Soil carbon and nitrogen stocks in a temperate hardwood forest: climate change effects and recovery from chronic acidification

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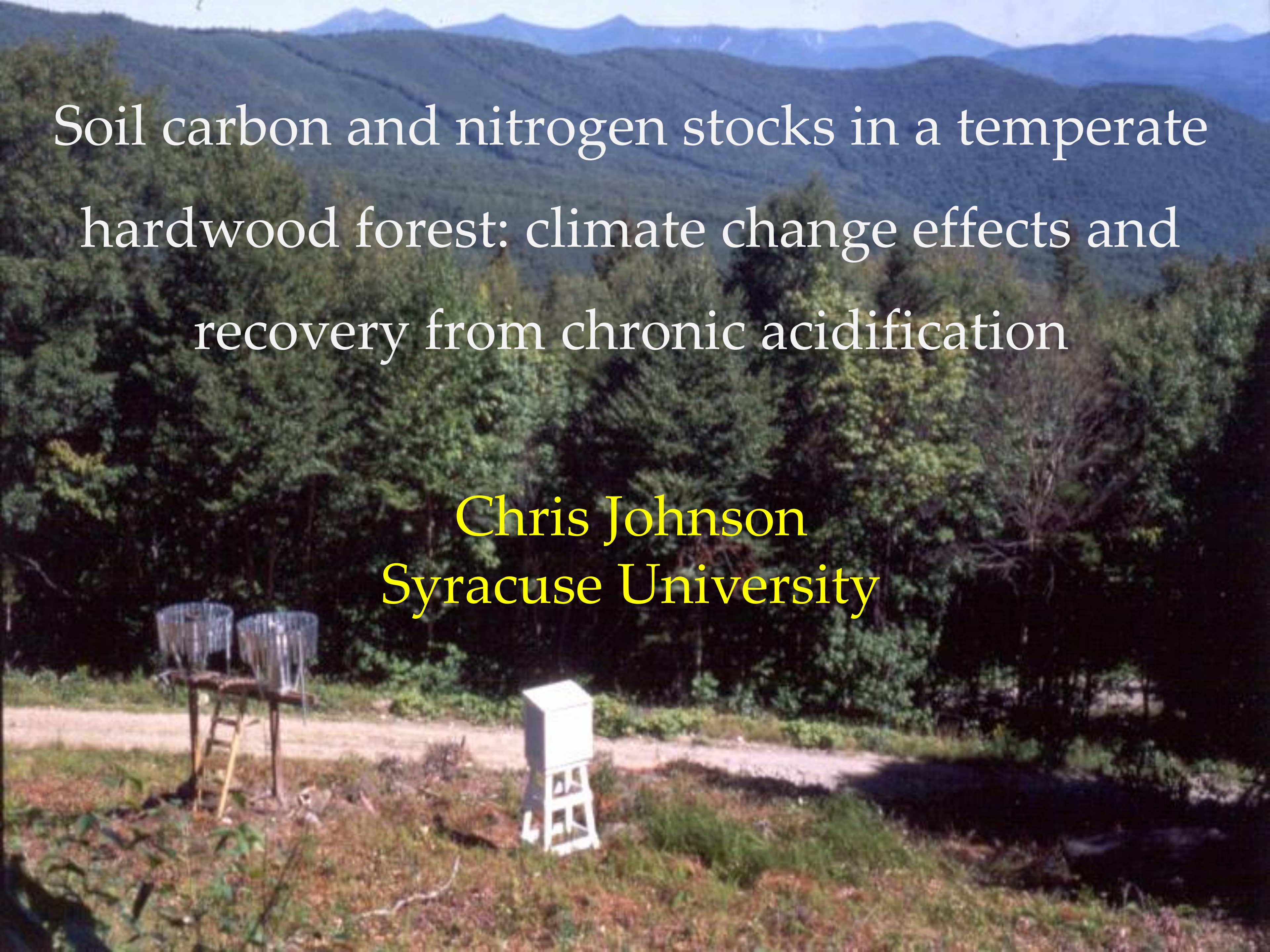
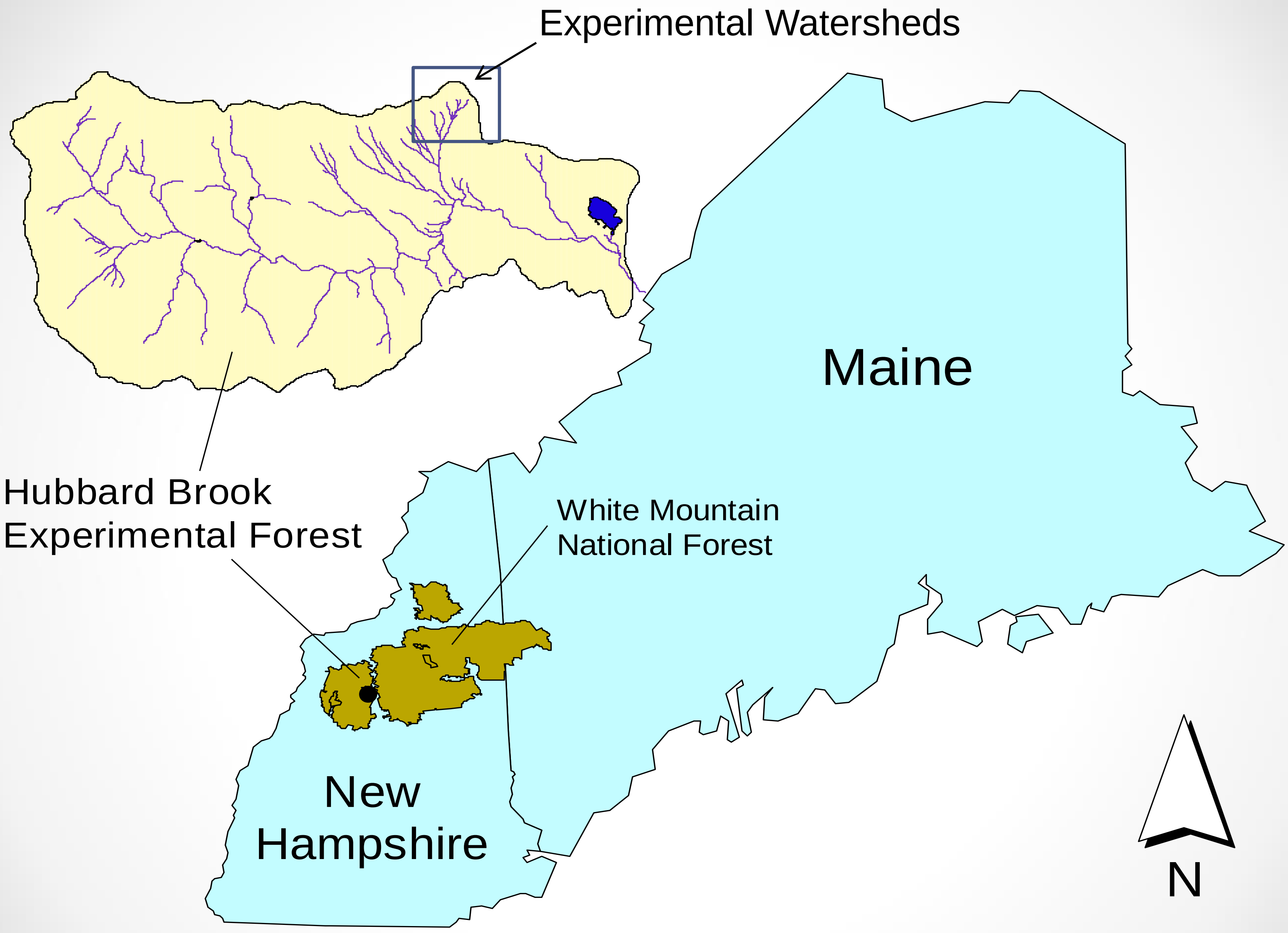


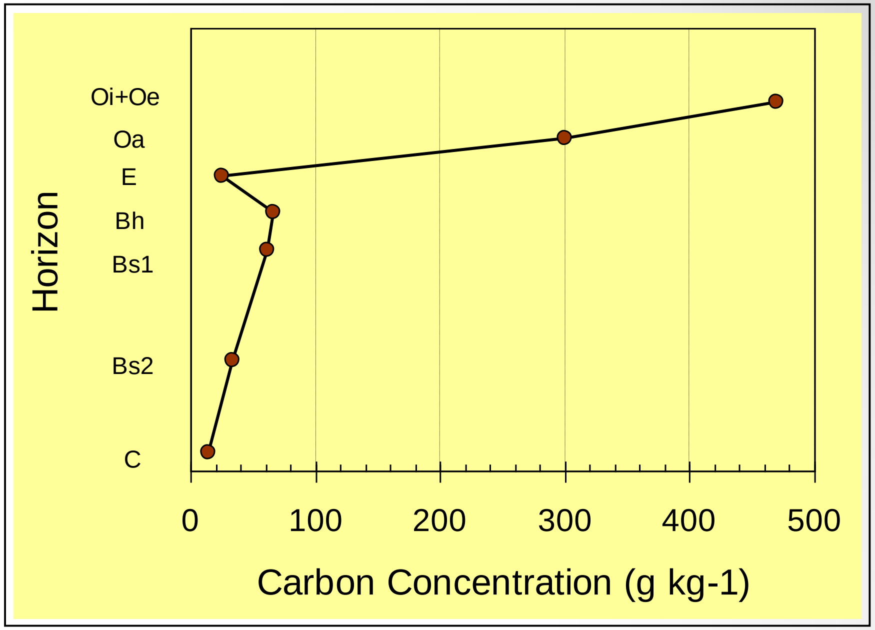
Global Change Context

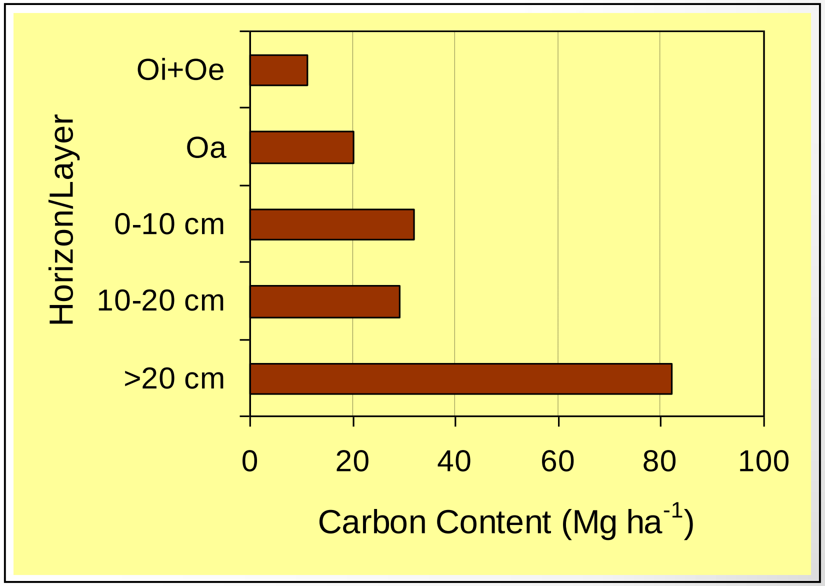
- Temperate forests are important C reservoirs
  - Will they be sources or sinks in a changing climate?
  - What is the range of possible change in soil C pools?
  - (Economic value/cost of C sequestration/loss)
- Land-use Impacts on C cycling
  - Temperate forests lie in many heavily industrialized regions
  - Historically impacted by acidic deposition
  - Now recovering in many regions (esp. Europe, N. America)



Experimental Watersheds
Maine
Hubbard Brook
Experimental Forest
White Mountain
National Forest
New
Hampshire
N

Hubbard Brook Experimental Forest


Horizon
Oi+Oe
Oa
E
Bh
Bs1
Bs2
C
0
100
200
300
400
500
Carbon Concentration (g kg-1)


Horizon/Layer
Oi+Oe
Oa
0-10 cm
10-20 cm
>20 cm
0
20
40
60
80
100
Carbon Content (Mg ha-1)

Characteristics of Monitored Watersheds

Watershed Number	Size (ha)	Year Started	Treatment
1	11.8	1956	Calcium silicate addition 1999
2	15.6	1957	Clear-felled in '65-66, no products removed, herbicide application '66,67, 68.
3	42.4	1958	None – Hydrologic reference.
4	36.1	1961	Clear-cut by strips in three phases – '70,72,74. Timber products removed.
5	21.9	1962	Whole-tree clear-cut in 1983-84. Timber products removed.
6	13.2	1963	None – Biogeochemical reference.
7	76.4	1965	None
8	59.4	1969	None
9	68.0	1994	None
101	12.1	1970	Clear-cut as block in 1970. Timber products removed.

“Facilitated Recovery” – Wollastonite Addition: W1, October 1999

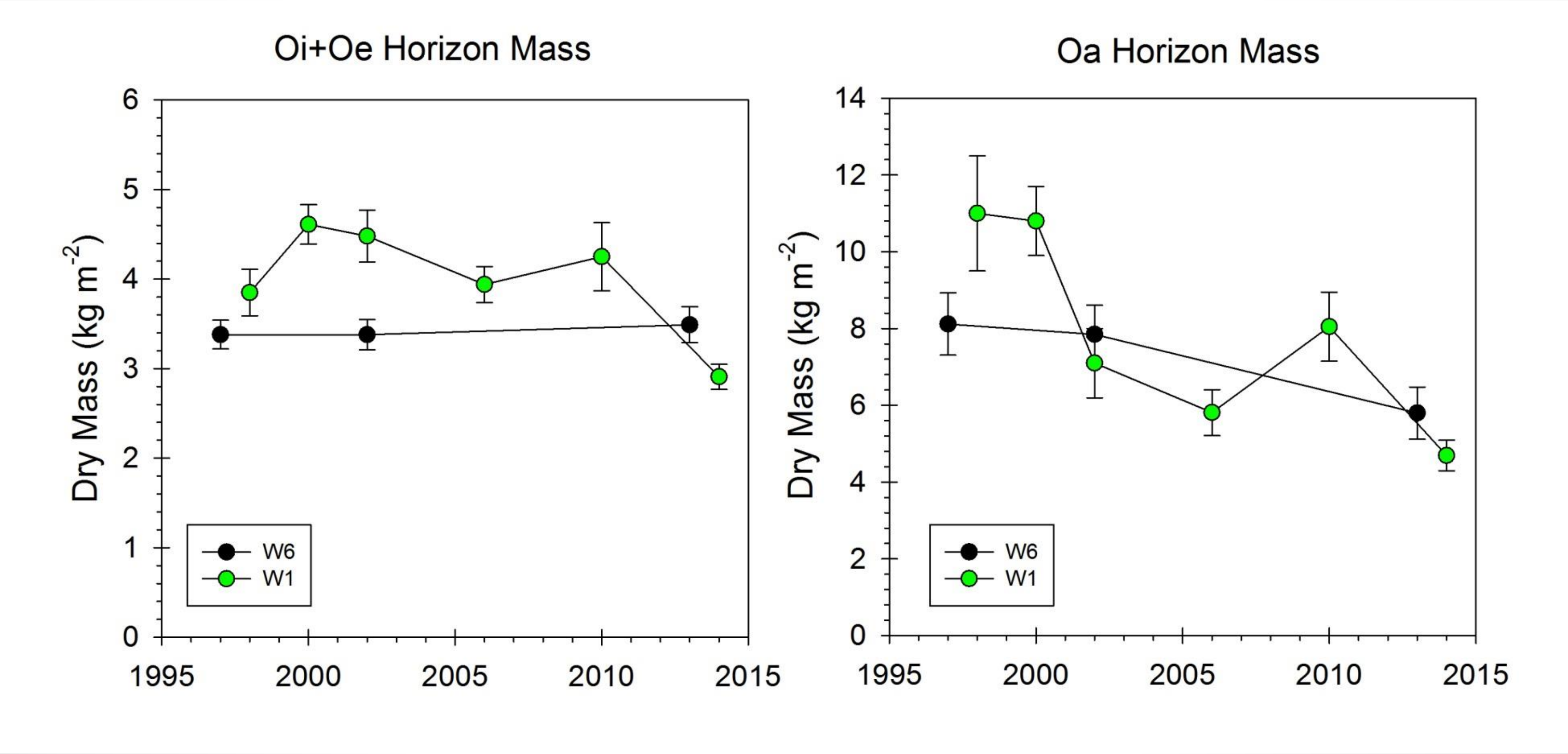
www.hubbardbrook.org

Motivation and Hypotheses

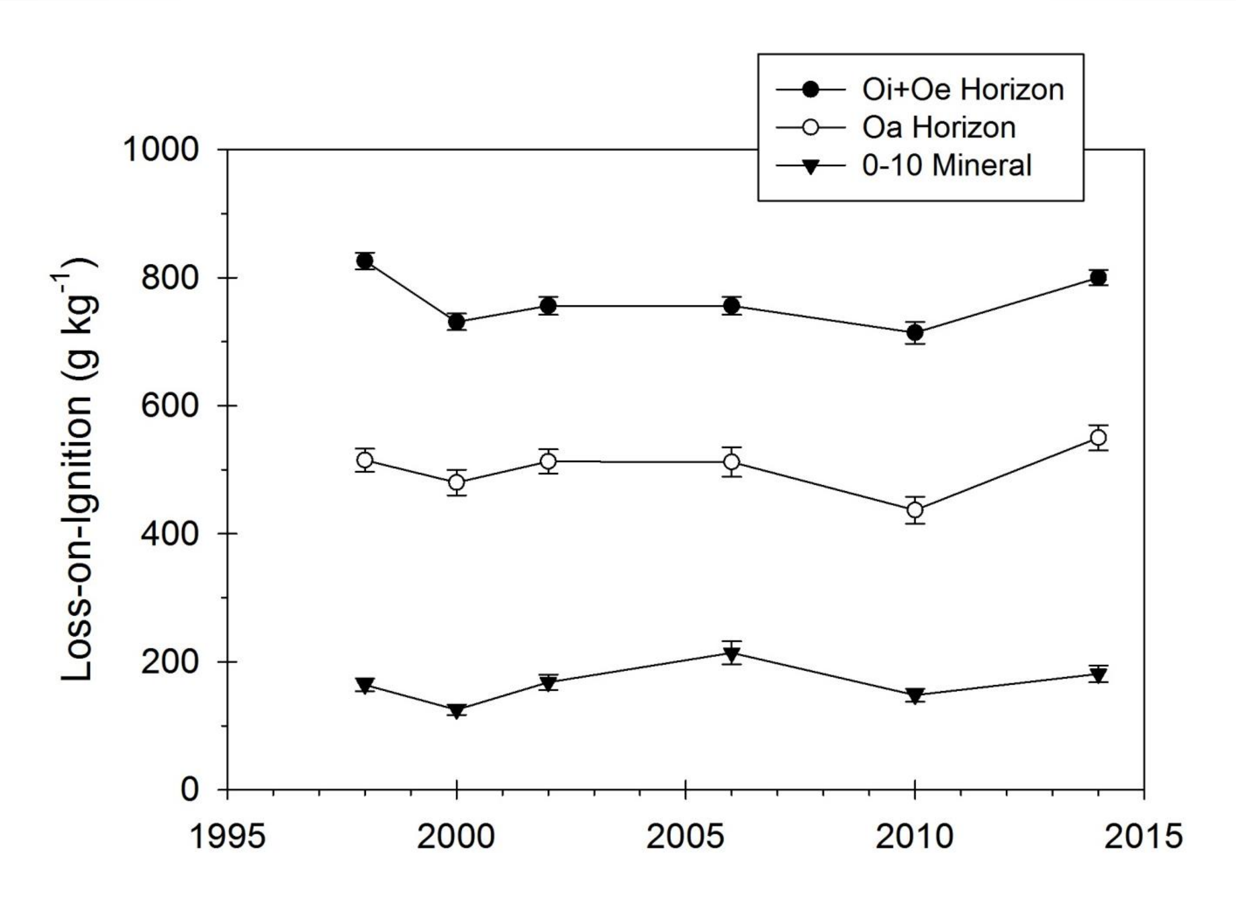
- Wollastonite = $CaSiO_3$
- "Replace" Ca depleted from soils by:
  - Acid rain
  - Successional vegetation growth

- Soil Hypotheses:
  1. Wollastonite application will result in increased pH, exchangeable Ca and base saturation in W1 soils.
  2. Soil chemical change will occur over many years, as a chemical "front" moving downward in the soil.
  3. Wollastonite treatment will result in faster rates of C and N cycling processes due to a more favorable environment for microbes.
     - Decline in soil organic matter, SOC?

Does Ca Addition Cause SOM Loss?

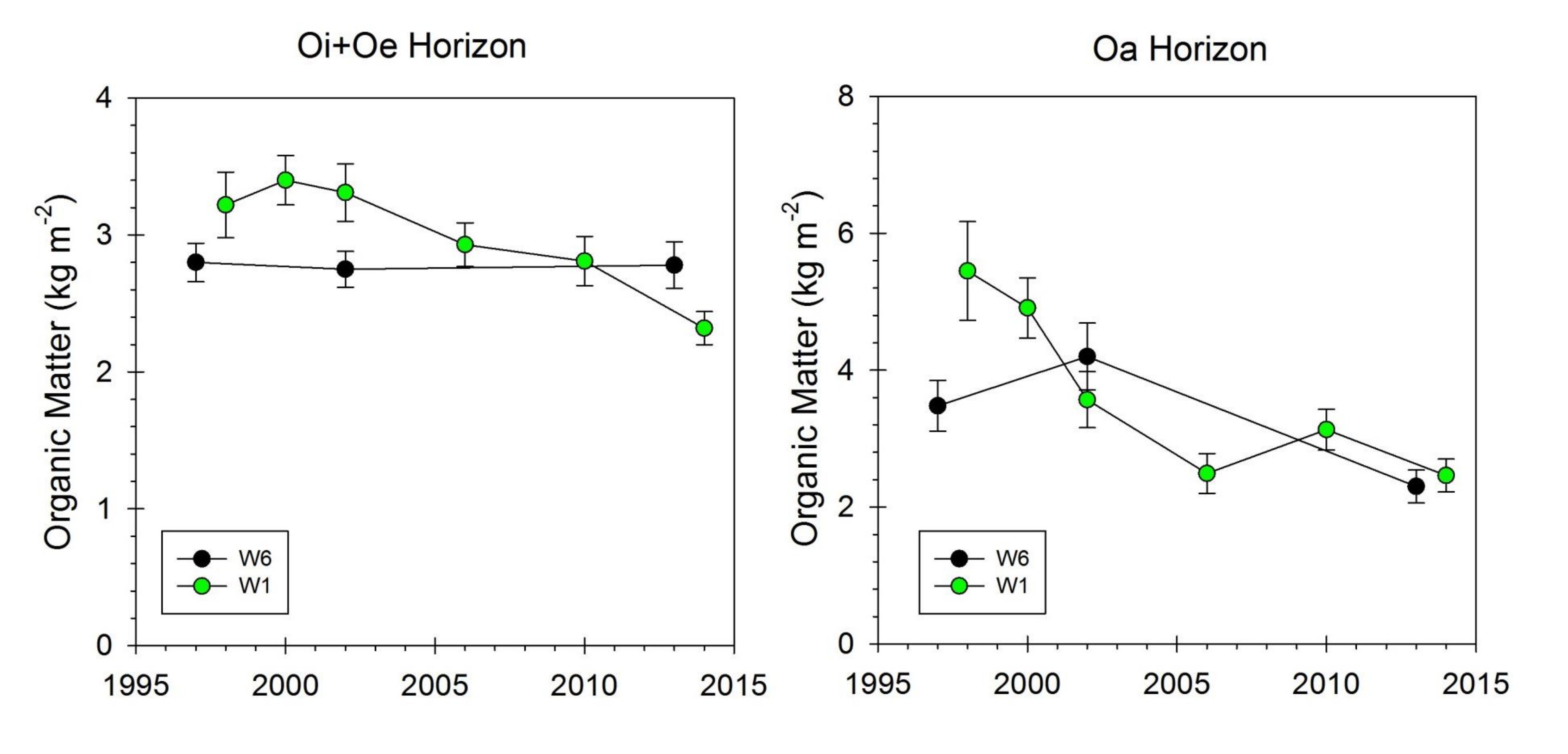


Does Ca Addition Cause SOM Loss?



It does not appear to be a sampling issue.

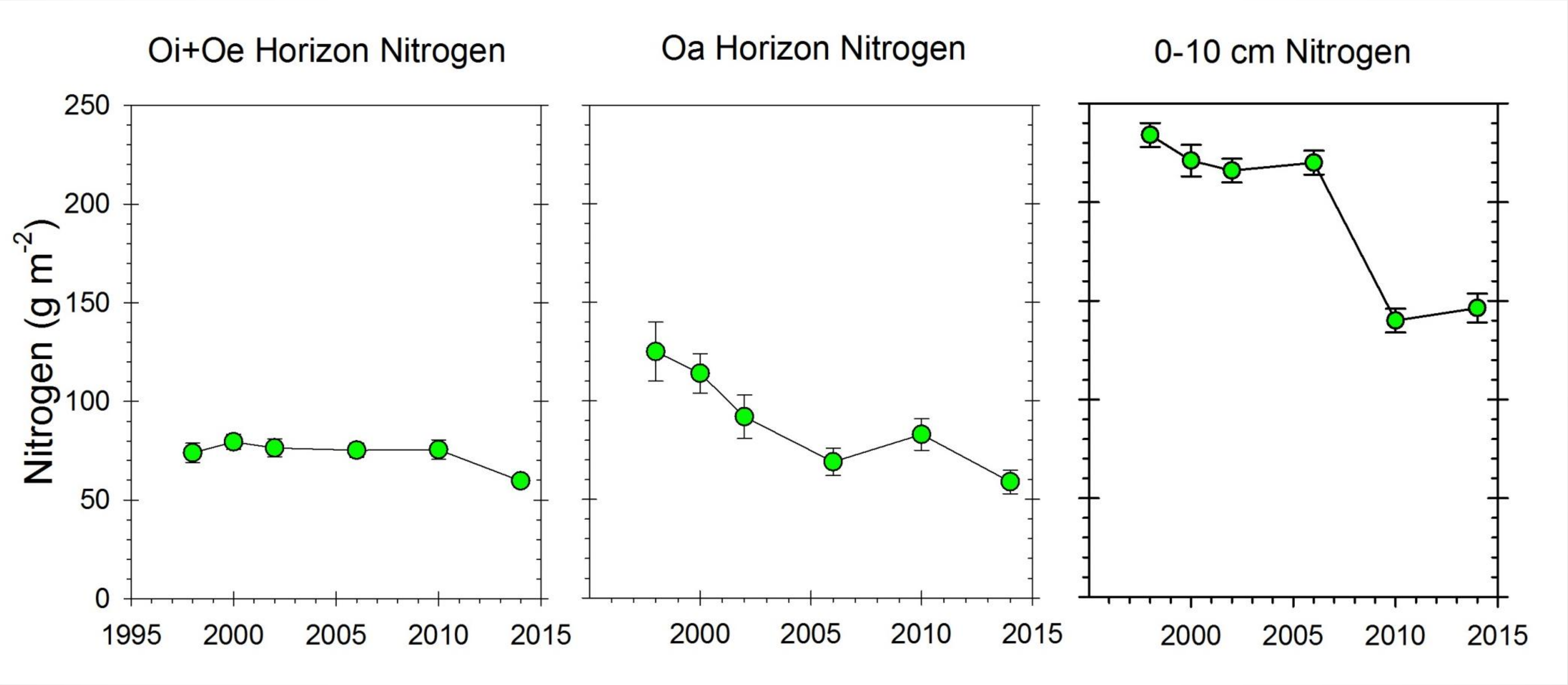
Does Ca Addition Cause SOM Loss?



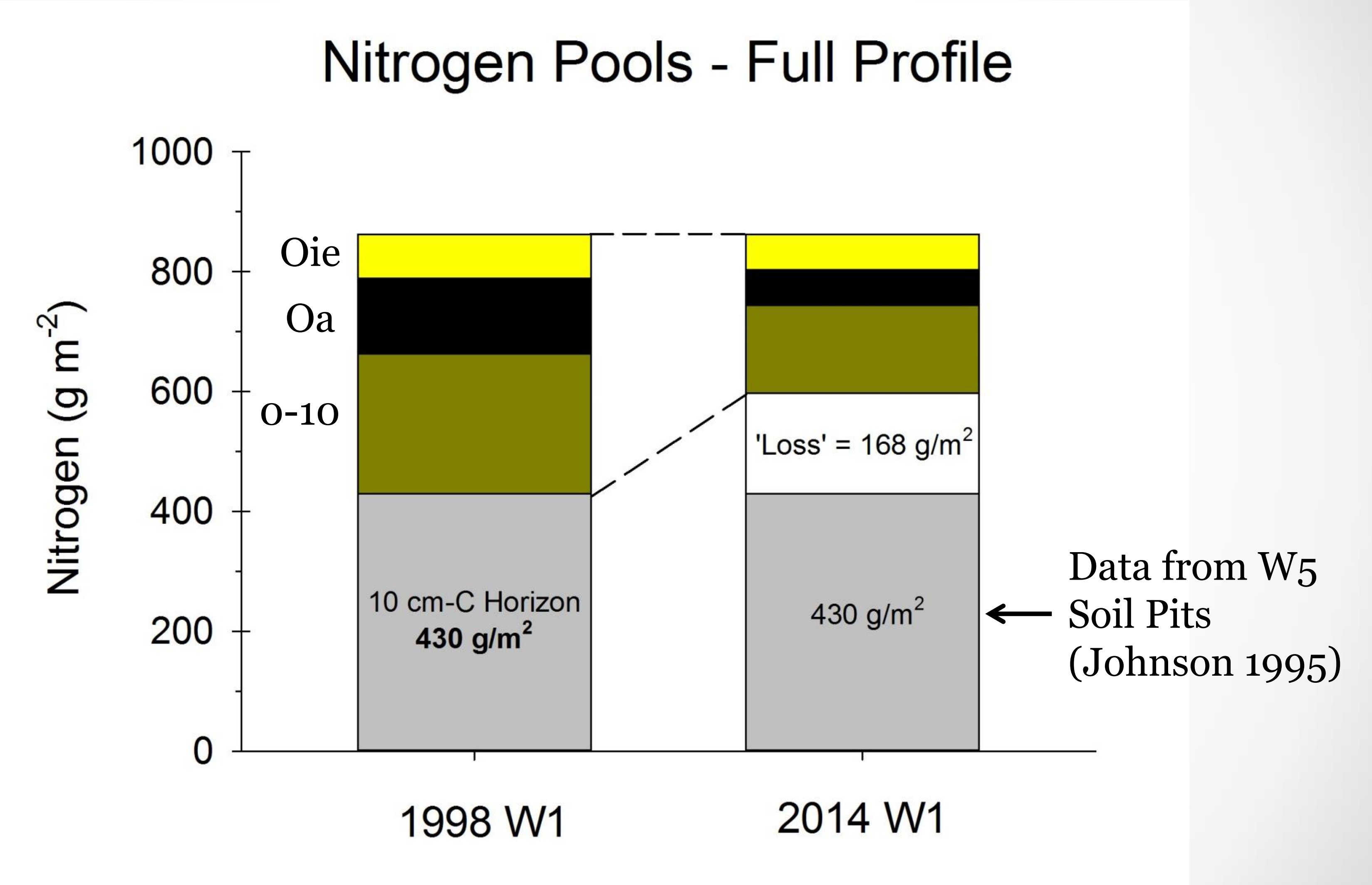
Possibilities

- Enhanced decomposition?
  - Groffman et al. (2007) saw little effect on microbial processes in W1…
  - …but Lovett et al. (2016) observed greater late-stage decomposition in litter.
- Greater C allocation to shoots = less root litter?
  - Fahey et al. (CJFR in Press) have documented lower fine-root biomass in the treated watershed.
- Higher OM solubility at higher pH? [There has been little or no change in soil solution DOC.]
- Mixing? [No earthworms at Hubbard Brook, but we have started to see them in W1.]

Soil Nitrogen Declines in W1



W1 Soil Nitrogen 'Loss' is Substantial



Soil C and N in Limed Forest Ecosystems

Ecological Applications, 23(8), 2013, pp. 1962–1975

Forest liming increases forest floor carbon and nitrogen stocks in a mixed hardwood forest

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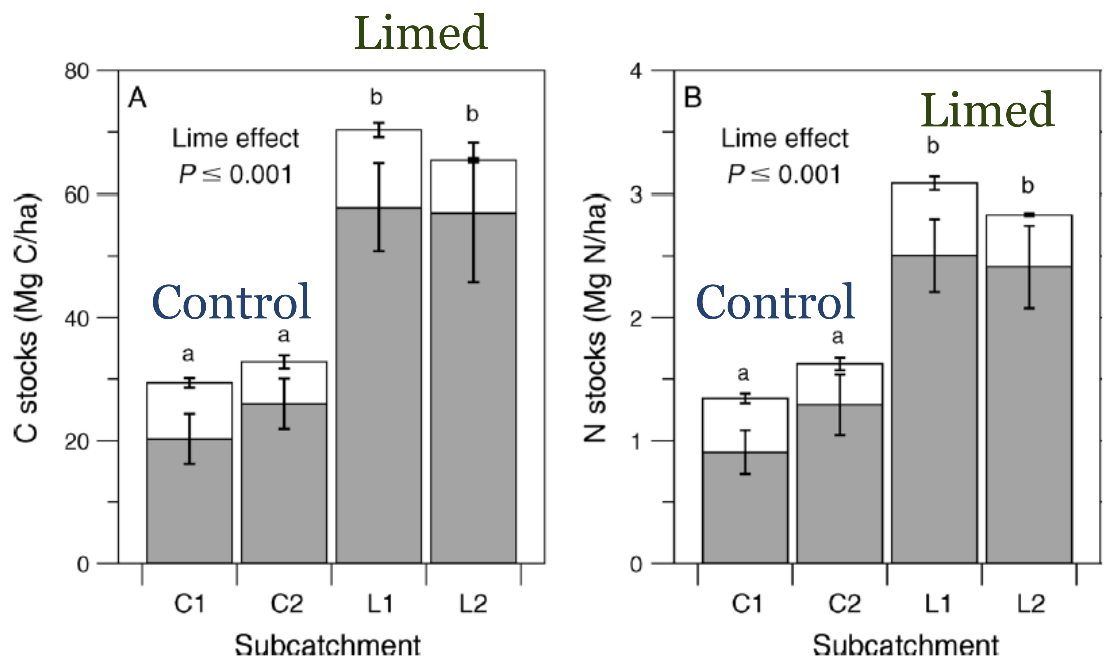
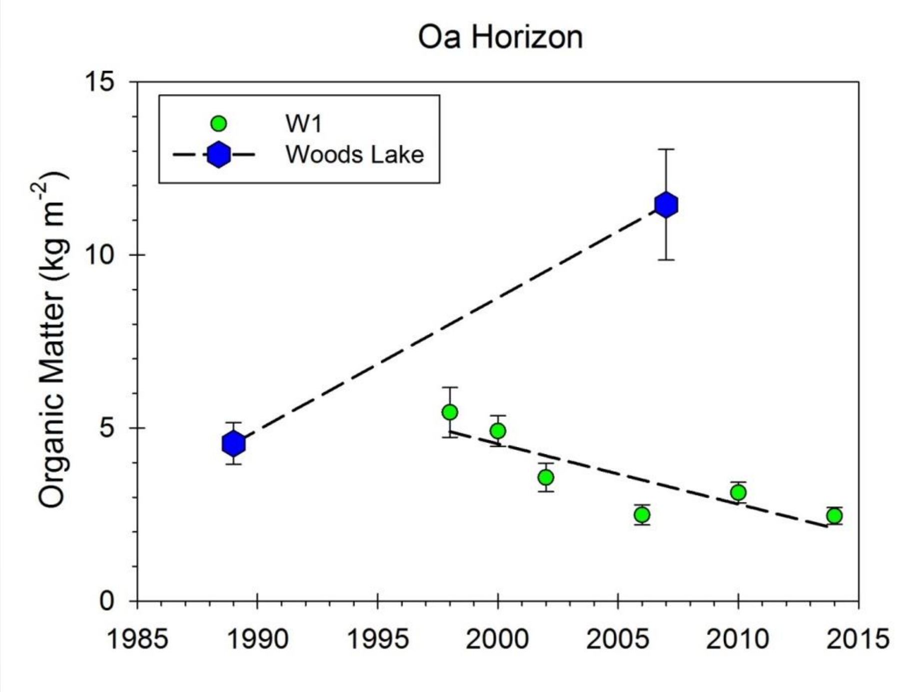
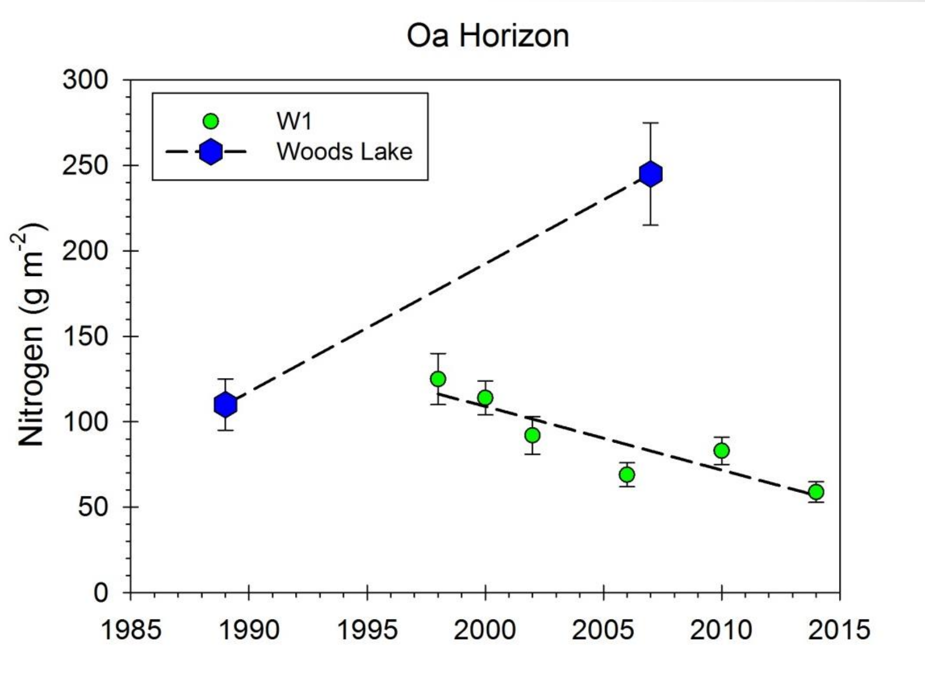


Fig. 2. Cumulative forest floor (A) carbon and (B) nitrogen stocks (mean ± SE) in control (C1 and C2) and limed (L1 and L2) subcatchments. The forest floor Oe horizon is displayed in white, and Oa in gray. Different letters indicate significant differences ($P < 0.05$) among subcatchments, and lime effect indicates the overall response to liming.

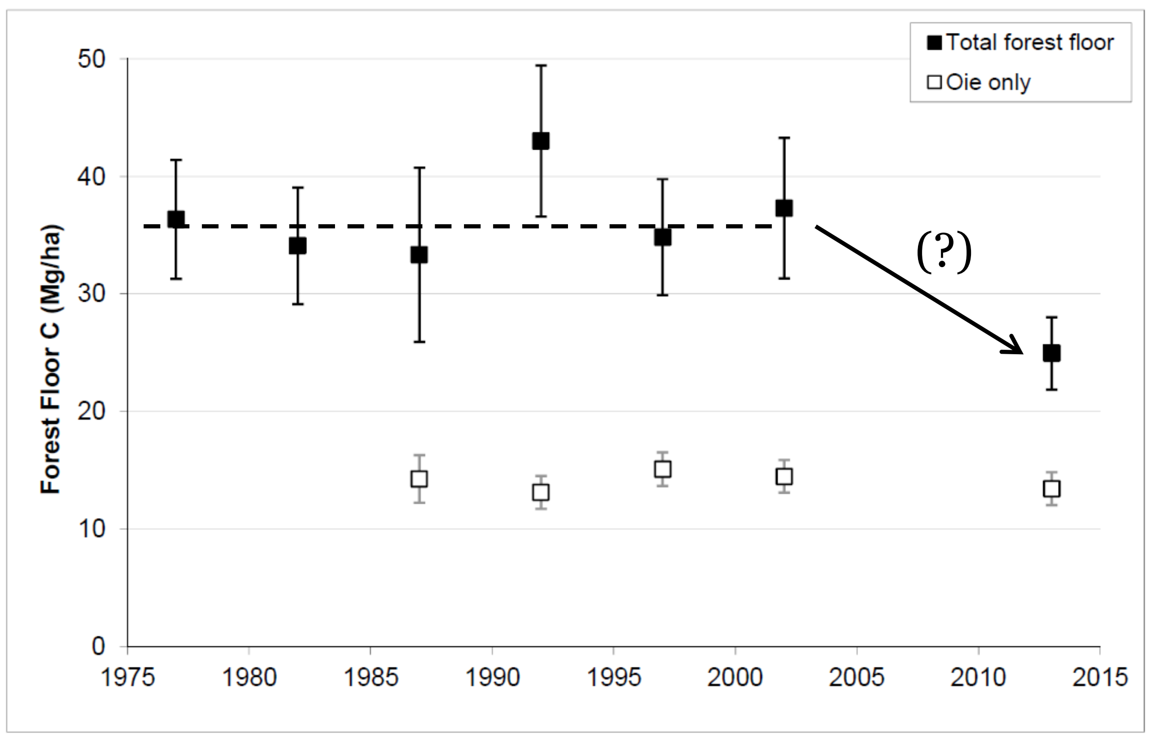
Contrasting Responses to Ca Addition

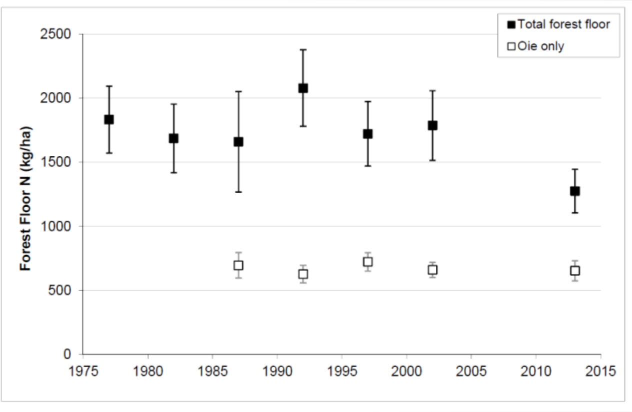


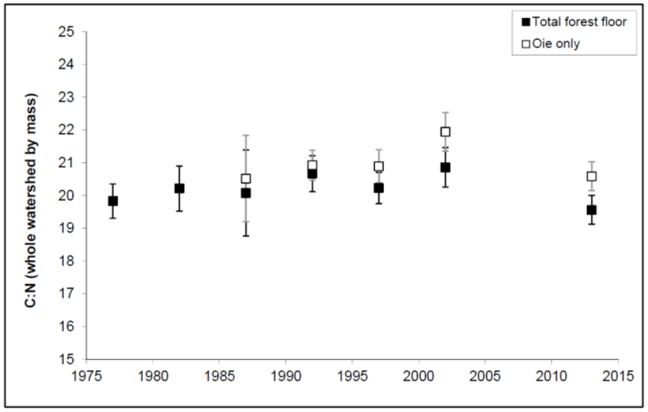


Woods Lake Data: Melvin et al. (2013)

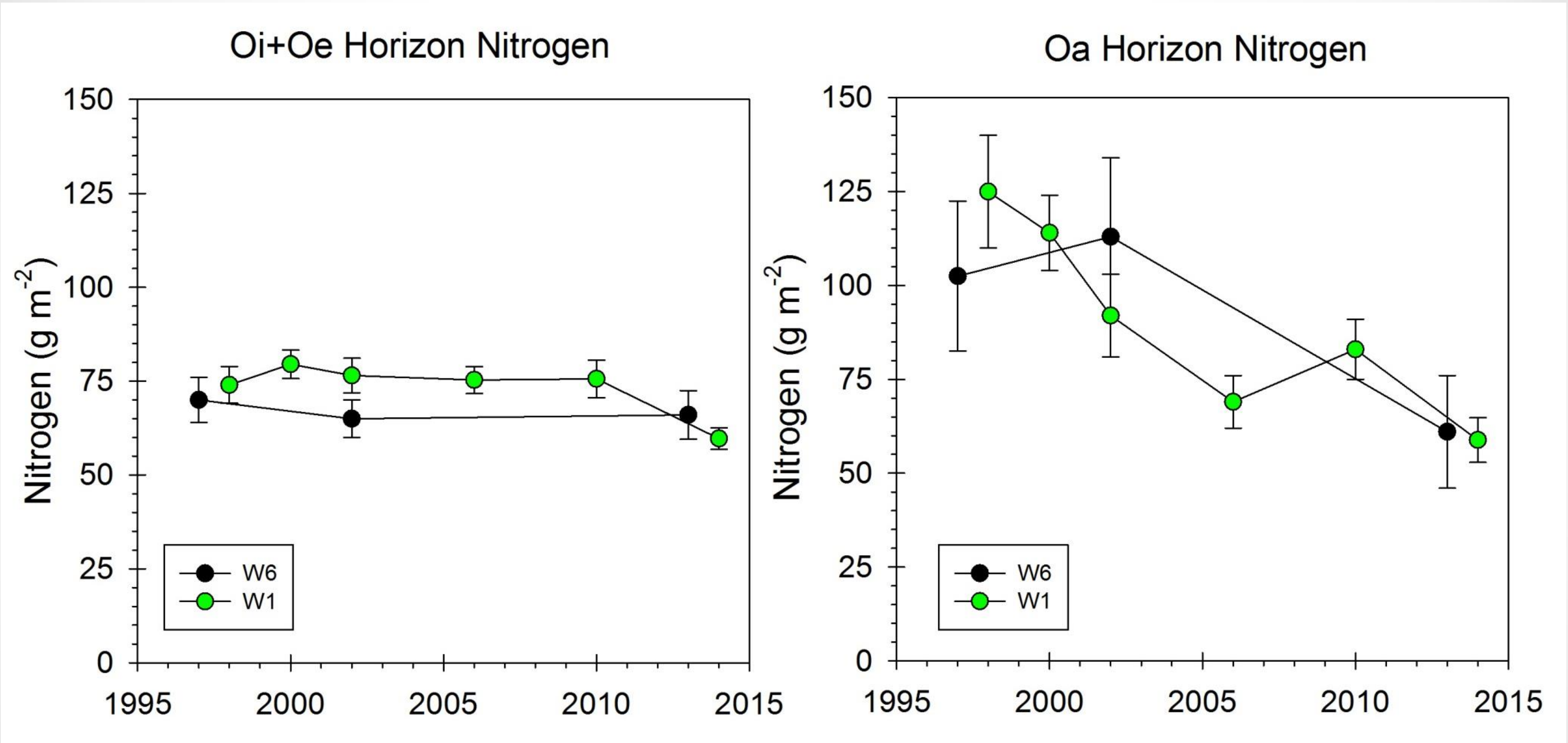
Observed Trends in Forest Floor C and N







Trends in Forest Floor N in W1, W6



W6 Data: Vadeboncoeur, Hamburg (unpublished)

Soil C, N in Recovering Forest Ecosystems

3120 F. OULEHLE *et al.*

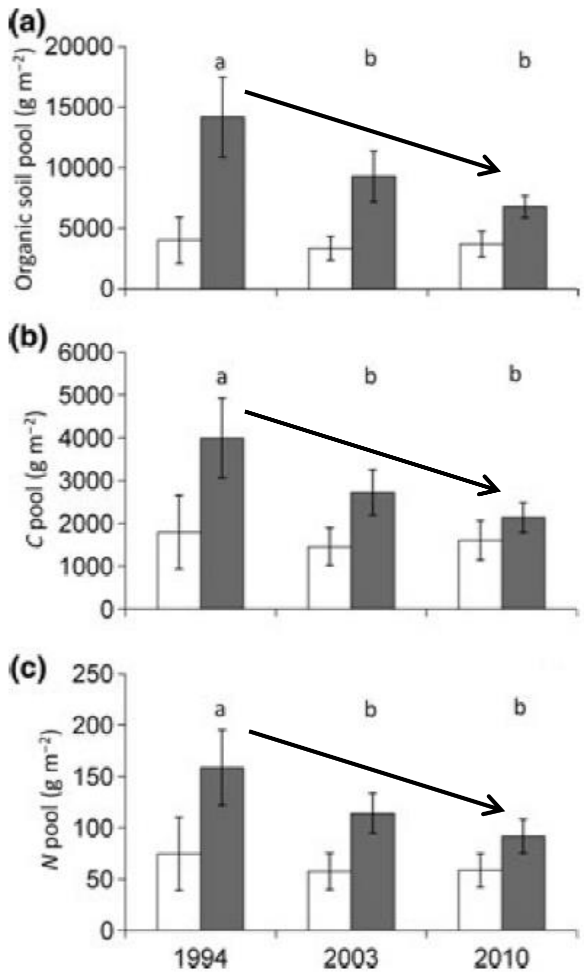


Fig. 4 Temporal change of the organic soil pool (a), carbon pool (b) and nitrogen pool (c) in the Oi + Oe (white) and Oa horizons (grey). Different letters indicate statistically different values ($P < 0.05$) in the Oa horizon. Mean values ± SD.

Global Change Biology

Global Change Biology (2011) **17**, 3115–3129, doi: 10.1111/j.1365-2486.2011.02468.x

Major changes in forest carbon and nitrogen cycling caused by declining sulphur deposition

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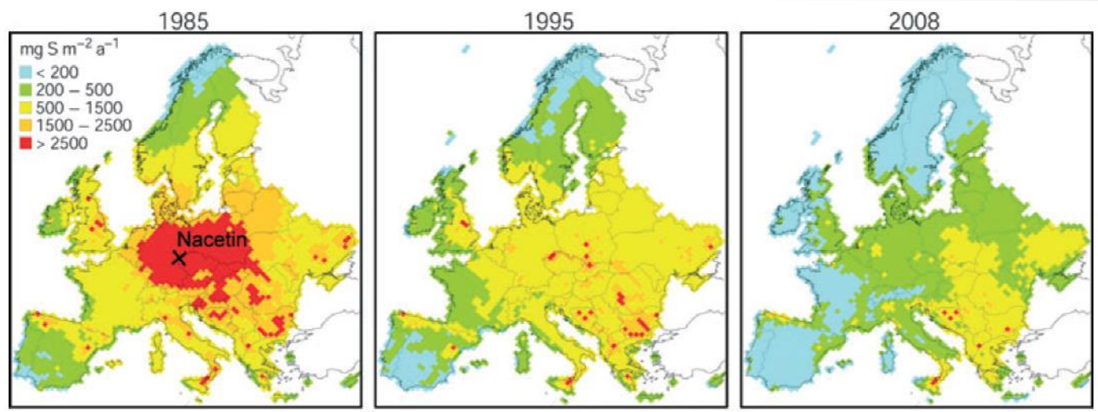
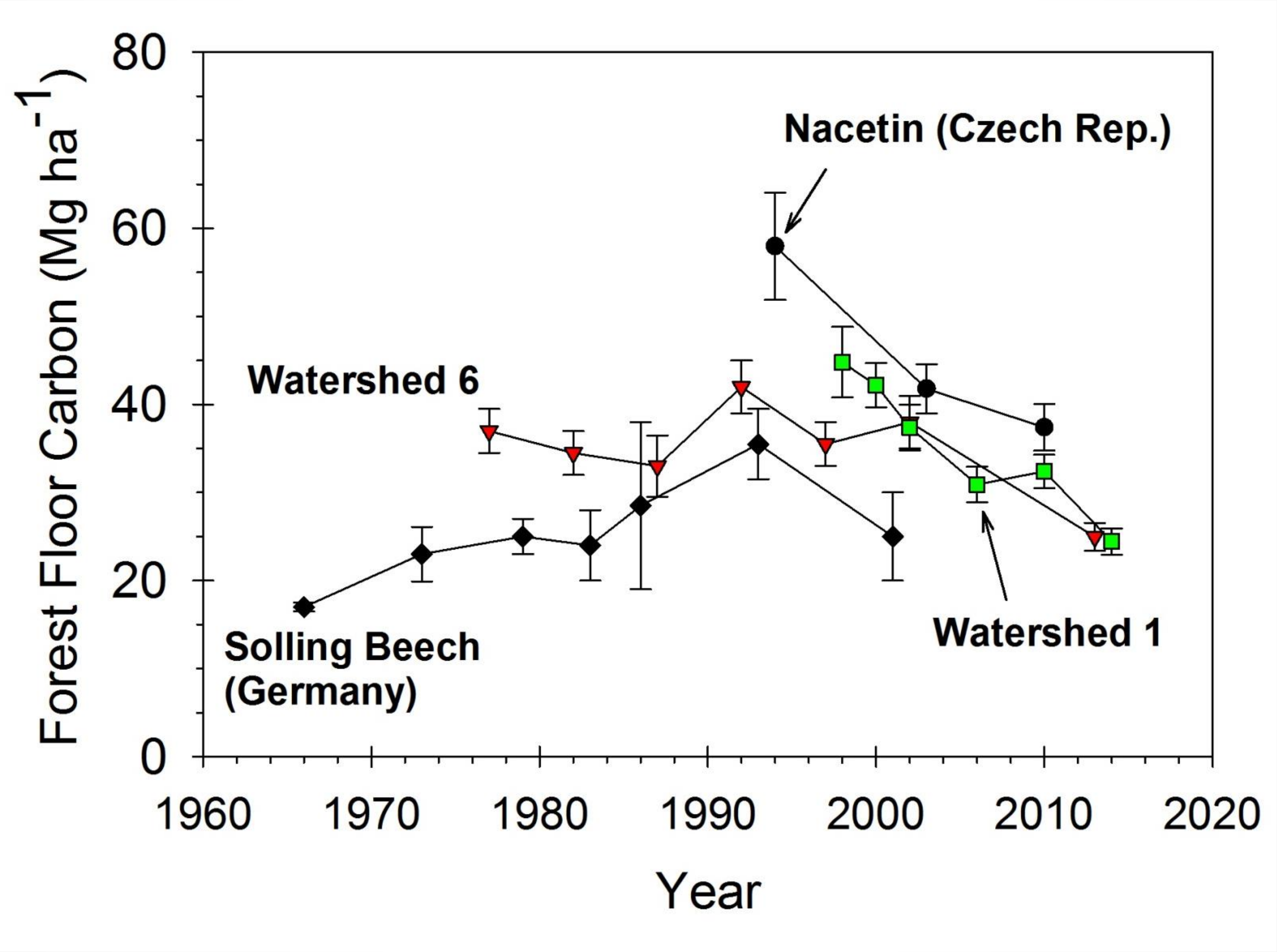


Large decline in SOC during recovery from chronic acidification. As at Hubbard Brook, loss is largely from the Oa horizon (gray bars).

Soil N in Recovering Forest Ecosystems



Conclusions

1. Data from temperate forests recovering from chronic acidification, including Hubbard Brook, suggest that:
   a. Acidification may have resulted in the accumulation of SOM in temperate forests;
   b. Soils may be C (and N) sources during recovery from historic acidification.
2. Calcium addition has resulted in large losses of soil organic matter (and carbon) from the humus layer. This contrasts with a long-term liming study conducted at a similar site.
3. Recovery from acid rain may confound long-term studies of climate change effects (including soil warming studies) on soil C dynamics.