The Heimburger Plots:
7+ Decades of Forest Soil Research in the Adirondack Mountains

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Northeastern Soil Monitoring Cooperative Workshop

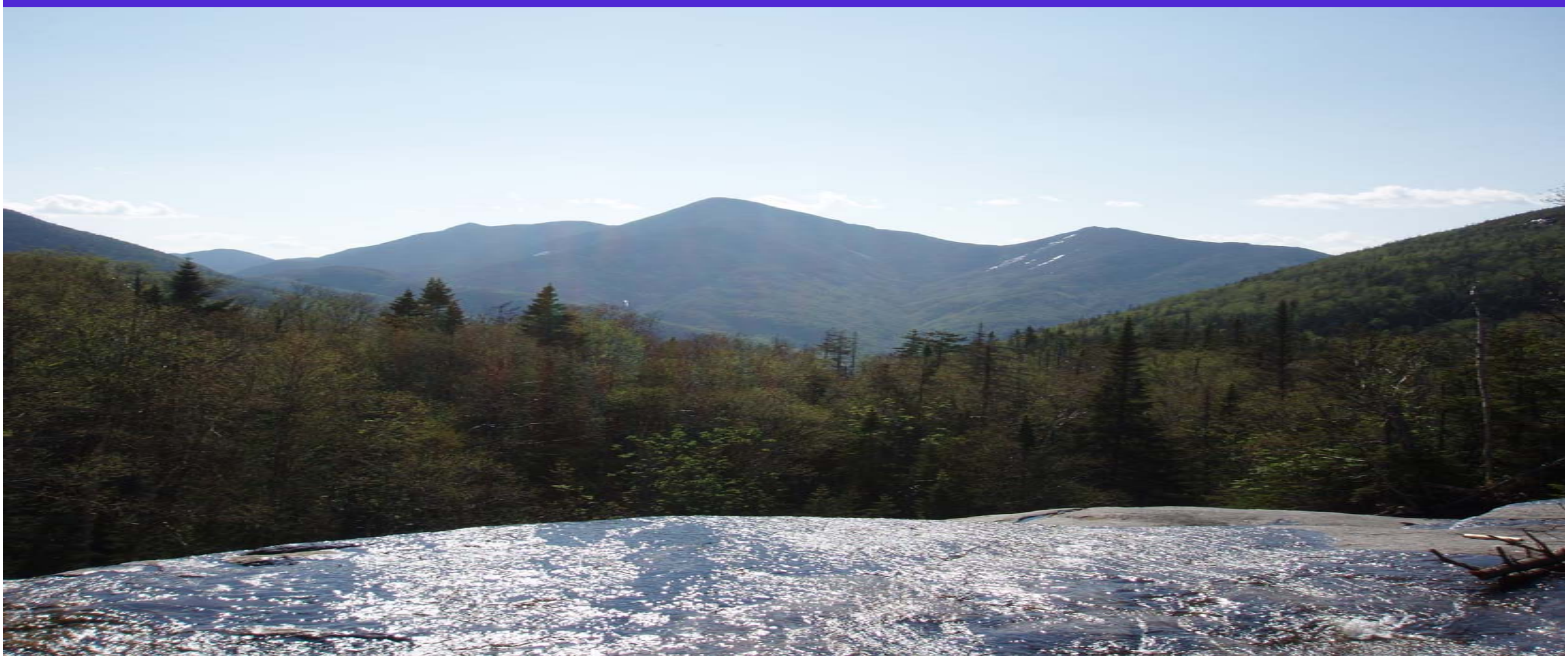
The Heimburger Plots

Where and what they are (and aren't)

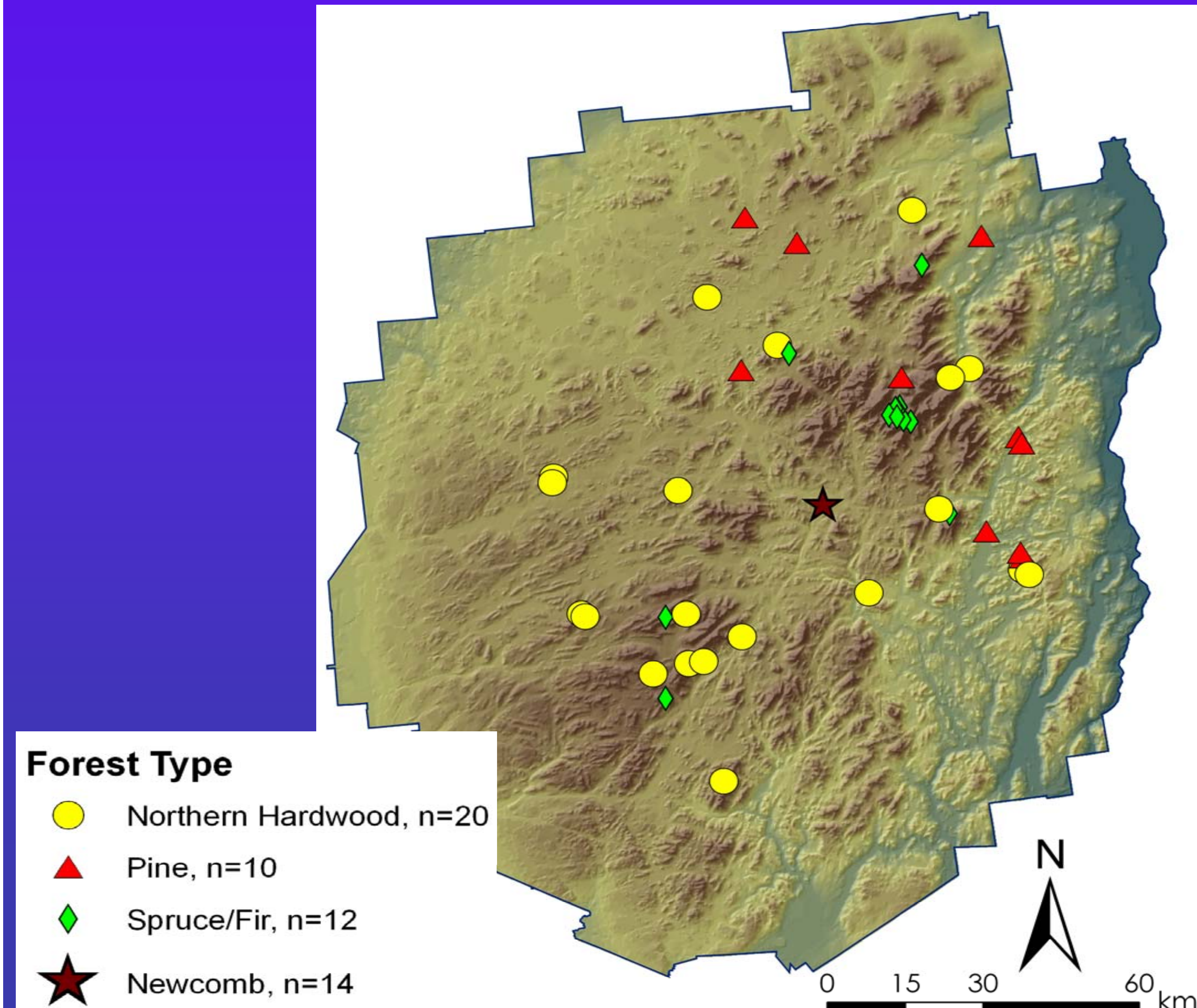
What's been done

What we've learned

Where and what they are (and aren't)



The “Heimburger Plots”



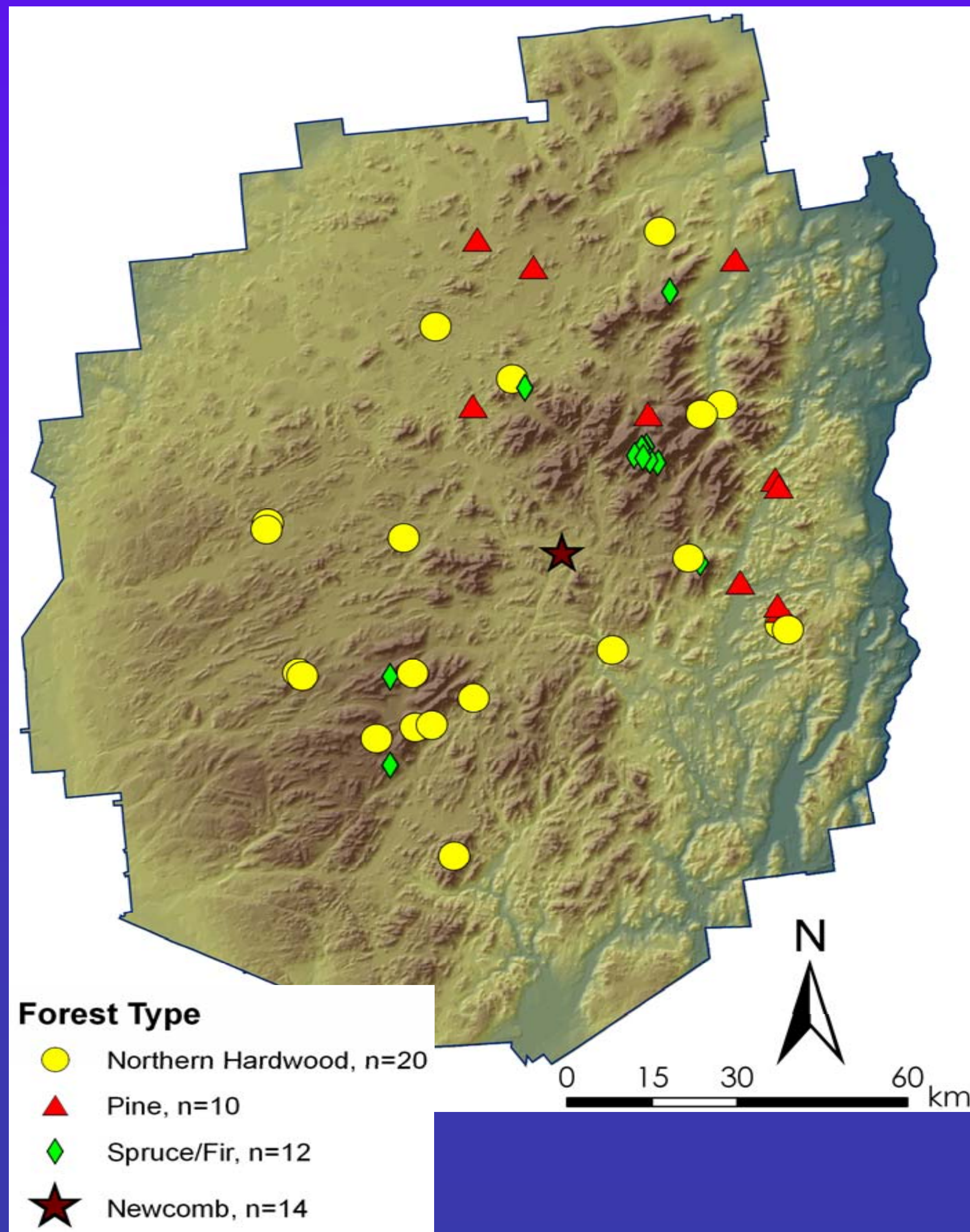
The "Heimburger Plots"

Forest Type Classifications

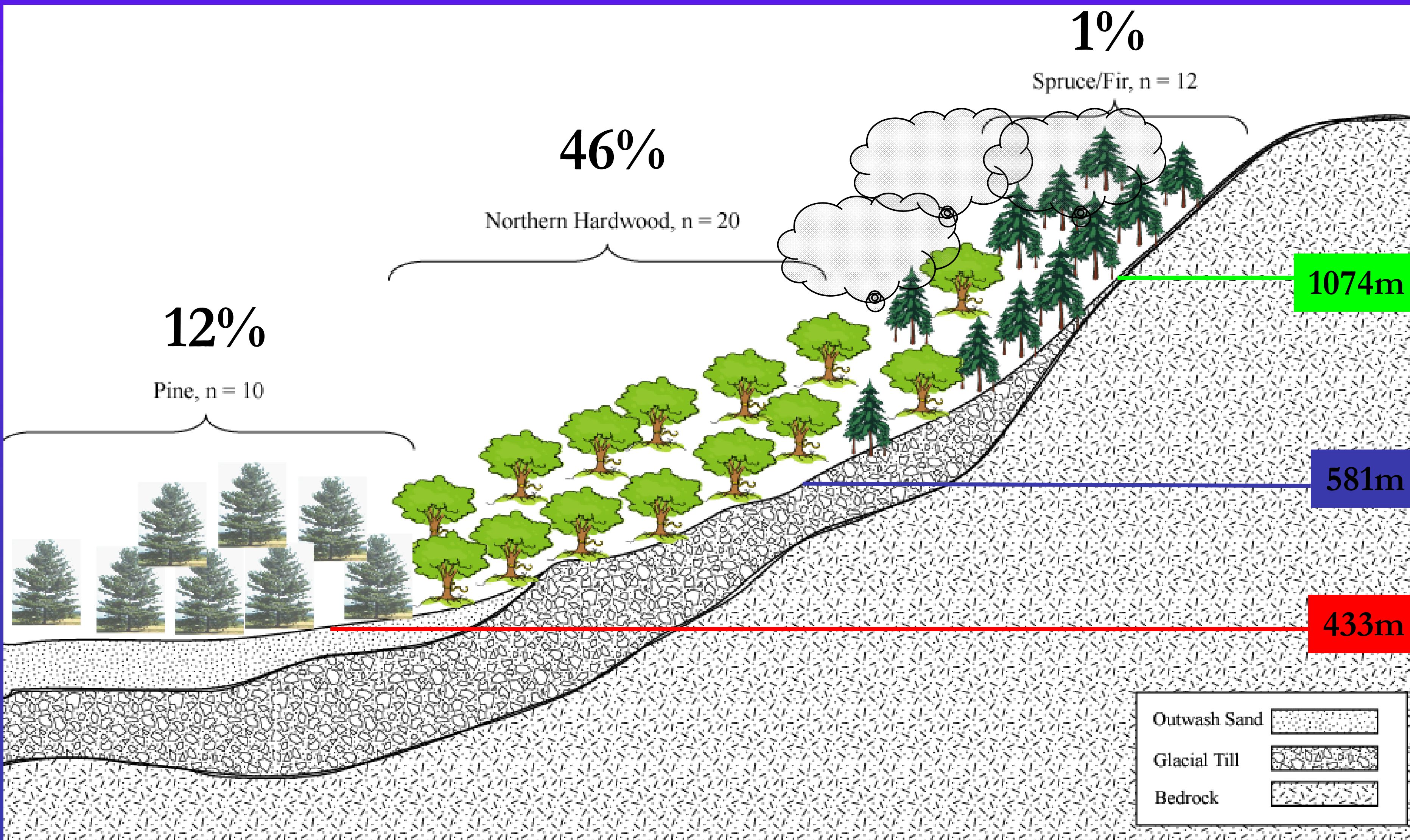
Spruce-Fir (1074 m)
Abies balsamea, Picea rubens, Betula papyrifera,
elevations ≥ 900 m

Northern Hardwood (581m)
Acer saccharum, Betula alleghaniensis, Fagus grandifolia,
elevations <800 m

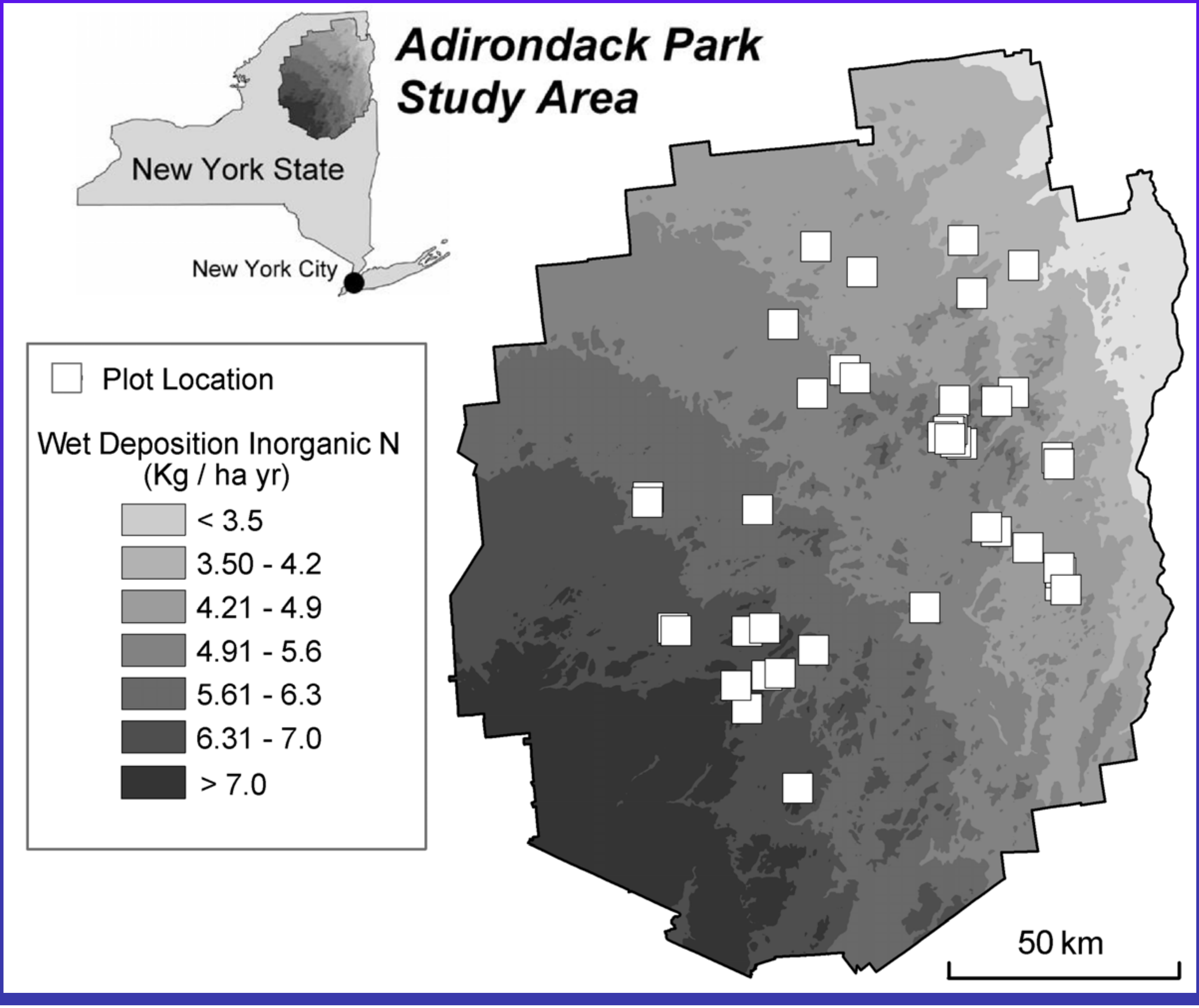
Pine (433 m)
Pinus strobus, Pinus resinosa,
well-drained outwash sands



An Adirondack Catena



The "Heimburger Plots"



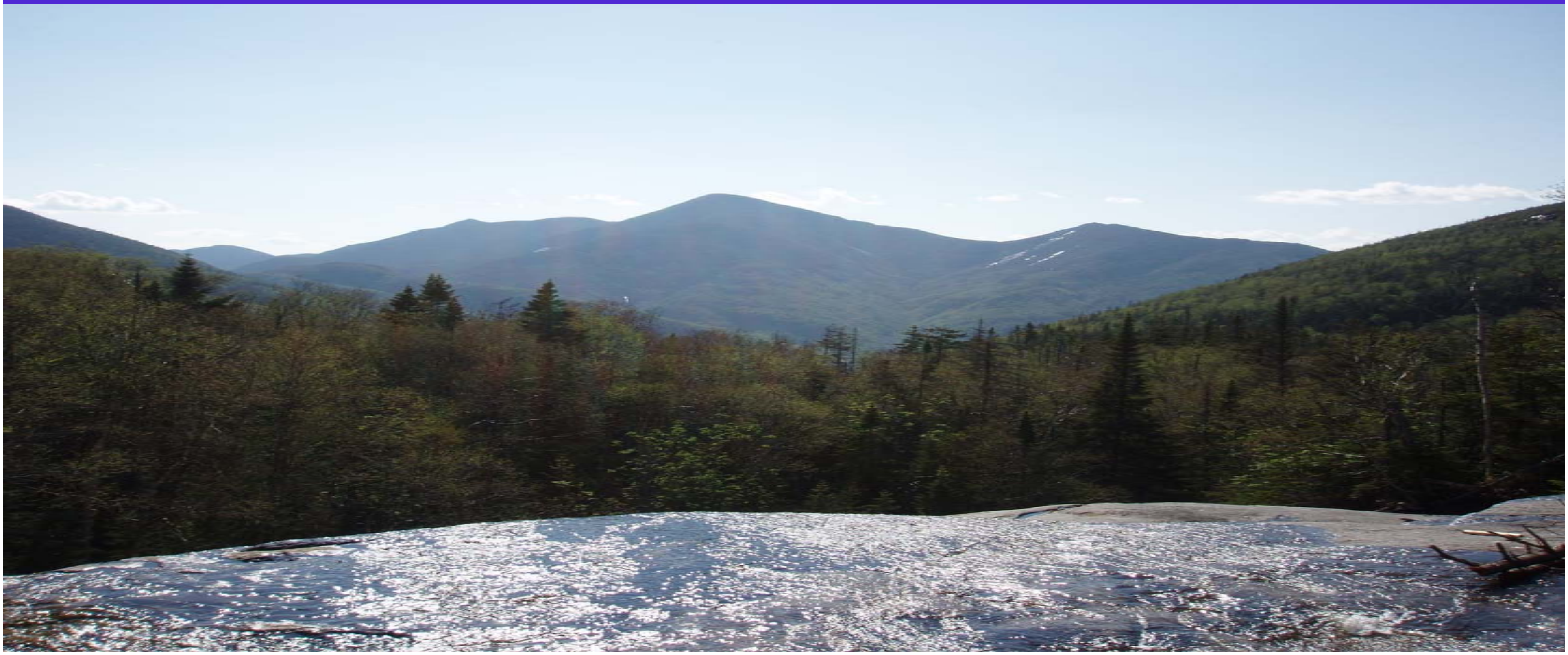
What the Heimburger Plots aren't

Randomly distributed

Managed (with the exception of the Newcomb sites)

Representative of "wet" soils

What's Been Done?



Genesis of a Legacy

1930-1932
Carl C. Heimburger

1984
Sally Andersen

Forest Type Studies in
The Adirondack Region

Long-term changes (1930-32 to 1984)
in the acid-base status of forest soils
in the Adirondacks of New York

Previous Work

1933

Forest Type Studies in the Adirondack Region

A Thesis Presented to the Faculty of the Graduate School of Cornell University for the Degree of DOCTOR OF PHILOSOPHY

By

Carl Constantine Heimburger

June 19, 1933

1988

LONG-TERM CHANGES (1930-32 TO 1984) IN THE ACID-BASE STATUS OF FOREST SOILS IN THE ADIRONDACKS OF NEW YORK

SARAH BEALE ANDERSEN

A DISSERTATION

in

GEOLOGY

Presented to the Faculties of the University of Pennsylvania in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy.

1988

Supervisor of Dissertation

Graduate Group Chairperson

2009

DECADAL-SCALE COMPARISONS OF VEGETATION AND SOIL PROPERTIES IN FORESTS OF THE ADIRONDACK MOUNTAINS, NY

James E. Bedison, Jr.

A DISSERTATION

In

Earth and Environmental Science

Presented to the Faculties of the University of Pennsylvania in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy

2009

Arthur H. Johnson – Supervisor of Dissertation

Arthur H. Johnson – Graduate Group Chairperson

Publication List

Soils

Bedison, J.E. and A.H. Johnson. 2010. 74 years of Ca loss from forest soils of the Adirondack Mountains, NY. Soil Sci. Soc. Am. J. *in press*.

Bedison, J.E., A.H. Johnson., and S.A. Willig. 2010. A comparison of soil organic matter content in 1932, 1984 and 2005/6 in forests of the Adirondack Mountains, NY. Soil Sci. Soc. Am. J. 74:658-662.

Bedison, J.E. and A.H. Johnson. 2009. Controls on the spatial pattern of carbon and nitrogen storage in Adirondack forest soils along a gradient of nitrogen deposition. Soil Sci. Soc. Am. J. 73:2105-2117.

Johnson, A. H., A. Moyer, J. E. Bedison, S. L. Richter, S. A. Willig, and M. Boyer. 2008. Seven decades of calcium depletion in organic horizons of Adirondack forest soils. Soil Sci. Soc. Am. J. 72:1824-1830.

Johnson, A.H., S.B. Andersen, and T.G. Siccama. 1994. Acid rain and soils of the Adirondacks I. Changes in pH and available calcium, 1930-1984. Can. J. For. Res. 24:39-45.

Ecology

Bedison, J.E. and B.E. McNeil. 2009. Is the growth of temperate forest trees enhanced along a nitrogen deposition gradient? Ecology 90:1736-1742.

Bedison, J.E., A.H. Johnson, S.A. Willig, S.L. Richter, and A. Moyer. 2007. Two decades of change in vegetation in Adirondack spruce-fir, northern hardwood and pine-dominated forests. J. Torrey Bot. Soc. 134: 238-252.

Soil Sampling

Quan
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0-10
10-20
20+

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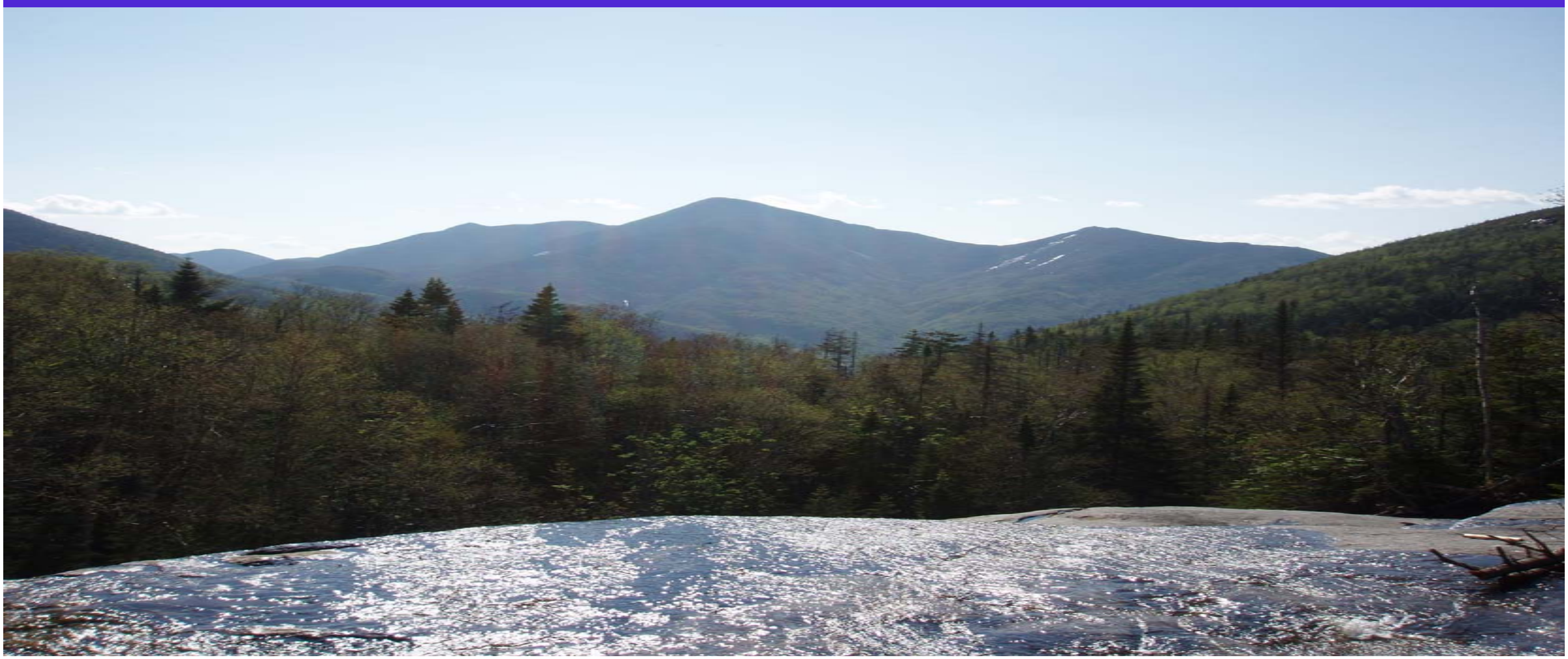
What we've learned

i. Soil Ca

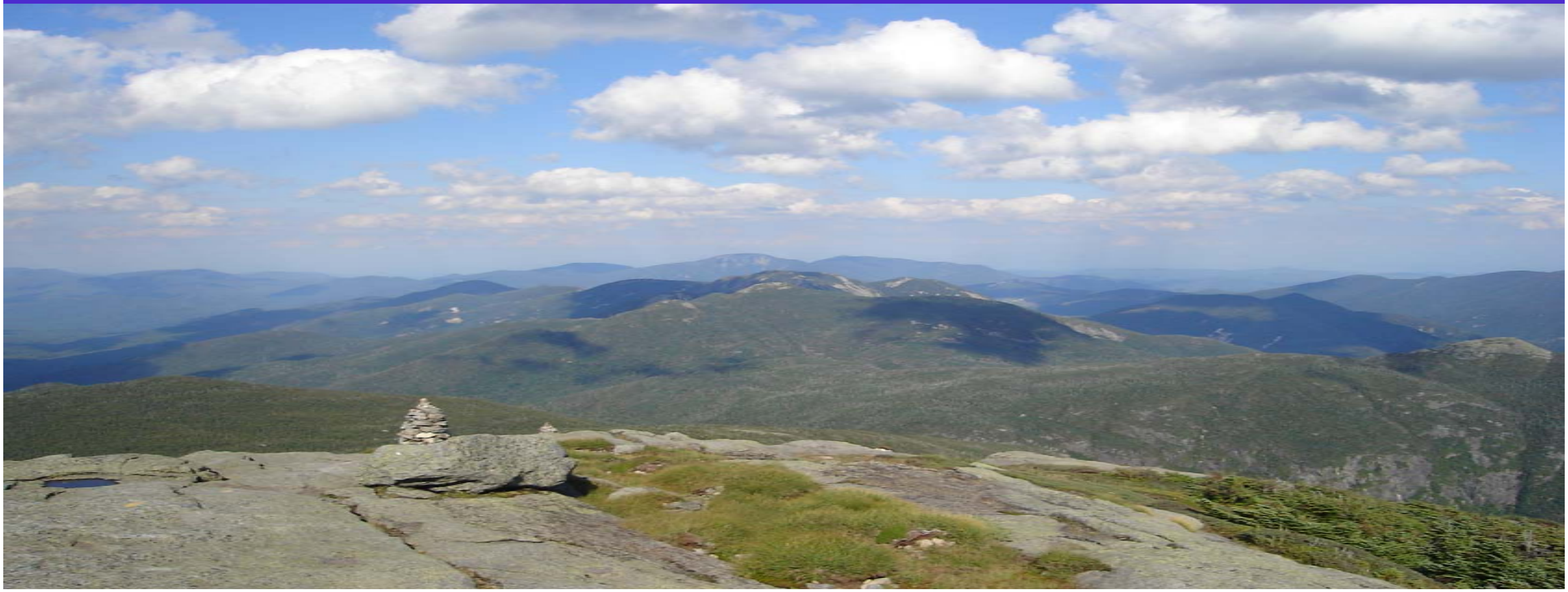
ii. Soil N

iii. SOM/C



Soil Ca

Has the loss of Ca from the soil continued since 1984, or have soil Ca pools stabilized or even increased since 1984 in light of reductions in acidic deposition over the past few decades in forests of the Adirondack Mountains?



Soil Ca content change

				Percentile		
Horizon	*n*	Year	Mean	25	Median	75
			kg Ca ha^{-1}			
Total Organic†	51	1932 a	993.5	427.6	763.6	1402.6
		1984 b	431.8	136.2	238.7	473.1
		2005/6 c	209.6	84.5	163.3	292.3
0-10 cm	54	1932 a	409.8	110.3	324.6	574.3
		1984 **b**	267.9	38.0	79.2	326.9
		2005/6 b	175.6	46.9	107.7	233.8
10-20 cm	54	1932 a	310.1	34.8	166.5	486.0
		1984 a	289.5	49.8	116.0	314.5
		2005/6 b	144.9	30.4	70.3	212.5
Whole-Profile‡	54	1932 a	1948.2	1200.2	1575.8	2490.7
		1984 b	1450.9	497.1	865.8	1499.9
		2005/6 c	891.9	265.7	571.1	1226.8

†Total organic = Oe + Oa

‡Whole-profile = total organic + total mineral

20+ cm mineral soil Ca content change

(or lack thereof)

				Percentile		
Horizon	*n*	Year	Mean	25	Median	75
			kg Ca ha^{-1}			
20+ cm	54	1932 a	301.7	0.0	62.4	372.7
		1984 a	485.7	21.6	175.7	657.0
		2005/6 a	373.4	15.4	151.2	447.5

†Total organic = Oe + Oa

‡Whole-profile = total organic + total mineral

Mineral soil Ca concentration

Horizon	Units	Year	Mean	Percentile: 25	Percentile: Median	Percentile: 75
0-20 cm	$cmol_c\ kg^{-1} OM$	1932 a	47.9	3.9	26.7	56.2
		1984 b	19.4	3.7	9.3	24.0
		2005/6 c	10.1	3.5	8.1	13.4
	$cmol_c\ kg^{-1} soil$	1932 a	2.6	0.8	1.5	3.6
		1984 a	2.1	0.4	0.9	2.5
		2005/6 b	1.4	0.3	0.9	1.8
20+ cm	$cmol_c\ kg^{-1} OM$	1932 a	27.1	0.0	7.1	36.2
		1984 a	32.8	3.4	14.6	45.2
		2005/6 a	21.8	1.4	11.0	34.7
	$cmol_c\ kg^{-1} soil$	1932 a	1.6	0.0	1.1	2.6
		1984 a	2.3	0.3	1.4	2.7
		2005/6 a	1.6	0.2	0.9	2.5

Soil Ca

Conclusions

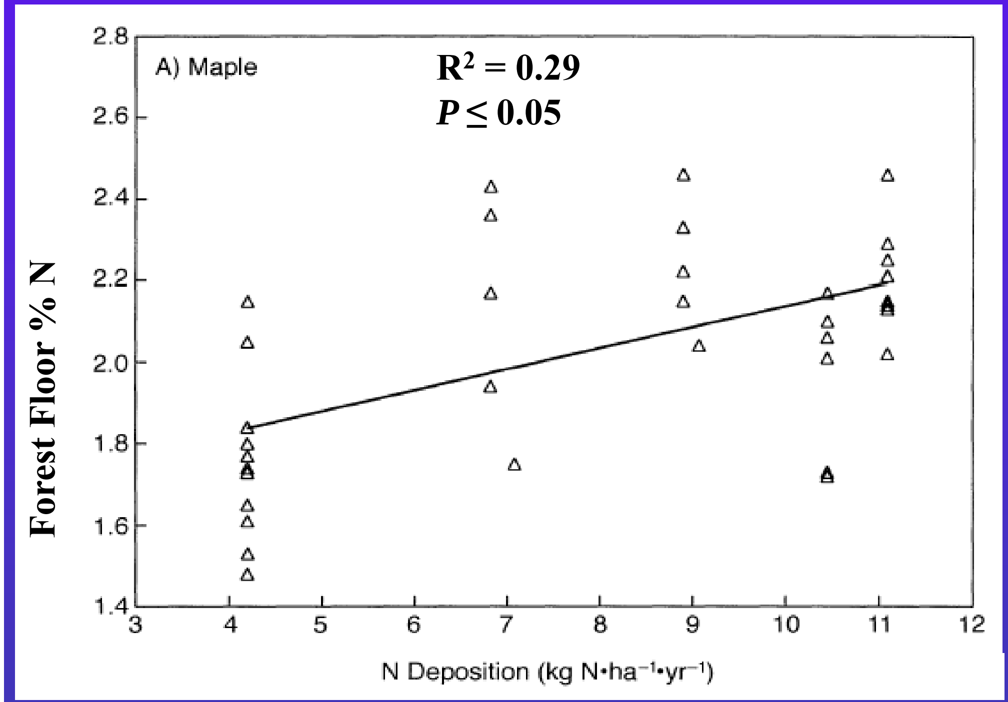
1. Ca decreased in organic and upper-mineral horizons during the 74-year interval (1932 to 2005/6) and has continued since 1984

2. Changes have been primarily confined to the upper horizons and have changed little below 20 cm

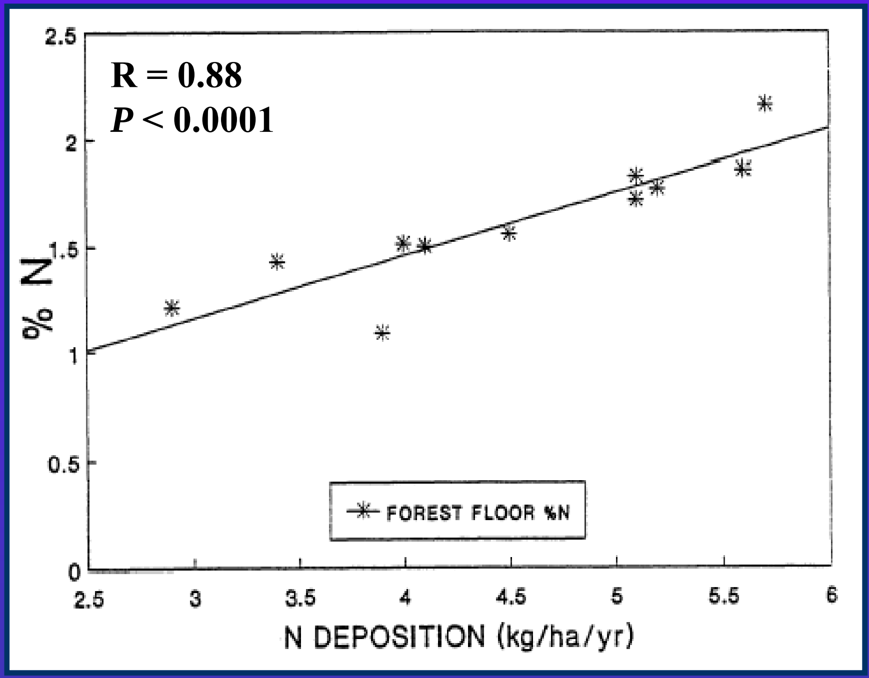
Soil N

Is there a measurable influence of N deposition on soil N pools?

Soil N



Modified from, Lovett and Rueth, 1999

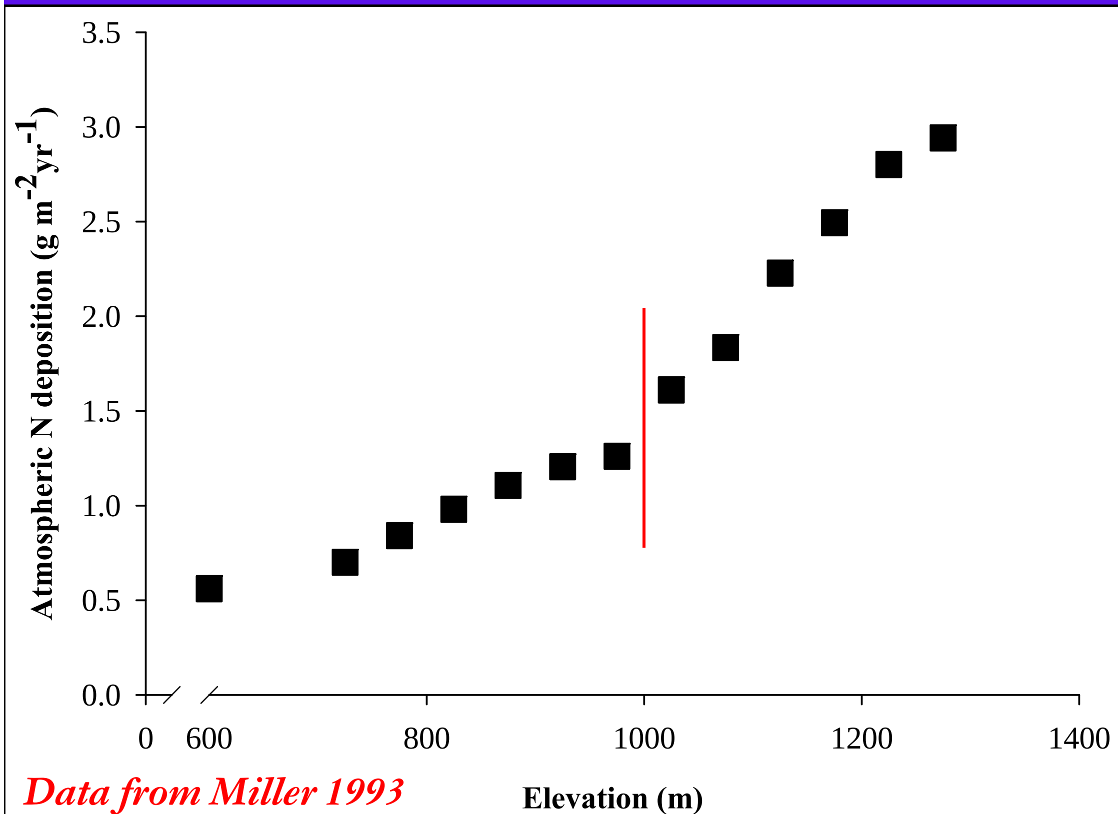


Modified from, McNulty et al., 1991

Range = 4-11 kg $ha^{-1}yr^{-1}$

Range = 3-5.5 kg $ha^{-1}yr^{-1}$

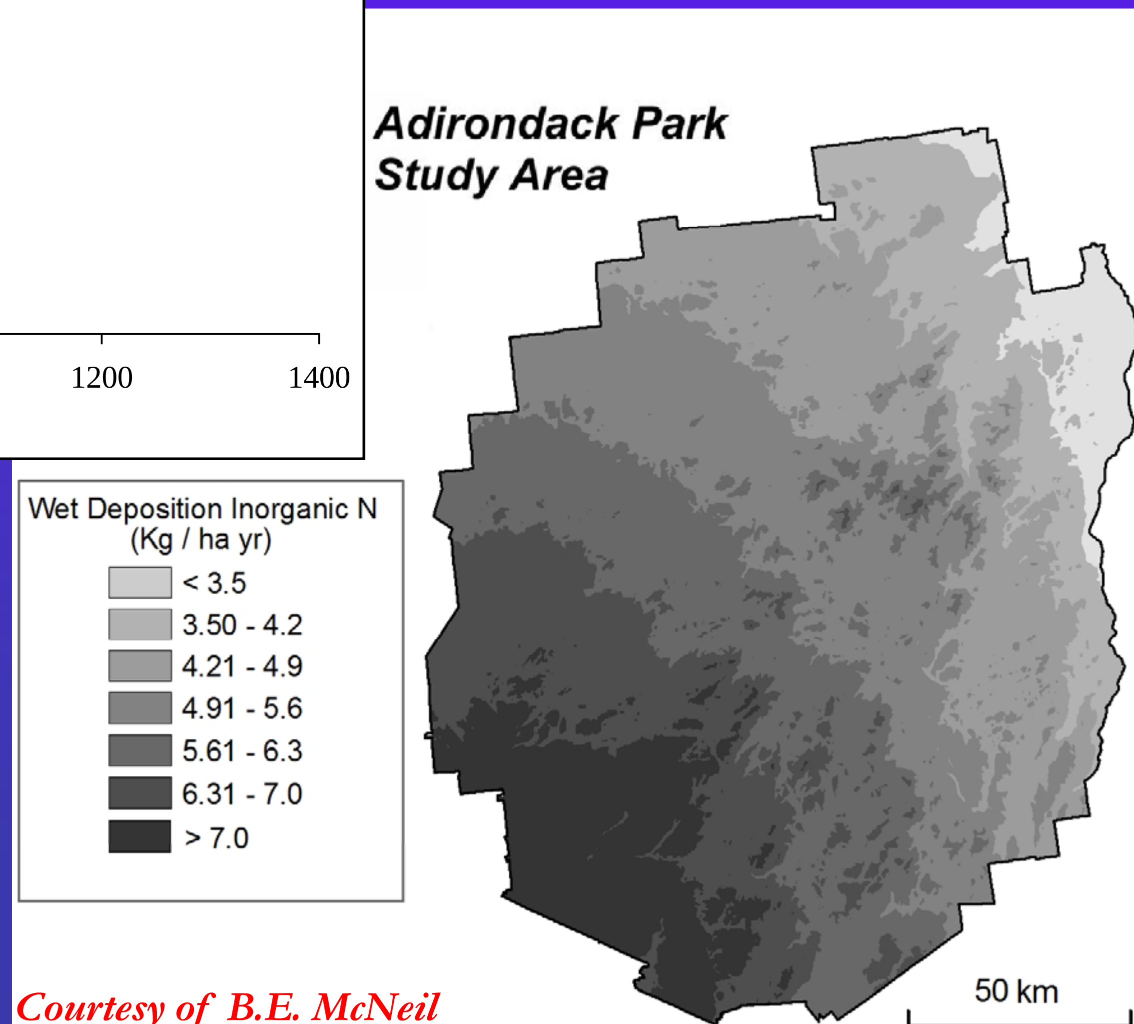
N deposition



Data from Miller 1993

Elevation Gradient

West-to-East Gradient



Courtesy of B.E. McNeil

Soil N

Total N dep estimates

McNeil et al., 2007 wet N dep

Miller, 1993 scaling factor

→ Total N deposition estimates

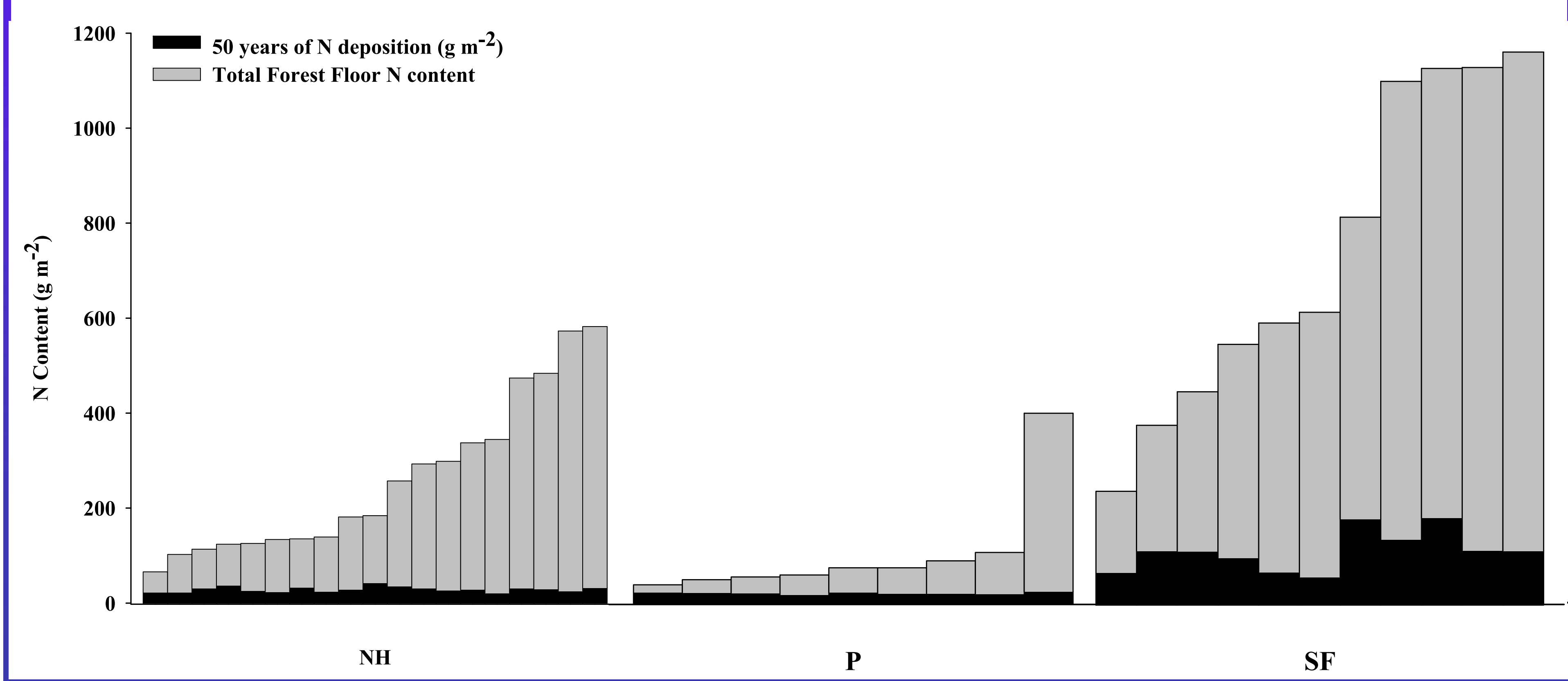
N deposition rates = 3.8 to 31 kg N $ha^{-1}y^{-1}$

Over 50 years:

190 to 1550 kg N ha^{-1} (mean = 460 kg N ha^{-1})

Soil N

Not enough N in deposition to have a measurable influence on soil N pools



Soil N

Multivariate Regression Tree analysis

Soil Stratum	GSDD†	MAP‡	N deposition	% silt + clay	Conifer Importance	Total§
	Variable					
	% SS¶ explained					
Organic N Content	58	–	9	–	2	69
Mineral N Content	50	8	–	6	–	64

† Growing season degree-days
‡ Mean annual precipitation
§ Represents the total sums of squares explained for each tree
¶ Sums of squares

Soil N

Conclusions

1. Growing Season Degree-Days (GSDD), appears to be the dominant influence on forest soil N storage

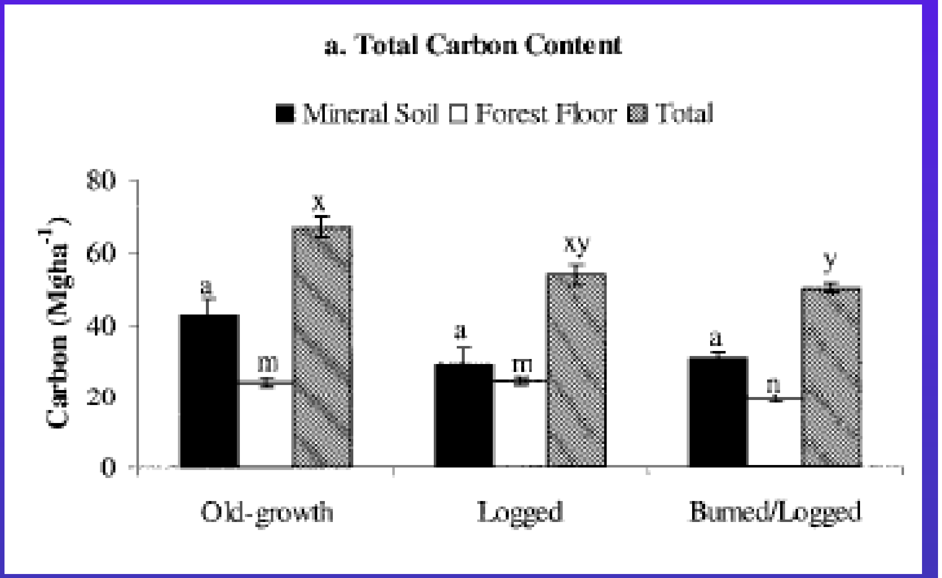
2. The contribution of atmospheric N deposition to soil N pools is small

*Even in organic horizons of SF soils where N dep rates are the highest (~30 kg N $ha^{-1}yr^{-1}$)

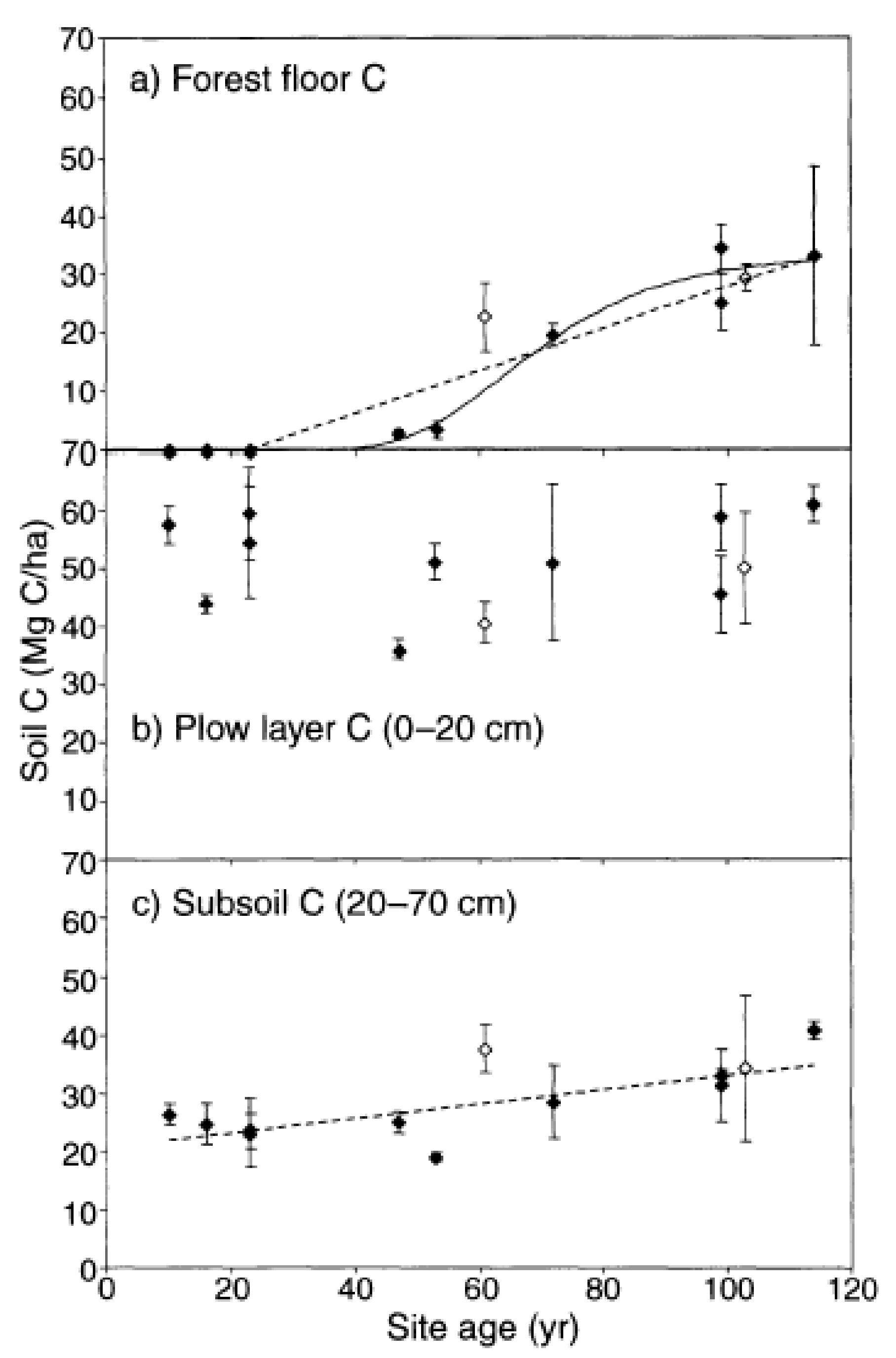
SOM/C

Is there evidence for an increase in SOM content between 1932 and 2006?

Soil organic matter/carbon change over time



Latty et al. 2004



Hooker and Compton 2003

Soil Organic Matter Content (Mg/ha)

Horizon	1932		1984		2005/6	
Oe†	27.1	**a**	37.9	**a**	22.2	**b**
Oa‡	71.5	**a**	70.1	**a**	63.8	**a**
Total Organic‡	105.7	**a**	113.5	**a**	88.3	**b**
0-10 cm†	60.0	**b**	73.6	**a**	70.1	**ab**
10-20 cm†	58.1	**b**	80.6	**a**	67.6	**ab**
20+ cm†	34.0	**a**	61.6	**a**	68.5	**a**
Total Mineral§	170.0	**b**	216.9	**a**	218.1	**a**
Whole-Profile†	322.7	**a**	374.3	**a**	321.8	**a**

†Wilcoxon signed-ranks test on untransformed data

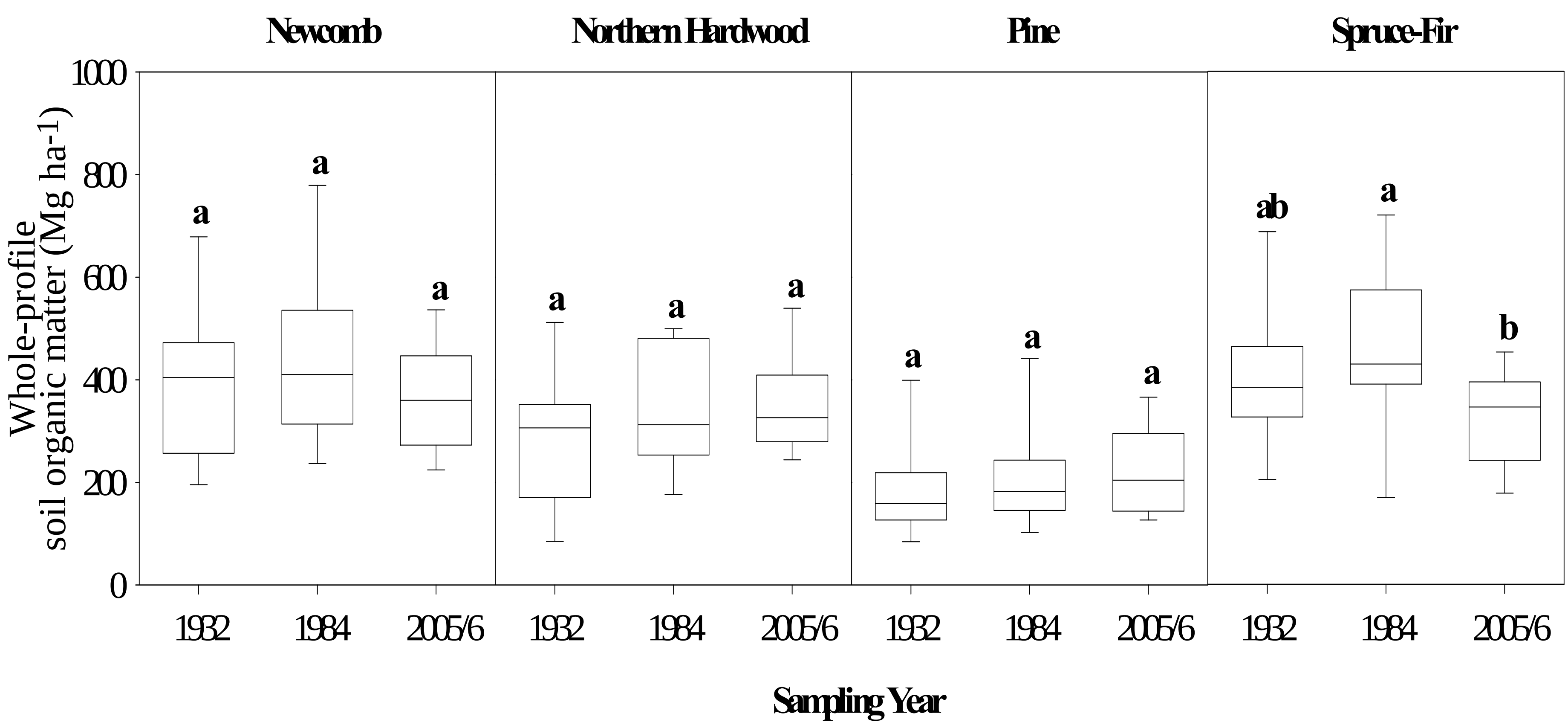
‡*t*-test on log transformed data

§*t*-test on untrasformed data

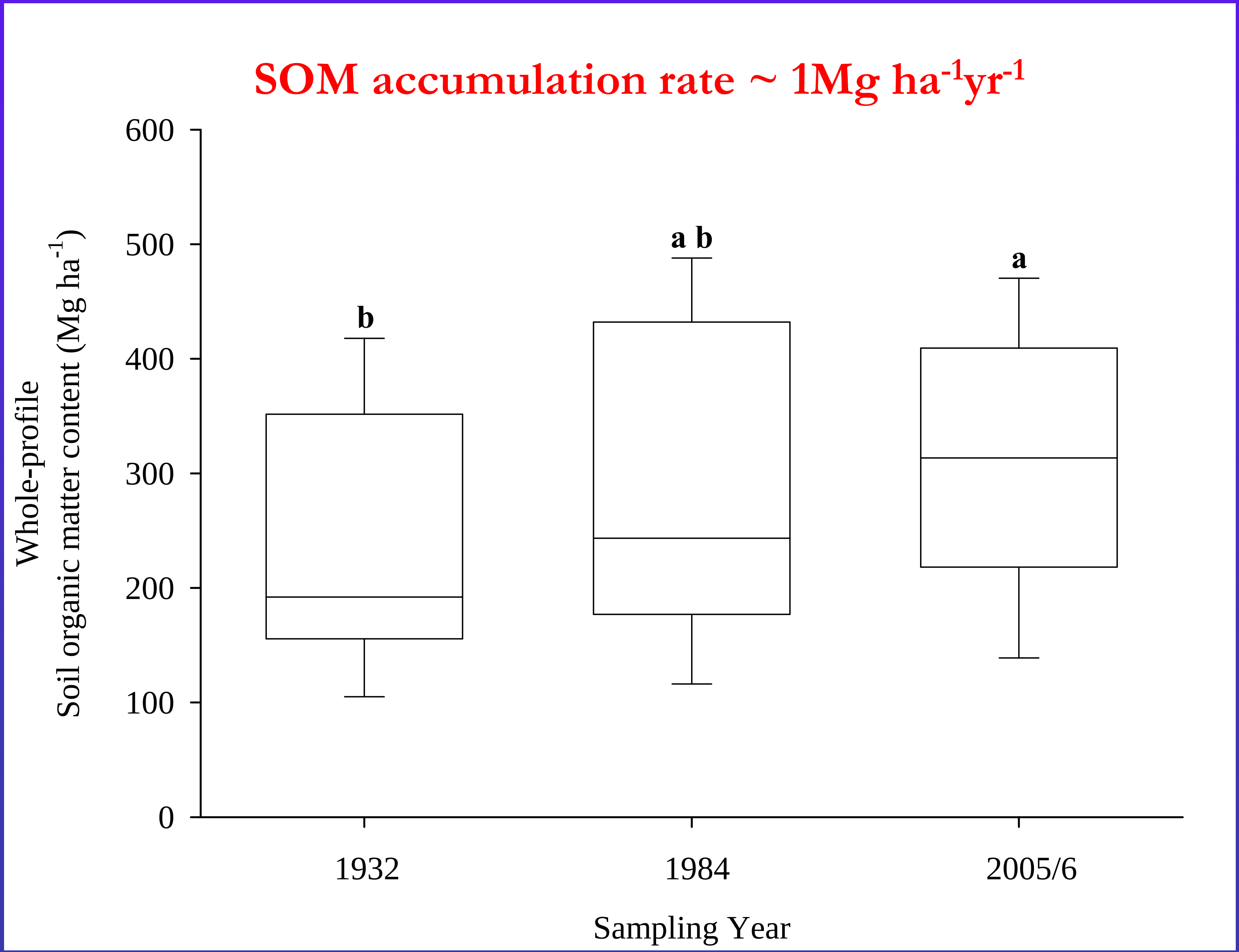
Little evidence of change over time

SOM/C

Changes by Forest type



Sites with an agricultural or fire history
n = 16



SOM/C

Conclusions

1. Measurements of the SOM content in Adirondack forest soils over 7 decades suggested that overall, the soils of this region had not been a large sink for C during the 20th century.

2. There was, however, evidence of a trend toward increased whole-profile SOM content between 1932 and 2005/6 in plots with an agricultural and/or fire history
   *The rates of C increase were similar to rates determined for similar conditions in other forests in New England.

Conclusions– overall

Soil Ca

Has continued to decrease in organic and upper mineral horizons, but not deeper in the profile

Soil N

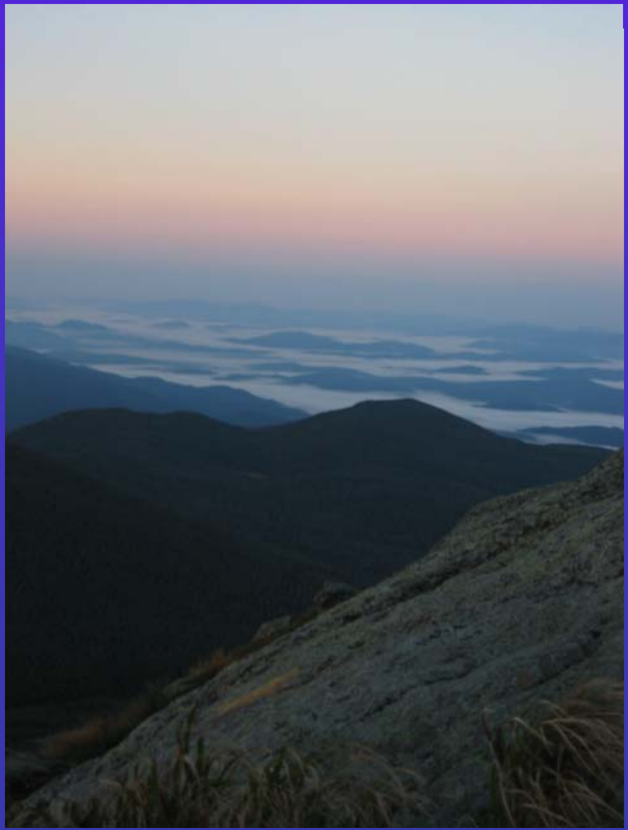
Despite the strong gradient of N deposition and large amount of N deposited over the past ~50 yrs, the influence of N deposition on soil N pools is small

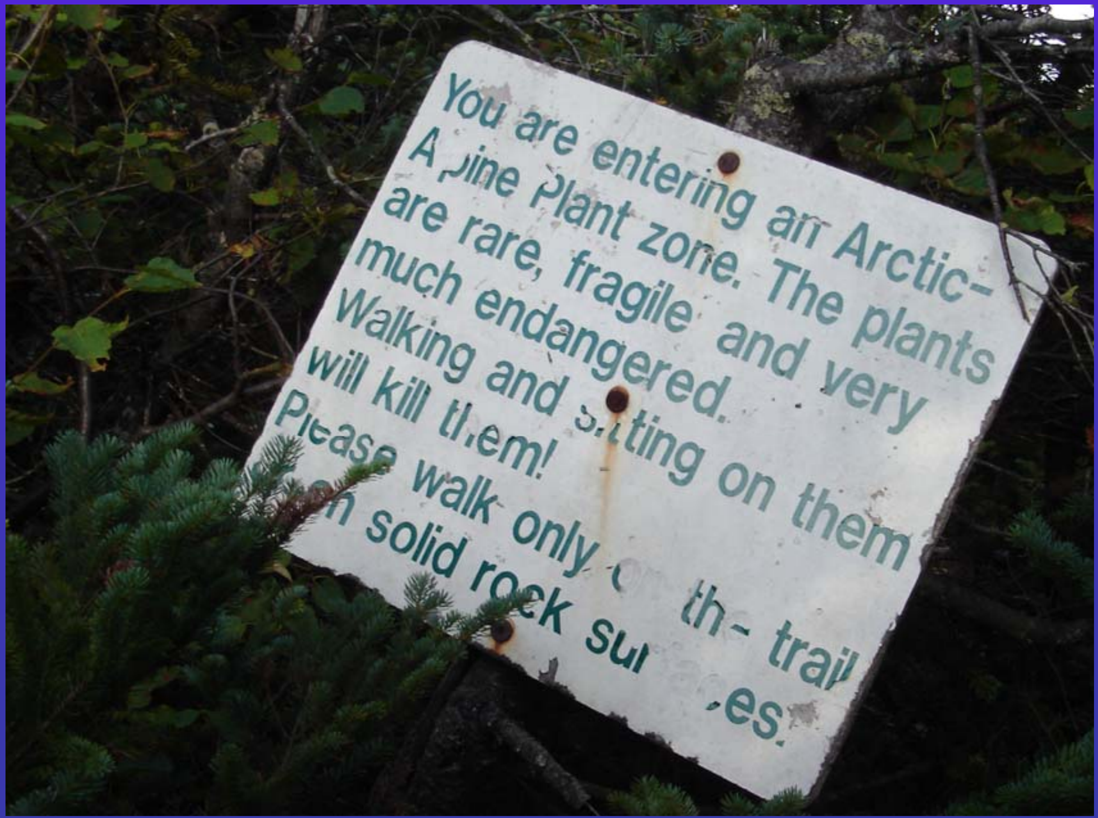
SOM/soil C

Overall, there has been little change since the early 1930's. However, in plots with evidence of past ag./fire, SOM has increased over time

Relevant Lessons

- sampling methodology– keep it consistent
- sample amount– you can never have too much
- start an archive– know what you have and keep it organized





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Marty Dranoff
Paul Battone
David Vann

Help
Gomaa Omar
Joan Buccilli
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E&ES Faculty

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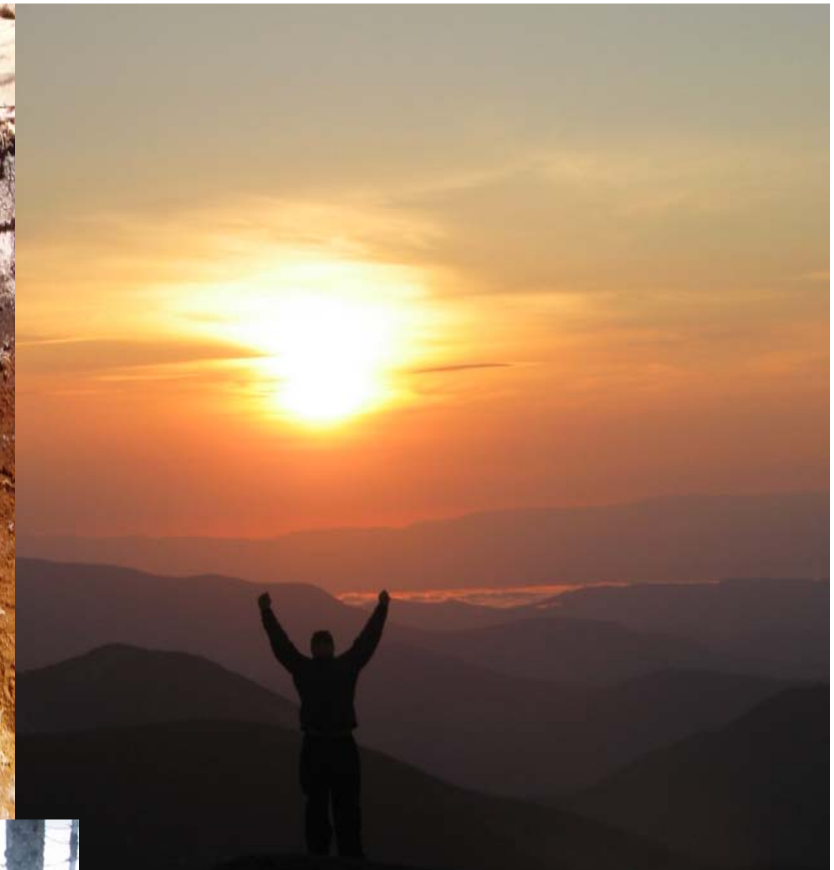


Mineral soil Ca concentration

Horizon	Units	Year	Mean	Percentile 25	Percentile Median	Percentile 75
0-20 cm	$cmol_c\ kg^{-1}OM$	1932 a	47.9	3.9	26.7	56.2
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		2005/6 c	10.1	3.5	8.1	13.4
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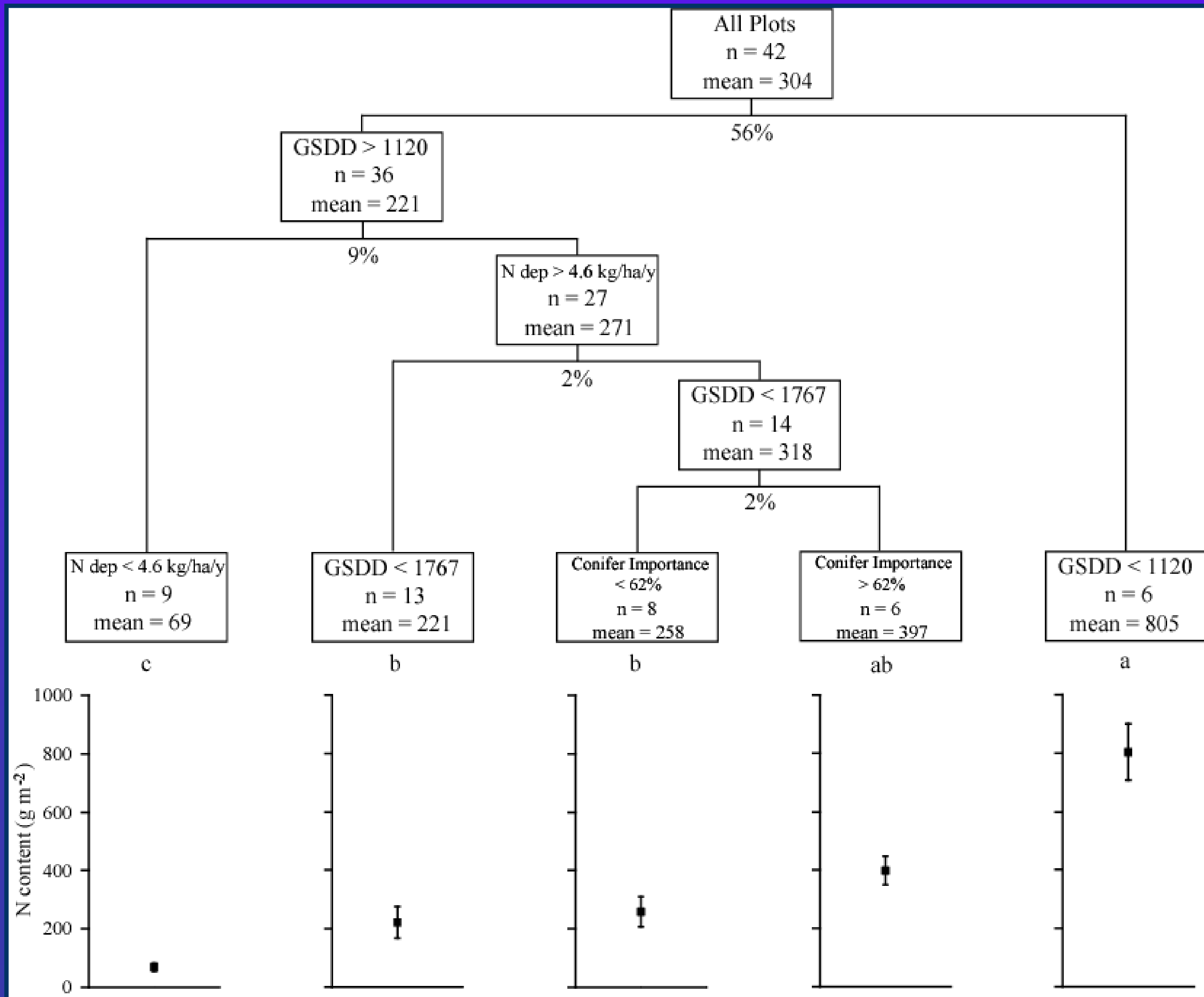
		1984 a	2.3	0.3	1.4	2.7
		2005/6 a	1.6	0.2	0.9	2.5

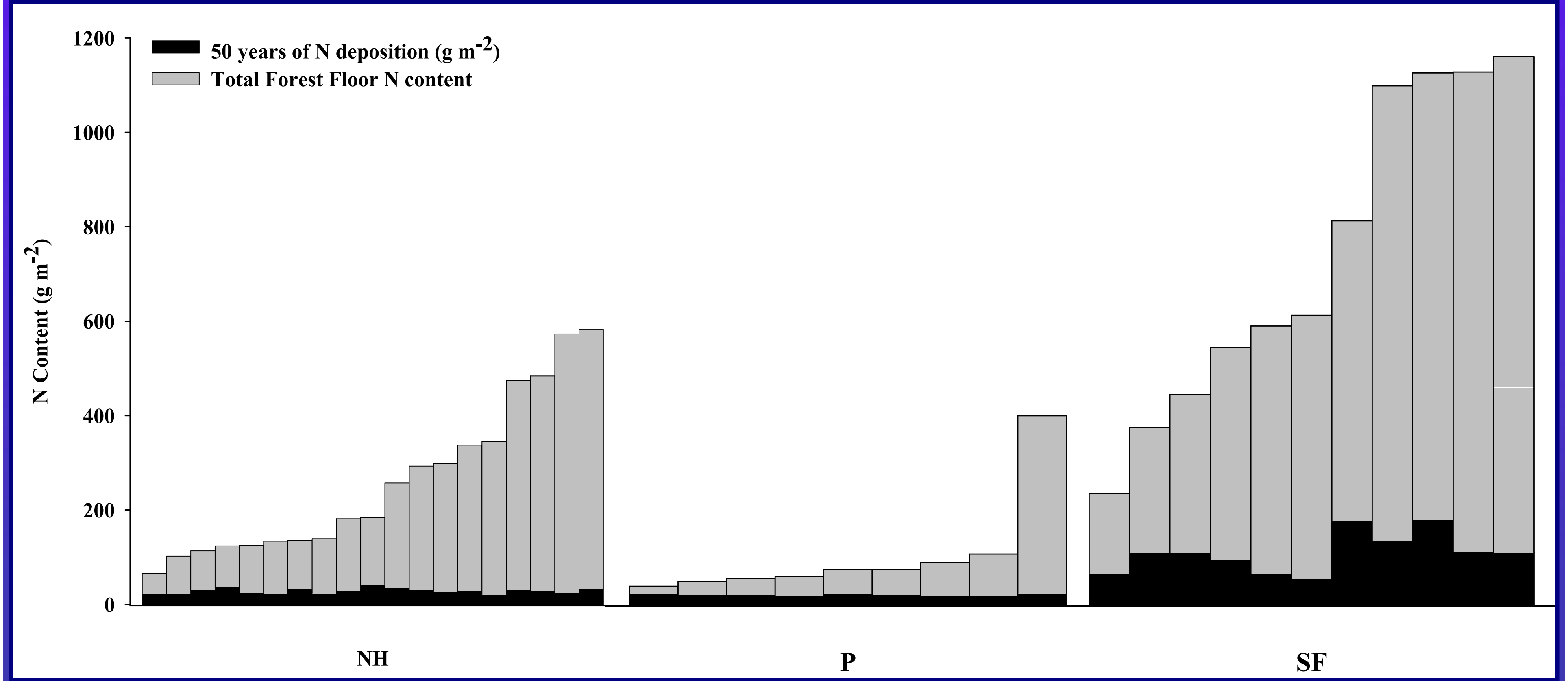
Influences on FF N content

MRT analysis of FF (Oe + Oa) N content



A Quantitative View

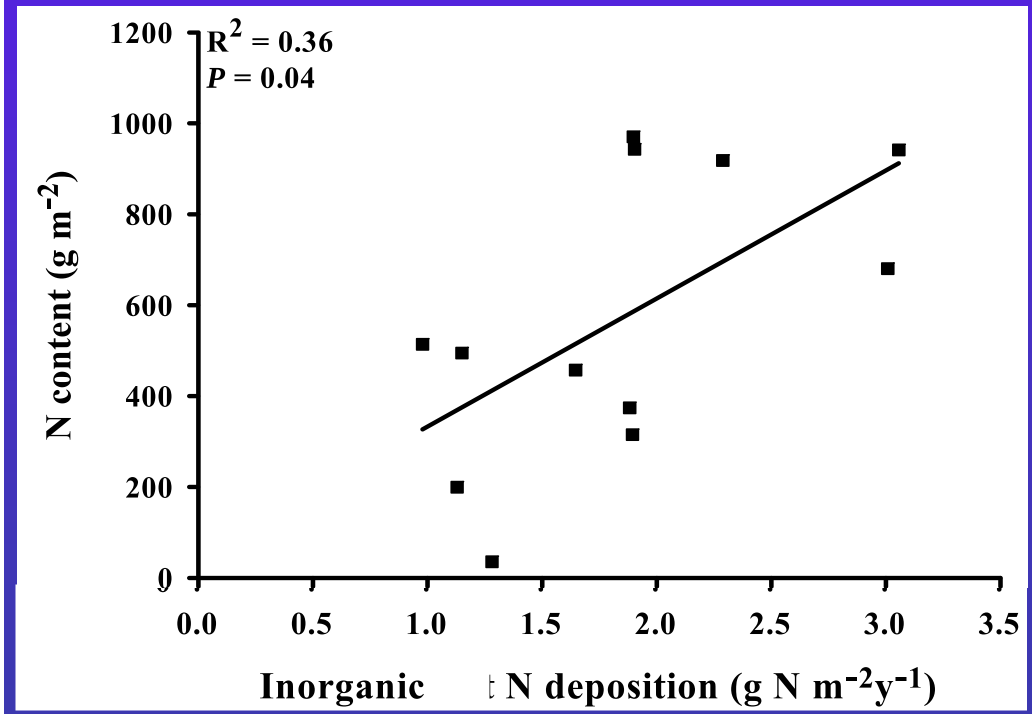
50 years of N deposition and Forest Floor N Storage



What about the highest N deposition plots?

N deposition

9.8 to 31 kg N $ha^{-1}yr^{-1}$



	SF	
		% SS†
Organic	N deposition	79
Mineral	GSDD‡	43

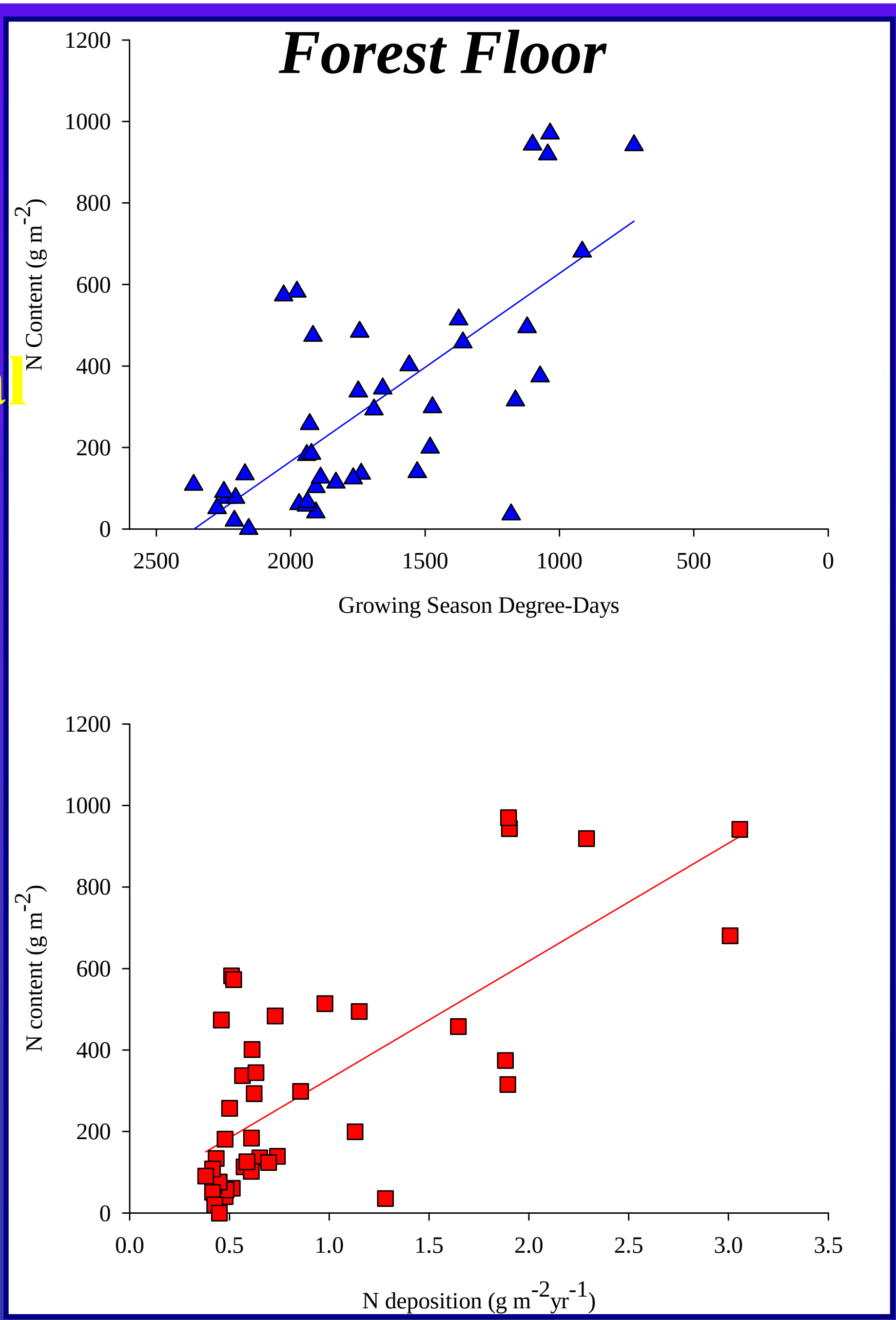
† Sums of squares explained

‡ Growing season degree-days

Correlated Variables

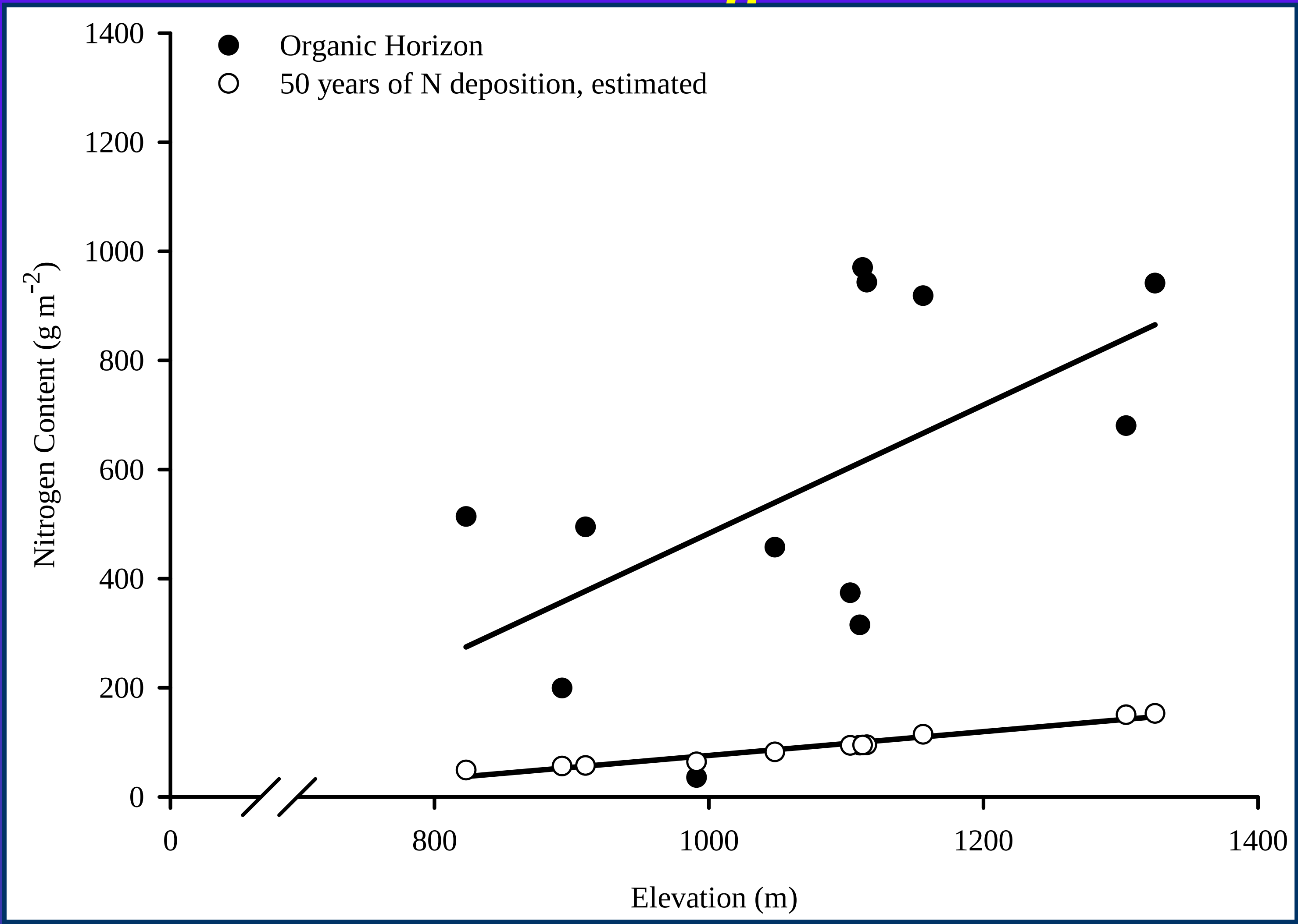
However, the same functional relationship exists for both temperature and N deposition

***Can this be resolved?**



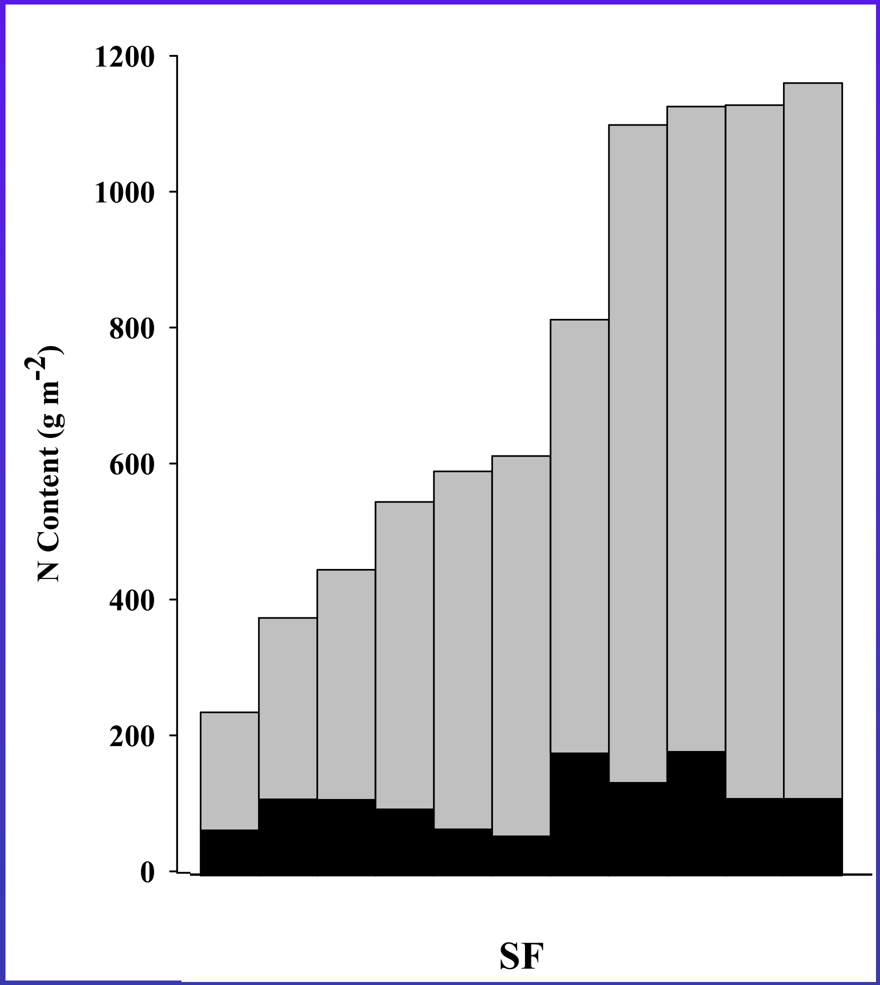
A Quantitative View

Can N dep account for differences in soil N?



570 g N m^{-2}, 1.8 g N $m^{-2}yr^{-1}$ * 50 yrs = 16%

Not enough N in deposition to have a measurable influence on soil N pools



5700 kg N ha^{-1}, 18 kg N ha^{-1}yr^{-1} * 50 yrs = 16%

Where is the N going?

<u>N budget (kg N $ha^{-1}yr^{-1}$)</u>

Atmospheric Input = 16.4
Mineralization = 40

Uptake = 42.8
Leaching = 4.8

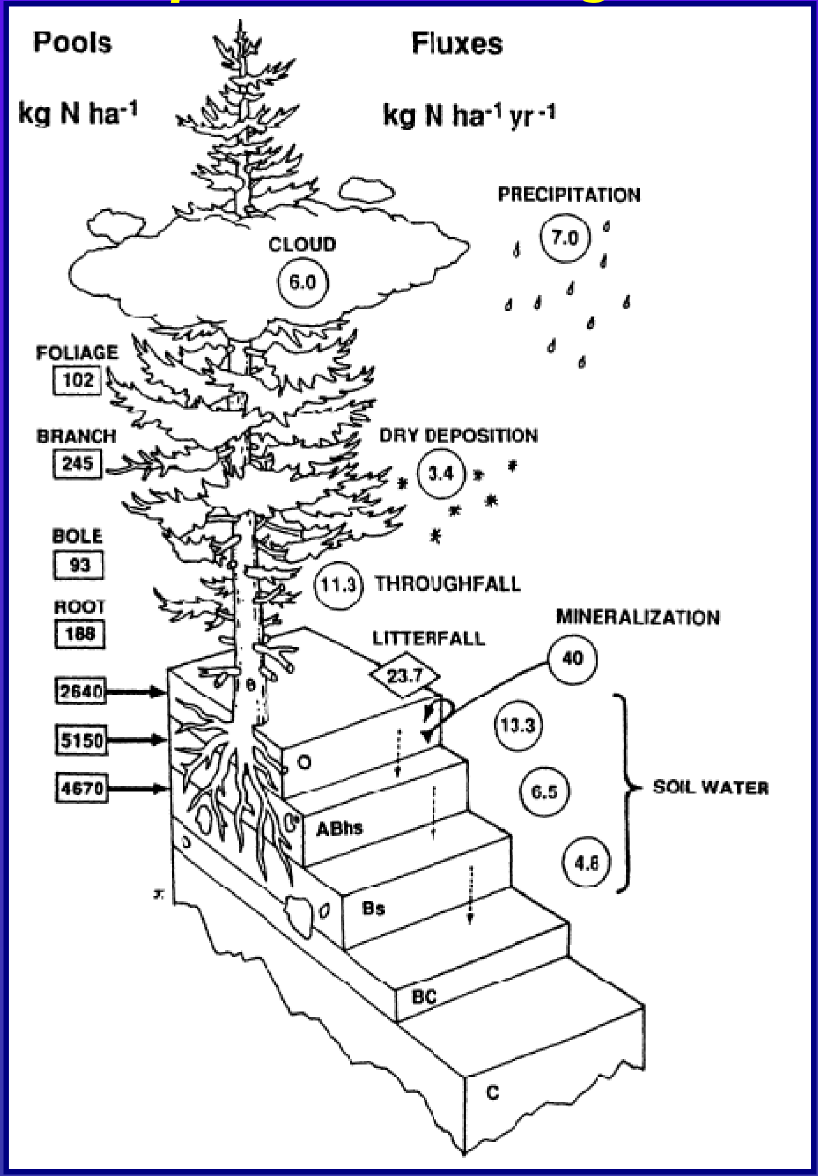
—

Retained = 8.8

FF Pool = 0.3% yr^{-1}

Total Pool = 0.07% yr^{-1}

Whiteface Mtn N budget



From Friedland et al., 1991

Adirondack forest transect