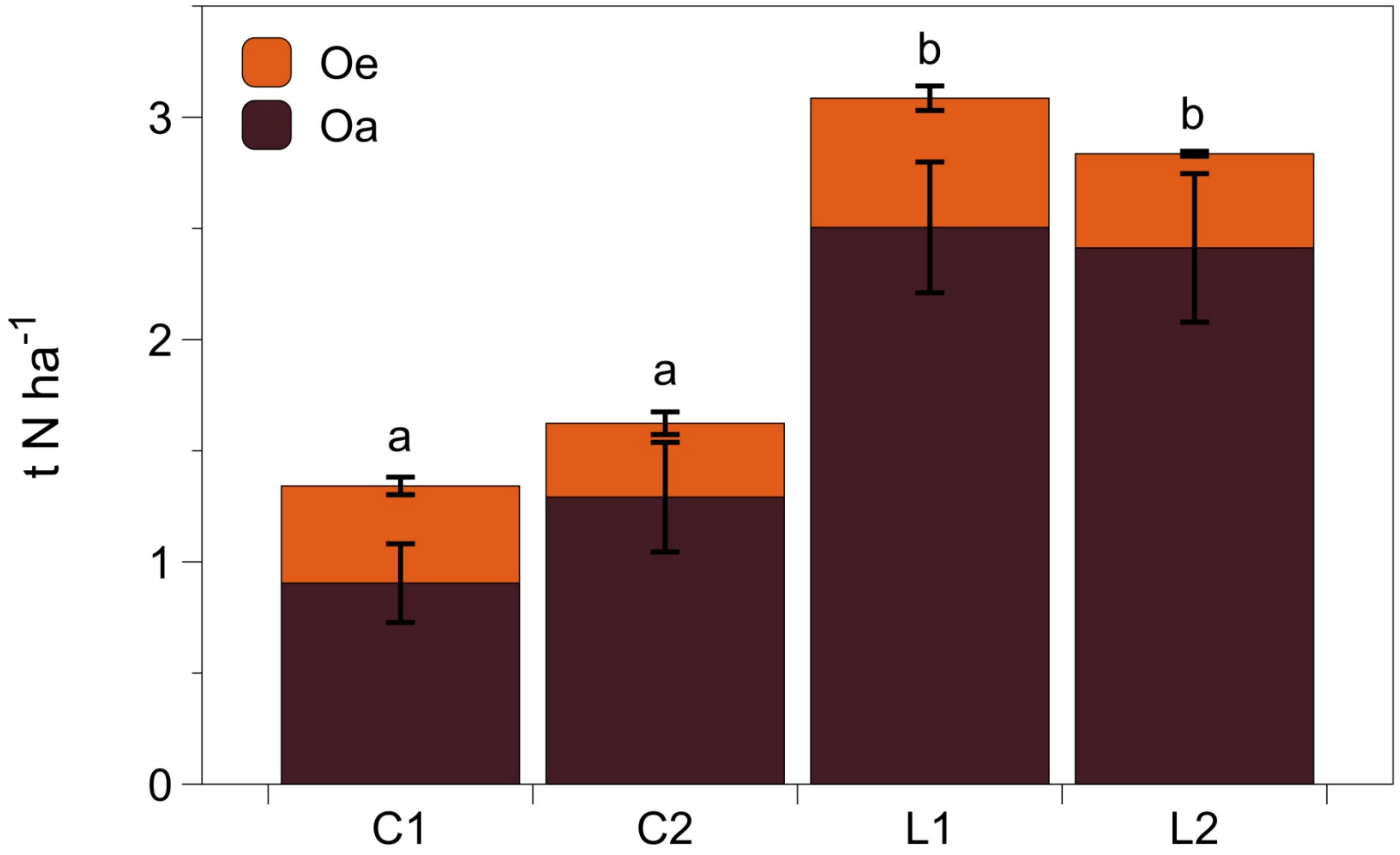
The Forest Floor



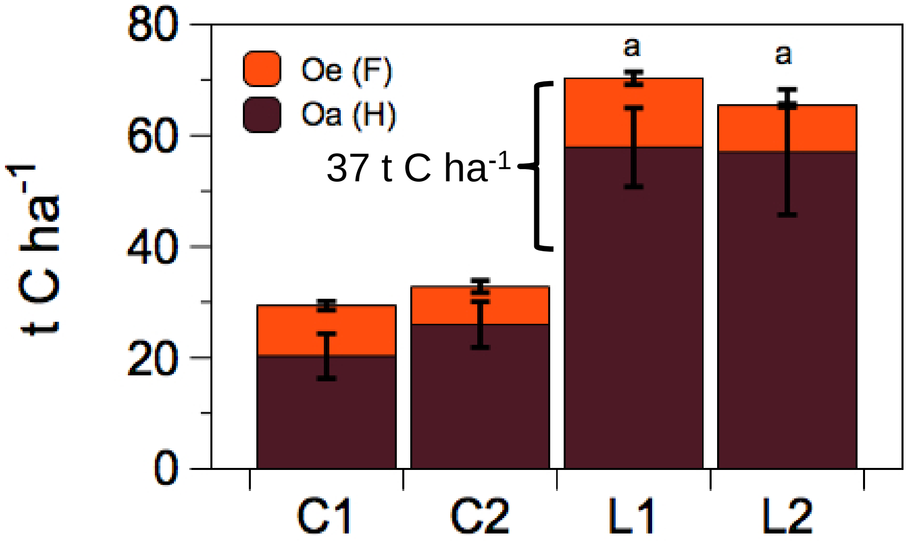
Liming increased forest floor N stocks



Lime effect: $P < 0.0001$

Why a difference in forest floor mass?

- Increased:
  - Litter production
  - Root production



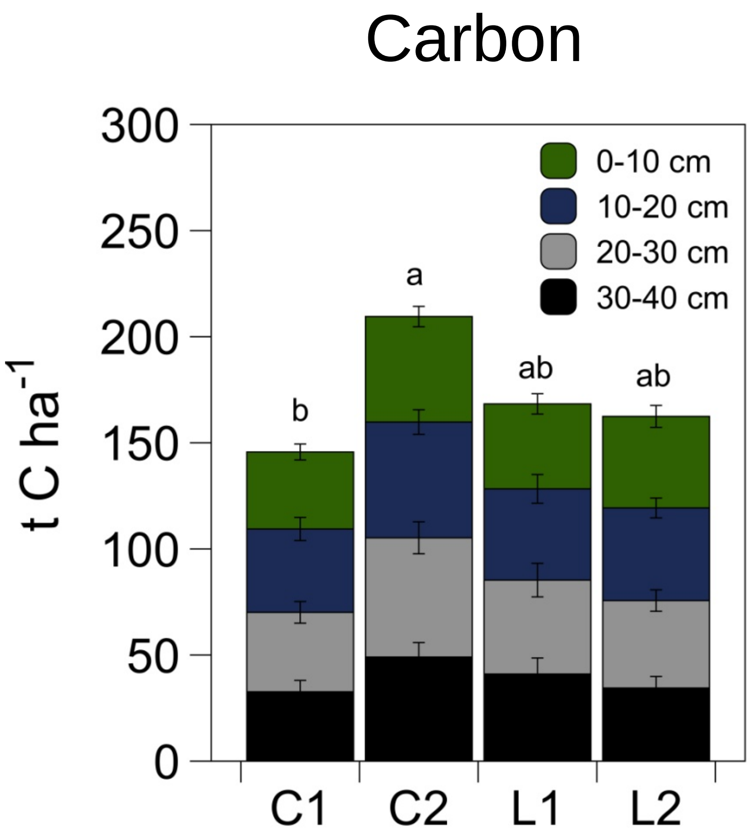
- Decreased:
  - decomposition

Forest floor C and N cycling

- Soil basal respiration
- Net N mineralization and nitrification

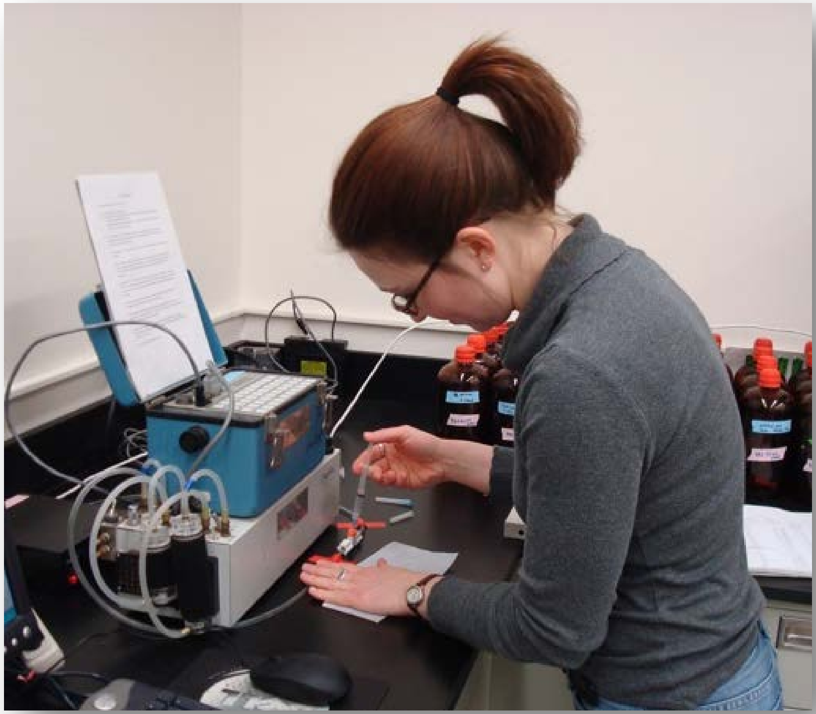
Belowground response

Mineral soil C and N stocks



Lime effect P = 0.33

Soil basal respiration



In situ net N mineralization

Why have C and N cycling rates changed?

Hypotheses

- Increased chemical recalcitrance

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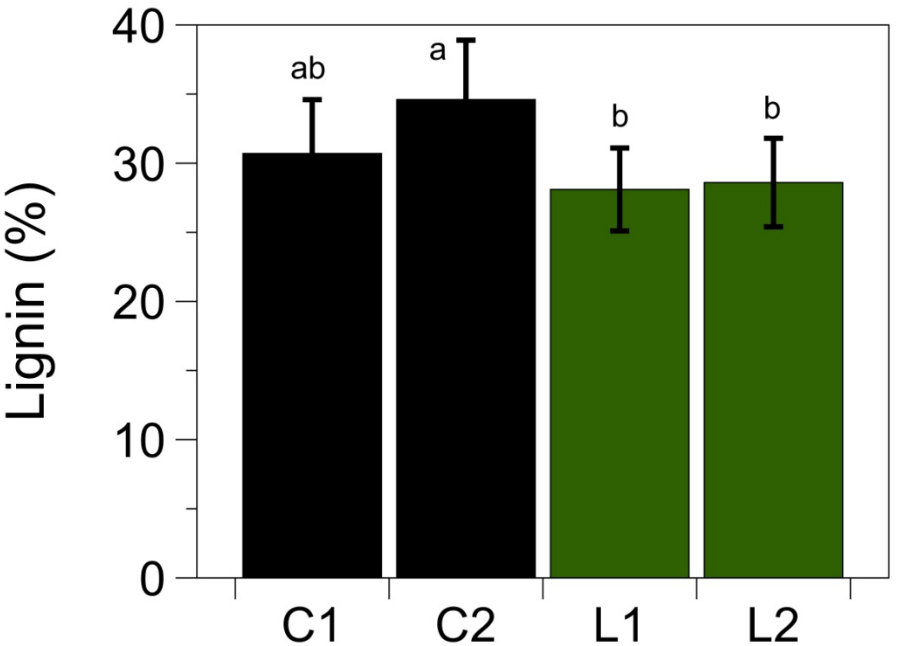

Lime effect P = 0.01

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Hypotheses

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- Change in the microbial community

Net C balance

Net C balance

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