Soil Chemistry and the Recovery of Sensitive Watersheds from Chronic Acidification

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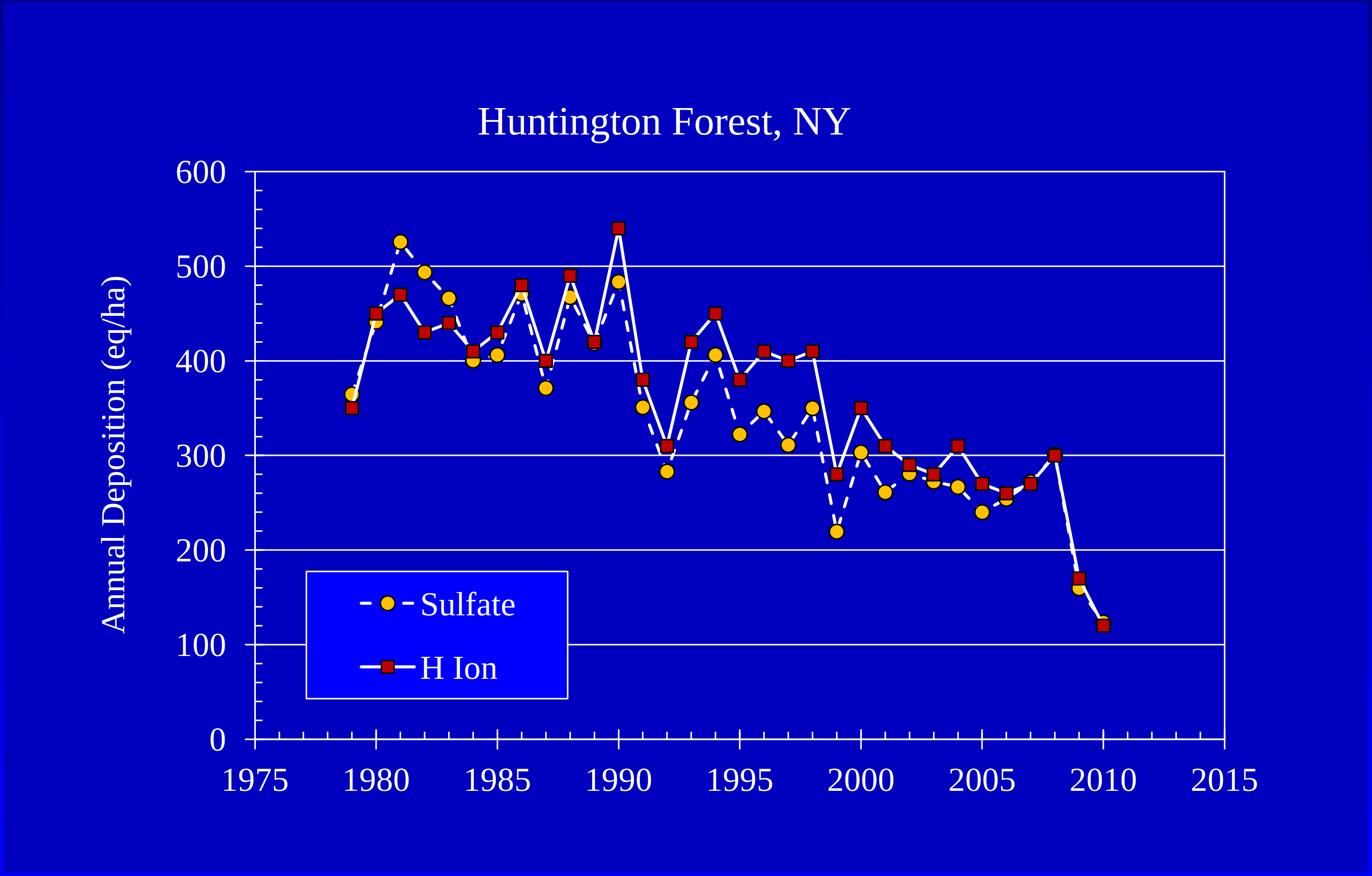
Decline in Acid Deposition



Data: National Atmospheric Deposition Program (http://nadp.sws.uiuc.edu/)

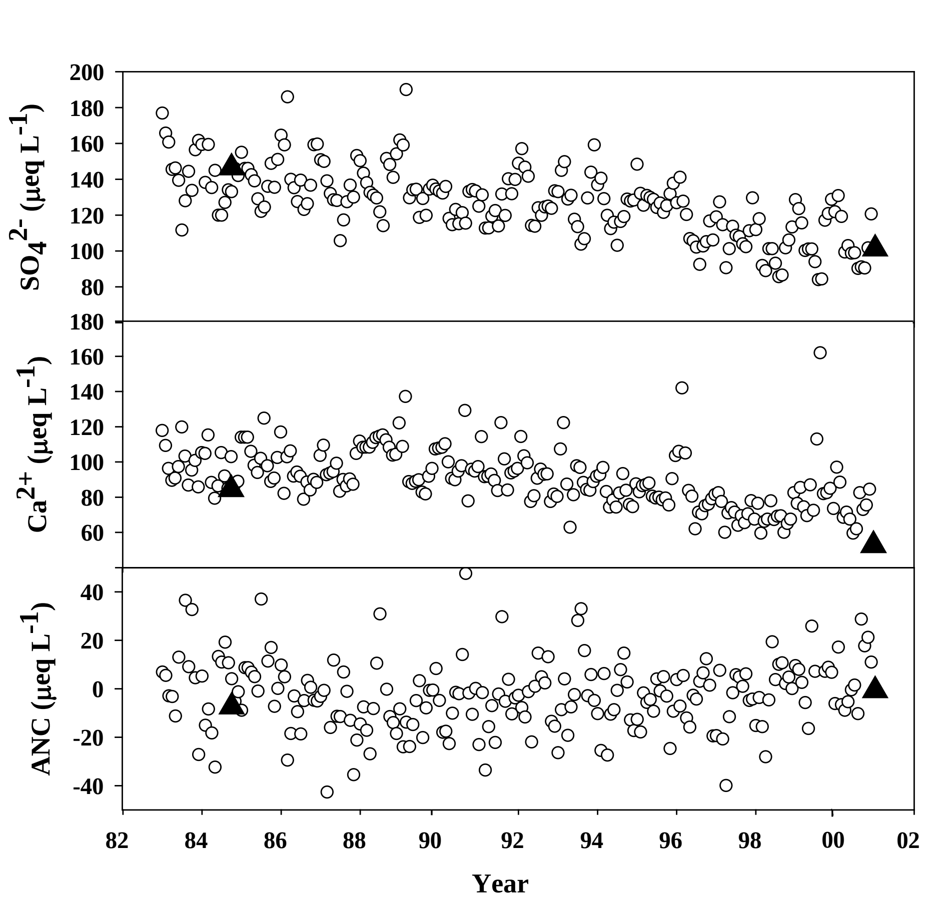
Surface Waters Are Showing Chemical Recovery

- Decreased SO_4^{2-} in drainage waters.
- Increased pH, ANC.
- Decreased Al concentrations.

BUT:

- ANC recovery is sluggish.
- Base cation concentrations continue to decline.

Constable Pond, NY

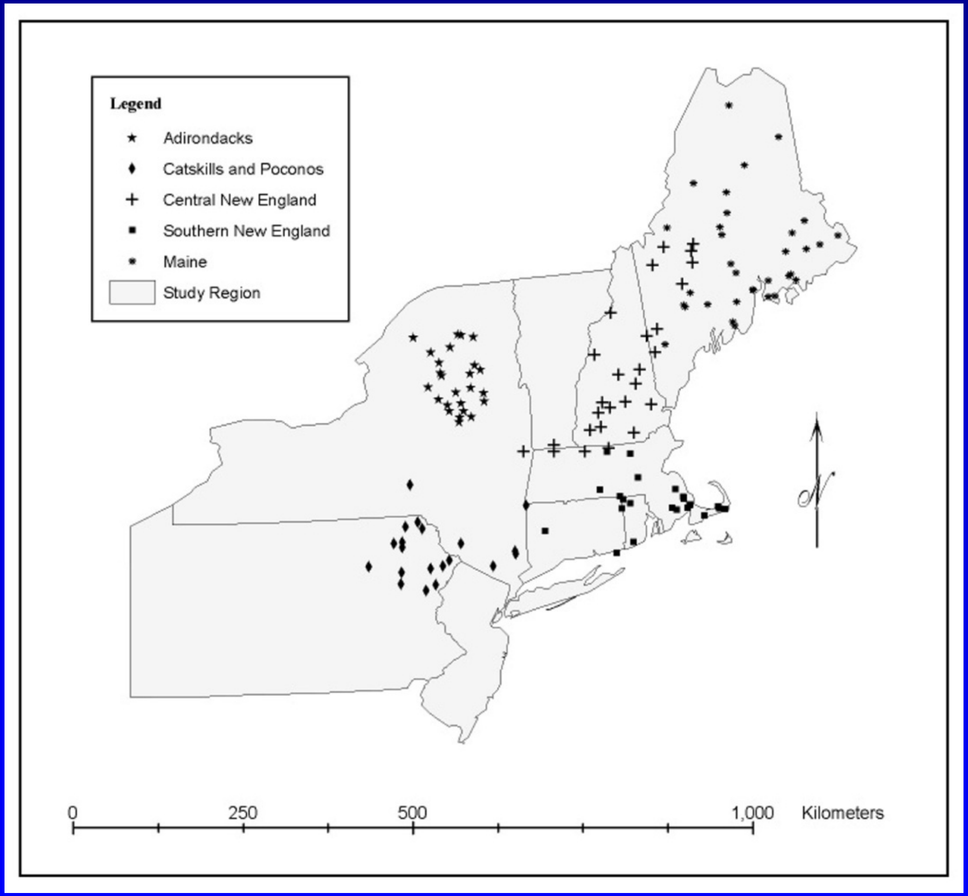


Warby et al. (2005)

Hypothesis

- The recovery of surface waters in the northeastern U.S. from acid rain is hindered by continuing acidification of soils.

Approach



- Sample soils from watersheds studied in the Direct/Delayed Response Program (DDRP) – 1984.
- Samples collected in 2001-02.
- Same chemical methods as DDRP, to the extent possible.


Oa Horizon

Region-Wide Results: Oa Horizons

	1984 Median	2001 Median	Significance
Calcium, $cmol_c$ $(kg\ C)^{-1}$	23.5	10.6	$P < 0.01$
Aluminum, $cmol_c$ $(kg\ C)^{-1}$	8.8	21.3	$P < 0.01$
Acidity, $cmol_c$ $(kg\ C)^{-1}$	23.6	38.0	$P < 0.01$
CEC_e, $cmol_c$ $(kg\ C)^{-1}$	62.7	60.6	None
pH	3.14	2.98	$P < 0.05$
Base Saturation, %	56.2	33.0	$P < 0.01$

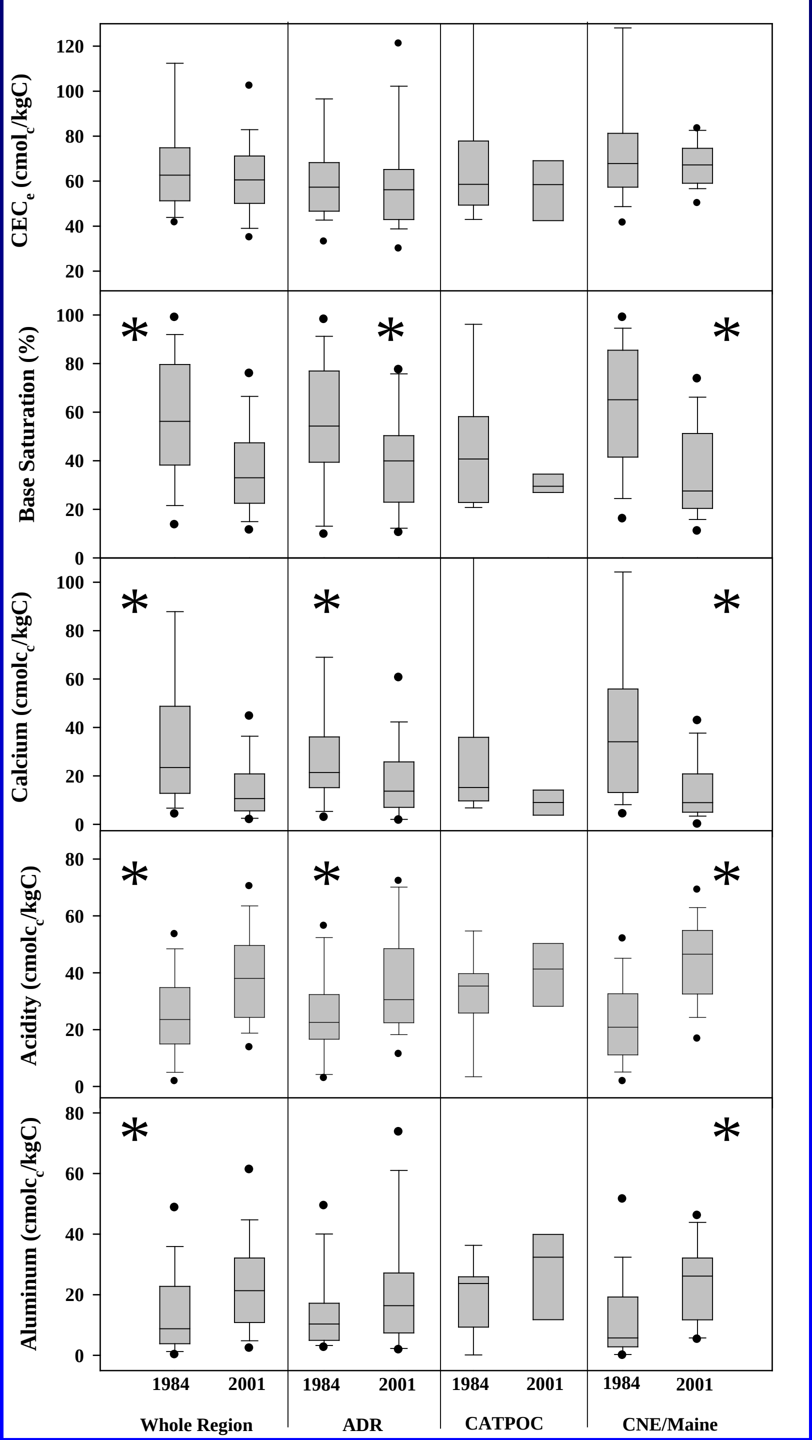
(Warby et al. 2009)

Sub-Regional Results: Oa Horizon

(Warby et al. 2009)

Sample Size (N):

Region	1984	2001
All	75	55
ADR	28	28
CATPOC	10	8
CNE/Maine	37	19



* Indicates $P < 0.05$


Bhs Horizon?


or Bs Horizon?


here?
Bhs Horizon

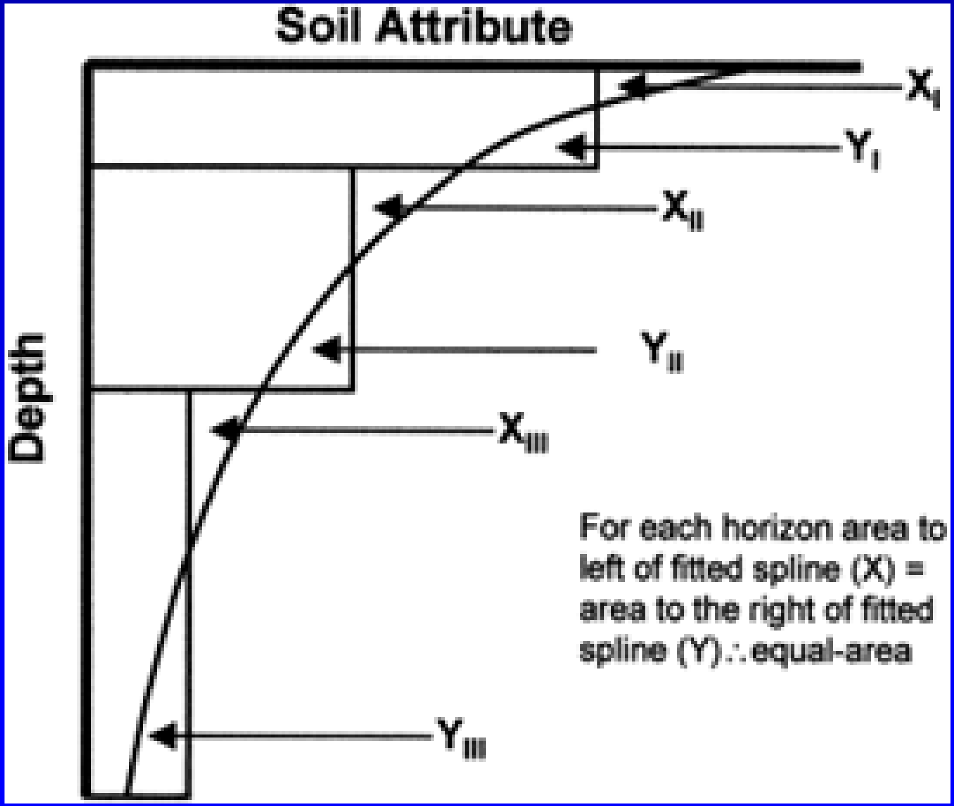

or here?
Bhs Horizon


Two Horizons?

or Three?

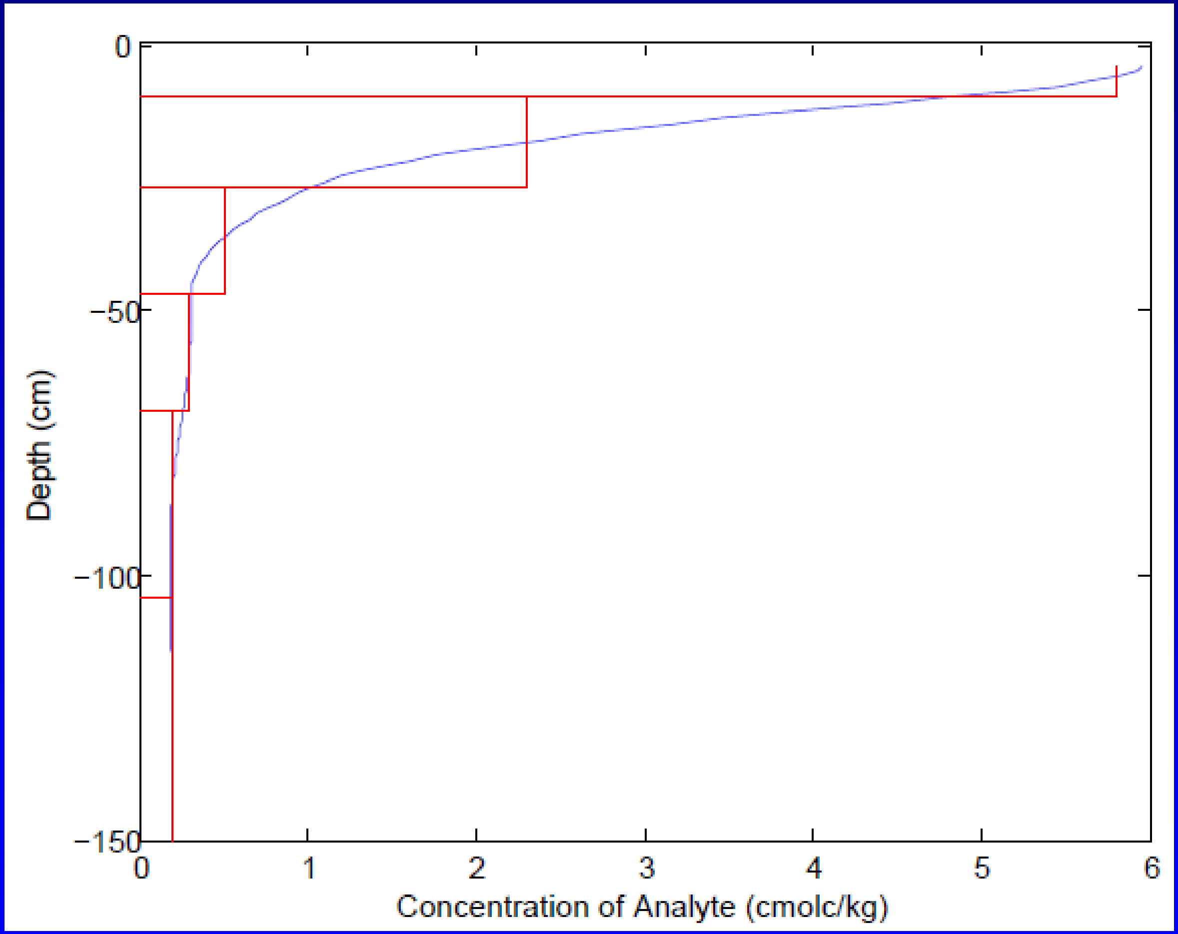
Equal-Area Quadratic Splines

- A series of local quadratic polynomials that join at "knots" located at the horizon boundaries (Bishop et. al, 1999).
- Area to the left of the fitted spline ("X") is equal to the area to the right of the spline ("Y") (Ponce-Hernandez, 1986).
- Mean value of each horizon is maintained by the spline.
- Minimizes the true mean squared error (Bishop et. al, 1999).



(Ponce-Hernandez et al.,1986)

Equal-Area Quadratic Splines



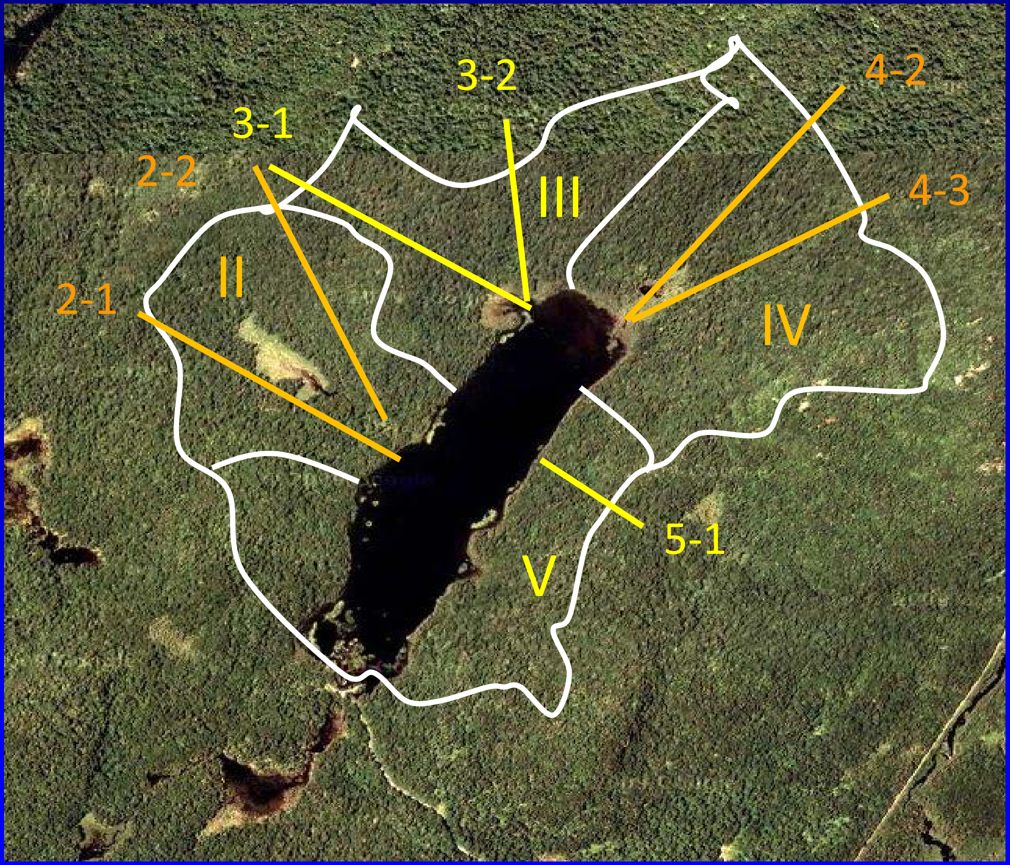
- Continuous depth-concentration function computed by the spline-fitting program.
- Mean concentration of analyte calculated for user-specified depth segment (e.g., 0-10 cm).

Adirondack Results: Mineral Soils

0-10 cm	1984 Mean	2001 Mean	Significance
Calcium, $cmol_c\ kg^{-1}$	0.77	0.43	$P < 0.01$
Aluminum, $cmol_c\ kg^{-1}$	4.34	4.82	NS
Acidity, $cmol_c\ kg^{-1}$	5.57	5.79	NS

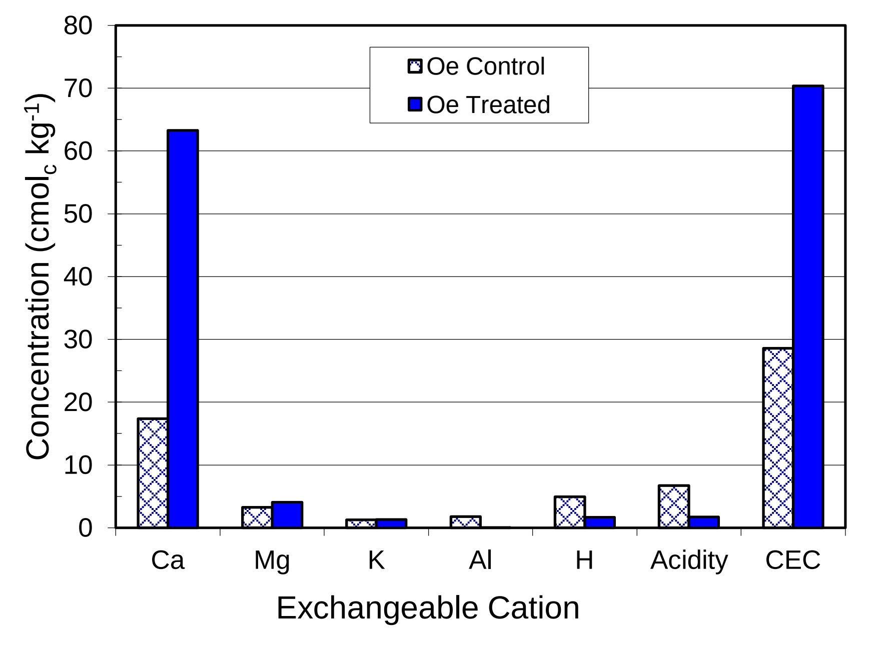
10-20 cm	1984 Mean	2001 Mean	Significance
Calcium, $cmol_c\ kg^{-1}$	0.60	0.37	$P < 0.01$
Aluminum, $cmol_c\ kg^{-1}$	3.58	6.25	$P < 0.01$
Acidity, $cmol_c\ kg^{-1}$	4.40	7.25	$P < 0.01$

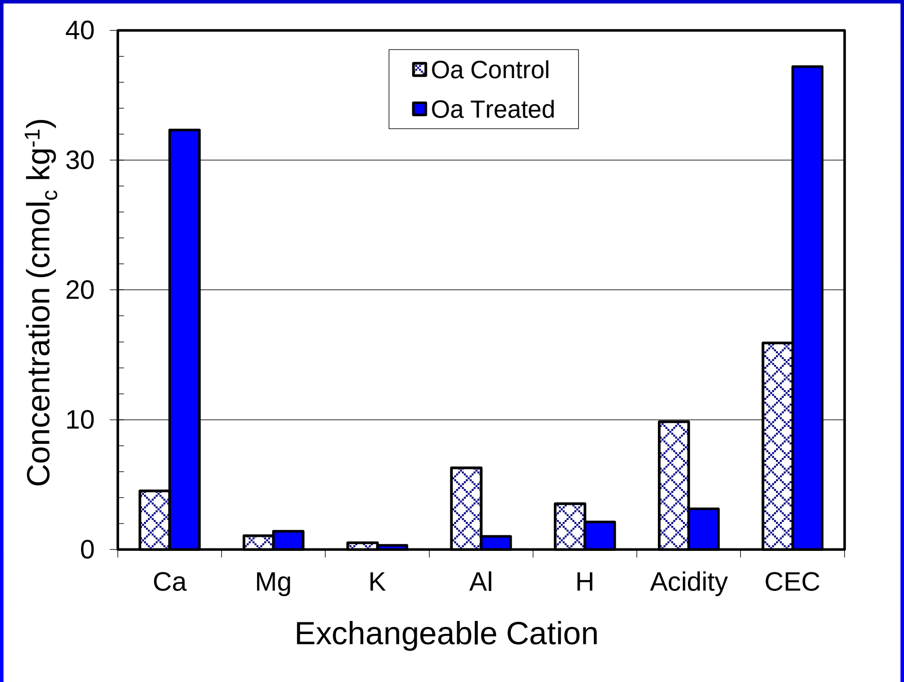
Woods Lake Watershed Liming Experiment

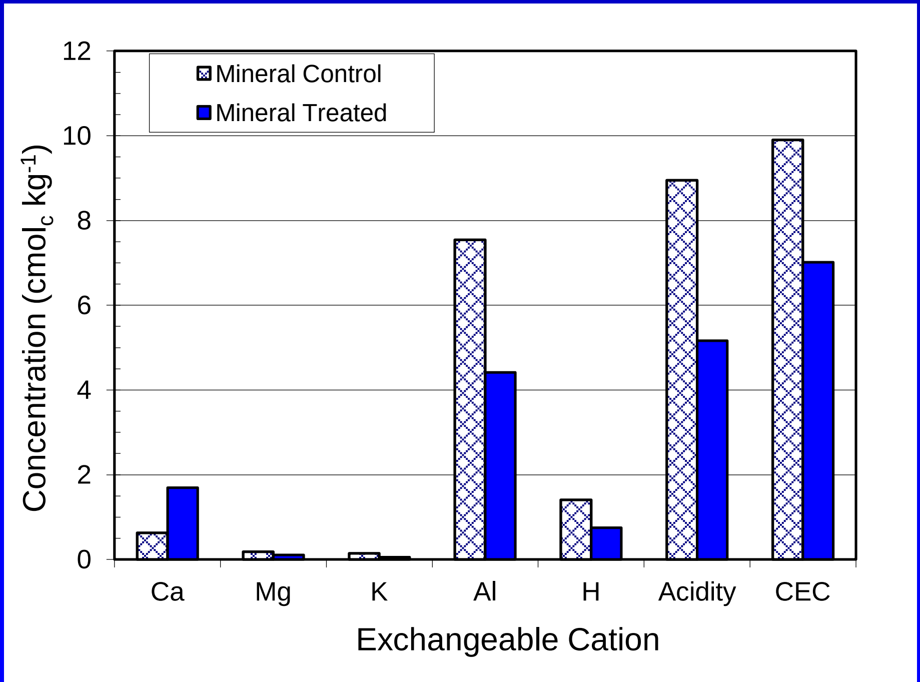


- Sub-watersheds II and IV limed in 1989.
- Sub-watersheds III and V not limed - controls.
- Transects sampled in 2008.
- Pre-treatment data – Blette et al. (1996)

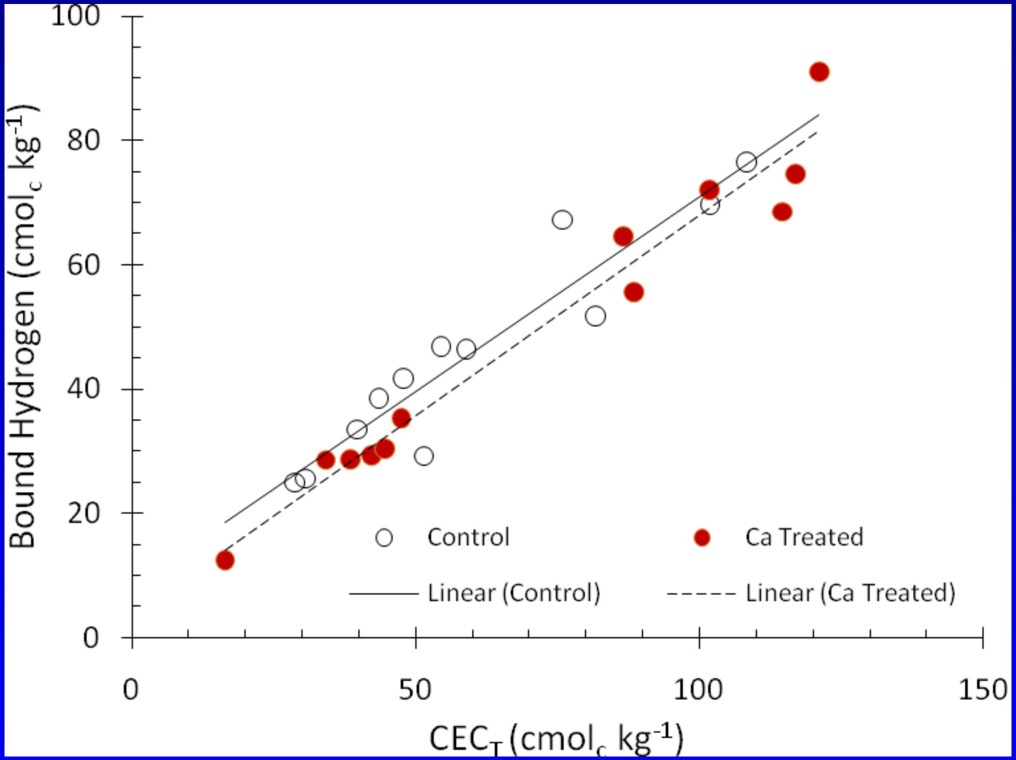
Liming Effects on Soil Chemistry

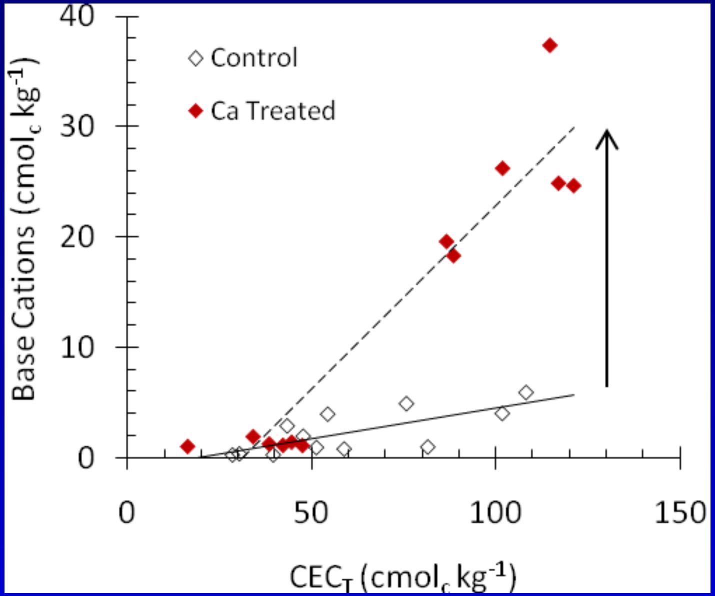


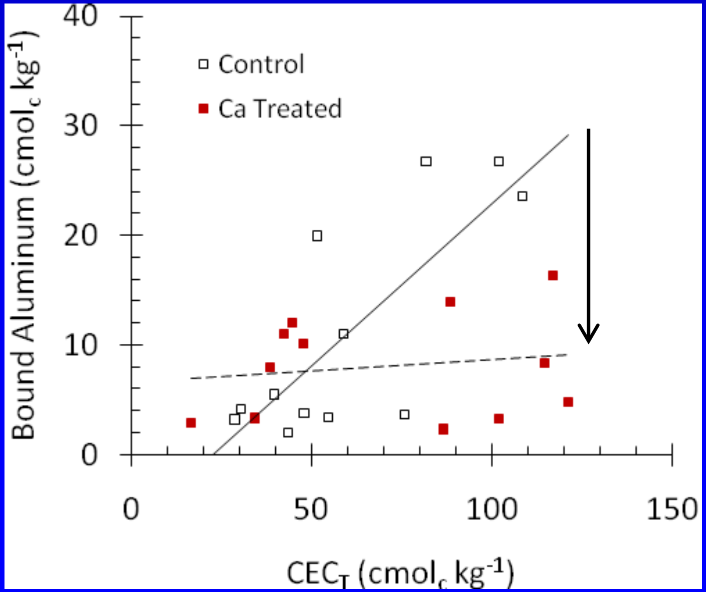




Ca-Al Dynamics After Liming







Conclusions

1. Oa horizons in the northeastern USA experienced substantial decreases in exchangeable Ca, and increases in exchangeable Al between 1984 and 2001-02.
2. These changes appear to be occurring in the upper layers of mineral soils in the region as well.
3. The continuing acidification of soils may help explain the sluggish recovery of ANC in regional surface waters.
4. Soils at Woods Lake were significantly less acidic 19 years after liming.
5. Increased Ca levels in Woods Lake soils appear to be equivalent to decreases in bound Al.