Assessment of repeated soil sampling as a monitoring tool for investigating the effects of changes in soil chemistry

Gregory B. Lawrence, U.S. Geological Survey, New York Water Science Center, Troy, NY, 12180; E-mail: glawrenc@usgs.gov
Scott Bailey: USDA Forest Service, Northern Research Station, 234 Mirror Lake Rd, North Woodstock, NH 03262; E-mail: swbailey@fs.fed.us
Paul Hazlett: Natural Resources Canada, Canadian Forest Service, Great Lakes Forestry Centre, 1219 Queen Street East, Sault Ste. Marie, ON P6A2E5, Canada; E-mail: phazlett@nrcan.gc.ca
Rock Ouimet, Laval University, Dept. Wood and Forest Sci., Quebec City, QC, Canada G1K7P4; e-mail: rock.ouimet@mrnf.gouv.qc.ca

Completion date:

Major Findings

- Repeated soil sampling was found to be an affective method for measuring chemical changes in soils over periods from 12 to 24 years.
- In general, organic soil horizons tended to become less acidic, whereas mineral soil horizons tended to become more acidic. Decreases in concentrations of exchangeable Al were more commonly observed than increases.

Funding support for this project was provided by the Northeastern States Research Cooperative (NSRC), a partnership of Northern Forest states (New Hampshire, Vermont, Maine, and New York), in coordination with the USDA Forest Service.
http://www.nsrcforest.org

Project Summary

Environmental disturbances such as acidic deposition can alter soils, but little data have been collected to document soil change. The few retrospective soil studies to date have shown that repeated sampling of soil over time can provide valuable information on soil change. To test the feasibility of repeated soil sampling to monitor soil change we resampled soils at 16 locations in the Northeastern U.S., Ontario and Quebec, where previous sampling was done 12 to 24 years ago. Investigators involved in the original sampling directed the resampling of their respective site(s) to ensure consistency of methods between previous collections and those to be done in 2009-2010. Original soil samples collected at each of the sites had been archived and were available for reanalysis to evaluate possible storage effects and analytical inconsistencies. A variety of sampling approaches and replication were used at the 16 sites, which enabled a comparison of collection methods. The same methods of chemical analysis were used for original and recently collected samples. A standard soil (mineral and organic horizons) provided by the Northeastern Soil Monitoring Cooperative was routinely analyzed by all labs for quality assurance.

Statistically significant changes were detected in all of the chemical measurements for at least one site and soil horizon. In general, organic horizons (Oe, Oa, F and H) showed the most changes and tended to become less acidic over time (decreases in exchangeable aluminum concentrations and or pH). There were some exceptions, including East Bear Brook ME, where exchangeable aluminum concentrations in the Oa horizon showed pronounced increases, and pH and exchangeable calcium concentrations decreased. Mineral horizons, (A and B) tended to become more acidic (increases in exchangeable aluminum concentrations, and or decreased calcium concentrations), although both increases and decreases in pH were observed and decreased concentrations of exchangeable Al were observed in B horizons at most Ontario sites. Some of the observed changes in soils, such as decreases in exchangeable Al in organic horizons, were related to decreasing acidic deposition, but some sites did not fit the overall patterns.

Results of this project substantiated soil resampling as a method for detecting changes in soil over varying time periods, in a variety of forest types with varying soil chemistry and acidic deposition history. This work also showed that recovery of acidified soils in response to decreasing acidic deposition had begun at some sites in some horizons, but at other sites, soils continued to acidify during the study period.

Background and Justification

- Acidic deposition has been linked to depletion of calcium and other effects on soils (Bailey et al., 2005).
- Most evidence of soil-calcium depletion has been inferred from changes in surface water chemistry and watershed studies (Likens et al., 1996; Lawrence et al., 1999;).
- A handful of studies have shown direct evidence of lowered calcium availability in soils, but there is insufficient data to assess soil recovery Warby et al., 2009.
- Opportunities for soil resampling to measure changes have resulted from numerous soil studies conducted in the 1980s and 1990s to relate soil conditions to surface waters and forests (Lawrence and Bailey, 2007).
- With these opportunities, interest in soil resampling has grown, but questions remain regarding the length of time required to detect changes, and the most affective methods for collection and analysis of soil in resampling studies.

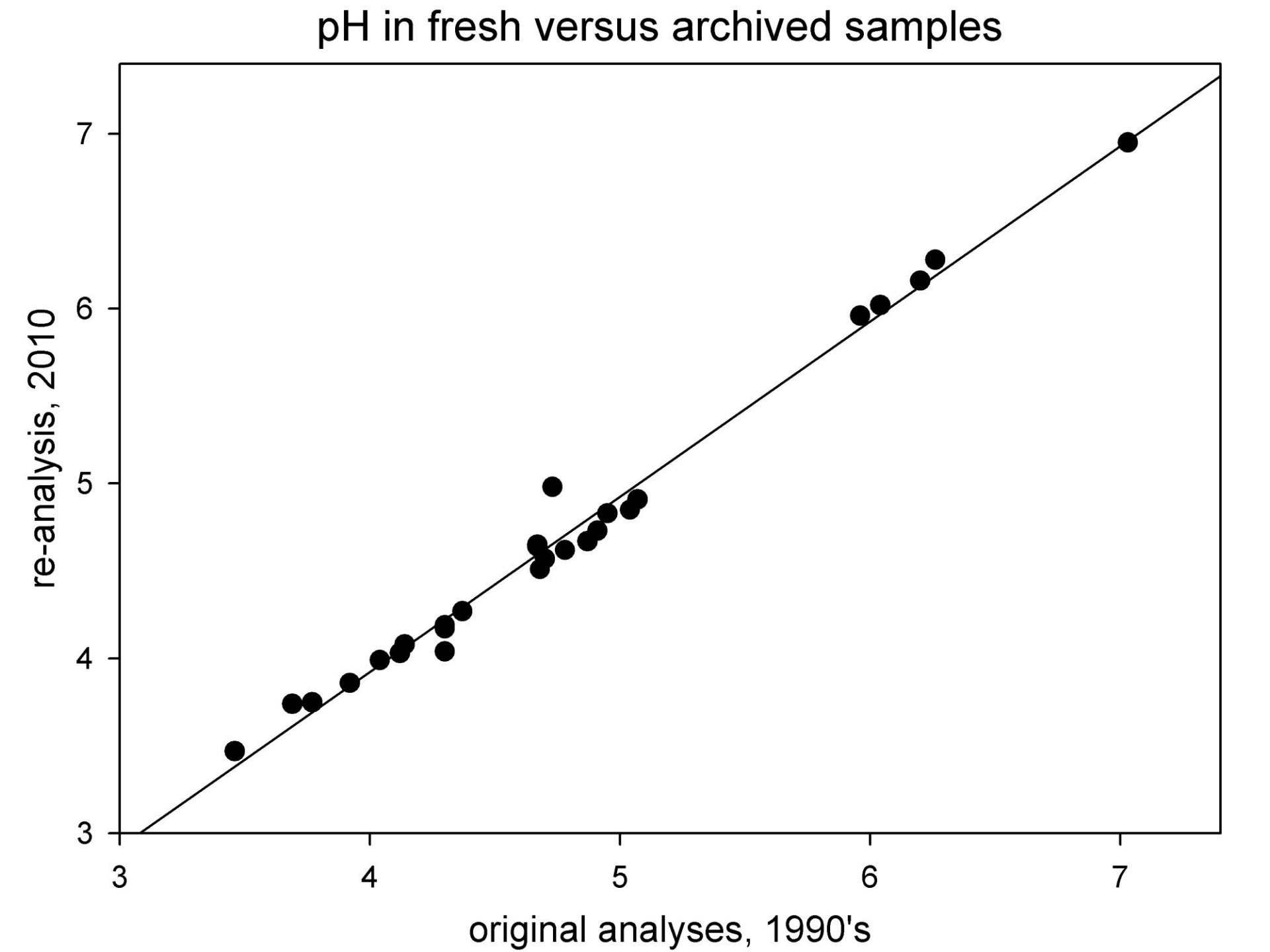
Methods

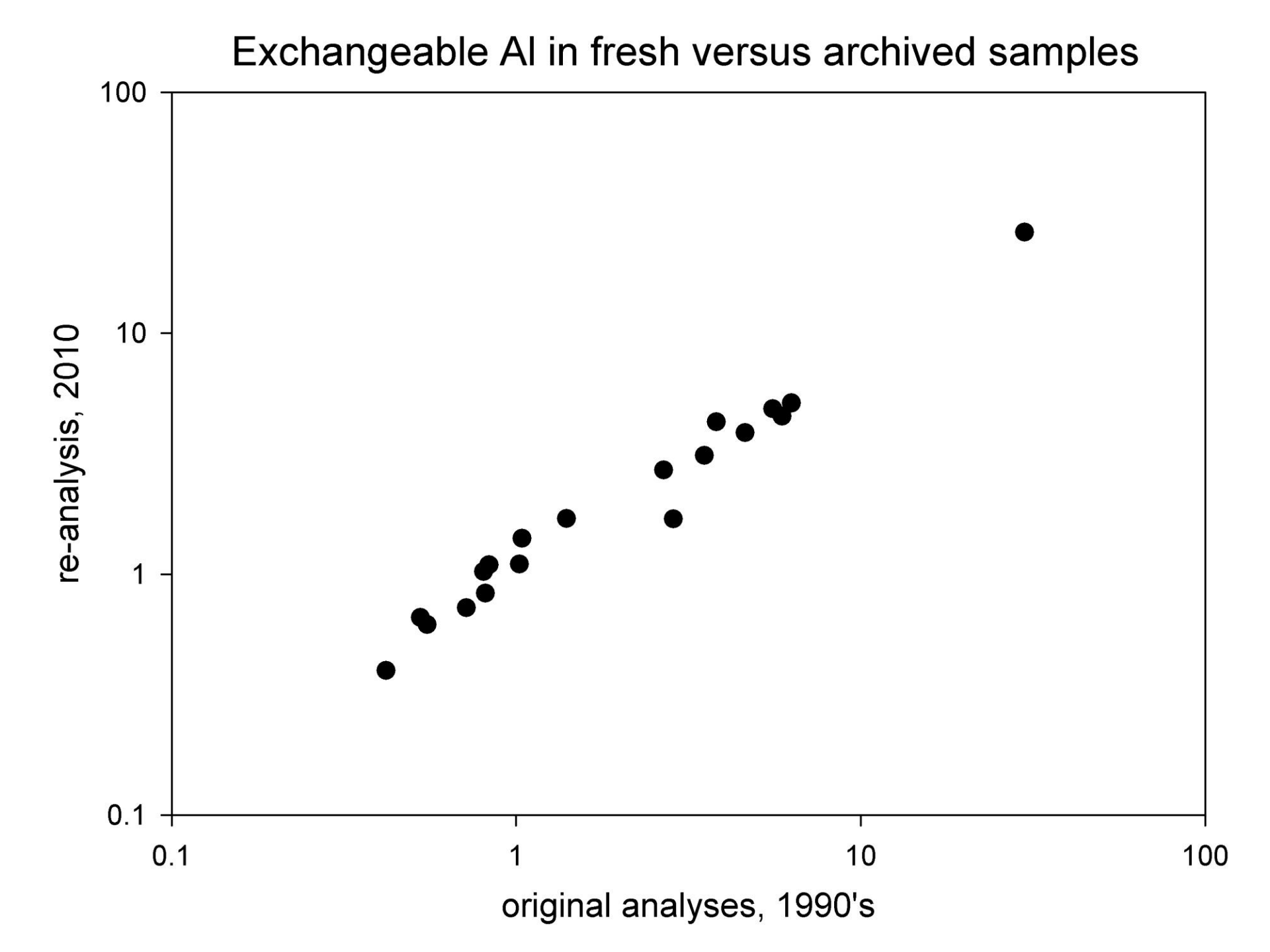
- Soils at 16 sites in Ontario, Quebec, NY, VT, NH and ME were resampled.
- Locations of original sampling were identified by field markers, GPS and detailed field notes.
- All resampling was overseen by the investigators involved in the original sampling.
- Sampling protocols of the original sampling were closely followed.
- Resampling at each of the original locations was replicated by 2 to 5 pits per plot except at Buck Creek, where sampling was repeated at 27 locations within a single 27-ha watershed.
- Samples collected and archived in the original sampling were available for all sites.
- Archived samples and the newly collected samples were analyzed for pH (0.01 M $CaCl_2$), exchangeable bases (1 M NH_4Cl), total acidity, exchangeable Al, total C, total N by the methods of (Bailey et al., 2004).
- Data obtained in the original analysis were compared to data obtained through the reanalysis of archived samples to evaluate possible storage effects and analytical inconsistencies.

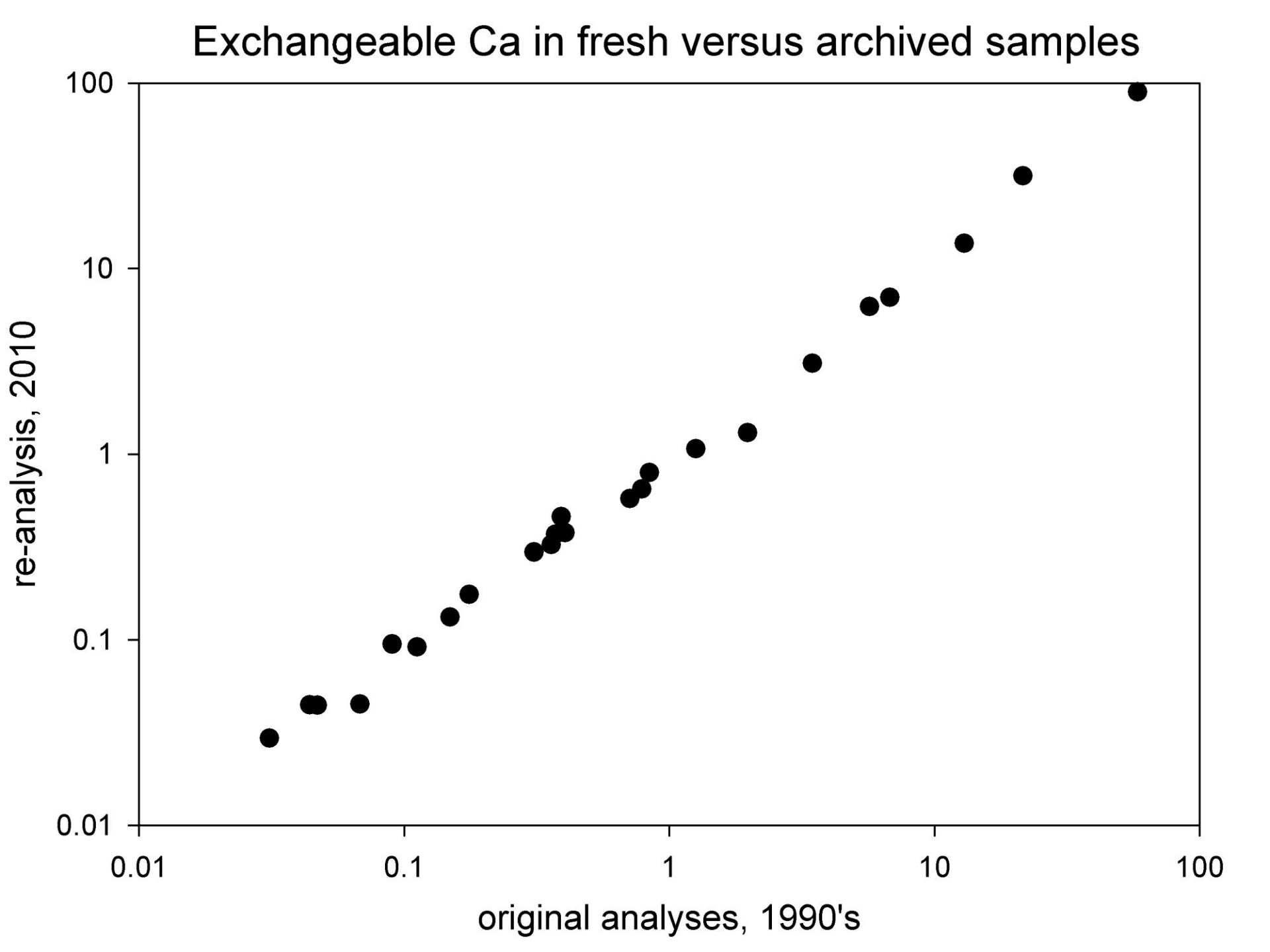

Soil Resampling Sites
Quebec
Ontario
DRYON
WAWON
KILON
DUCQC
New Brunswick
FLLON
TLWON
EEBME
Maine
LMLON
Vermont
SR4VT
JB1NH
HB8NH
CRTON
BCWNY
New Hampshire
EQ1VT
AUBON
Michigan
New York
Wisconsin
Massachusetts
Connecticut
©2012 Google
Image © 2012 TerraMetrics
©2012 Cnes/Spot Image
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Google earth

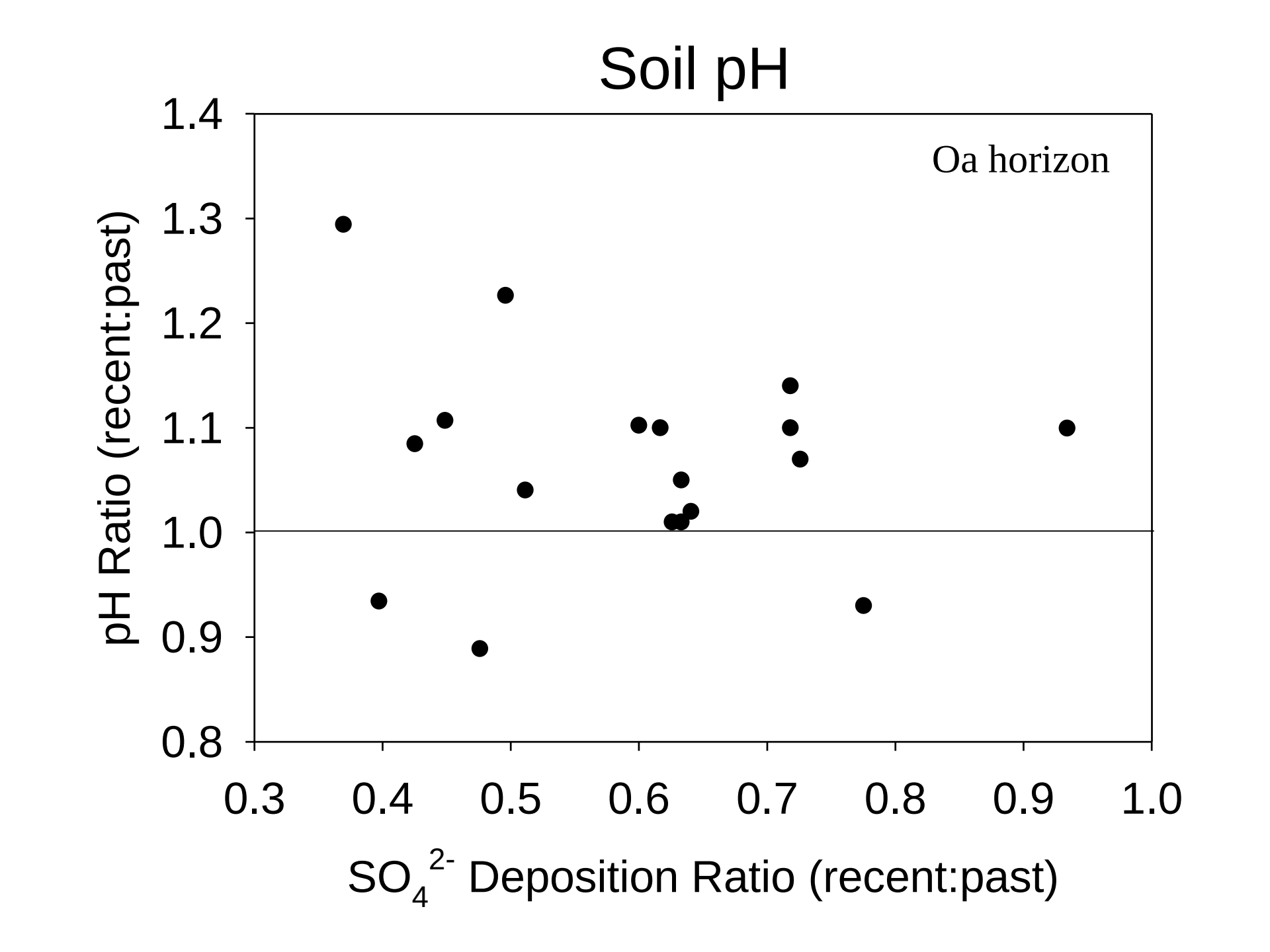
Soil Resampling Sites	Project	Type	Wet Dep. of SO_4 in 1985/2005	Year Sampled	% Base Saturation in Oa/upper B	Number of Pits Sampled	Horizons Sampled
East Bear Brook, Downeast ME	N'east Spruce	Spruce-fir	20/16	1992-93	30/8	12	Oa, upper B
Sleepers River, VT	N'east Spruce	Conifer/ hardwd	22/14	1993	58/10	6	Oa, upper B
Sleepers River, VT	Regional Sugar Maple	North'n hardwd	22/14	1996	37-93/9-42	4	All major horizons
Jeffers Brook, NH	Regional Sugar Maple	North'n hardwd	18/15	1997	27-44/6-56	4	All major horizons
Hubbard Brook, NH	Regional Sugar Maple	North'n hardwd	18/15	1997	4-41/3-8	4	All major horizons
Mount Equinox, VT	Regional Sugar Maple	North'n hardwd	20/14	1997	48-93/9-94	4	All major horizons
Duchesnay, QC	RESEF	North'n hardwd	30/18	1989	60/3	4	All major horizons
Buck Creek, NY	NYSERDA Monitoring	Spruce-fir	20/12	1997	29/9	30	Oe, Oa, upper B
Turkey Lakes, ON	ARNEWS	Sugar maple	31/17	1985	42/29	26	Oe, A, upper B
Little Margaret Lake, ON	ARNEWS	Sugar maple	26/13	1985	27/19	26	Oe, A, upper B
Craighurst, ON	ARNEWS	Sugar maple	26/13	1985	42/74	26	Oe, A, upper B
Auburn, ON	ARNEWS	Sugar maple	33/20	1985	61/100	26	Oe, A, upper B
Flame Lake, ON	ARNEWS	Jack pine	20/11	1985	14/9	26	Oe, A, upper B
Wawa, ON	ARNEWS	Jack pine	31/17	1985	17/13	26	Oe, A, upper B
Dryden, ON	ARNEWS	Jack pine	7/5	1985	26/21	26	Oe, A, upper B
Kirkland Lake, ON	ARNEWS	Jack pine	20/11	1985	26/9	26	Oe, A, upper B

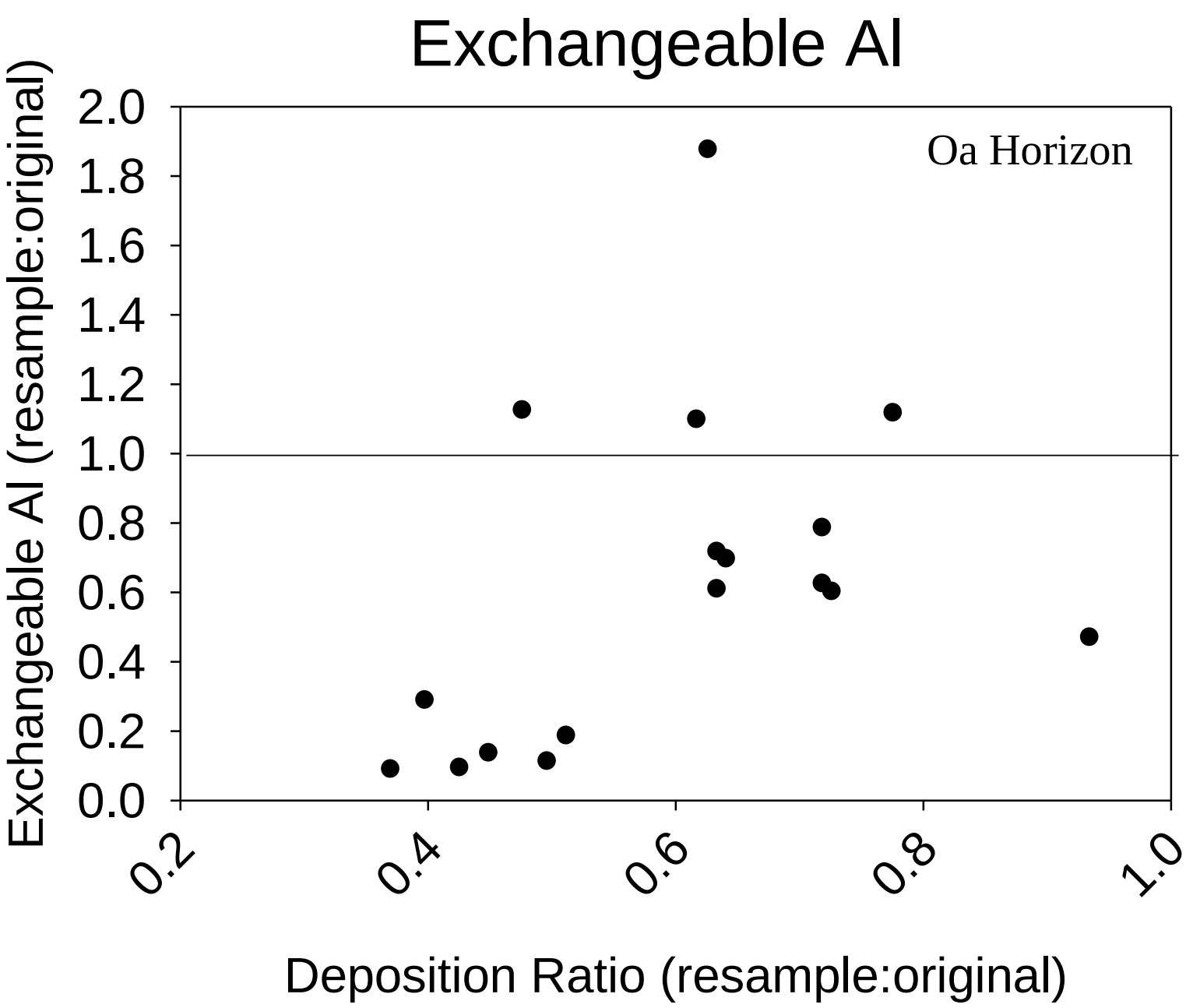
Soil profile at an ARNEWS site

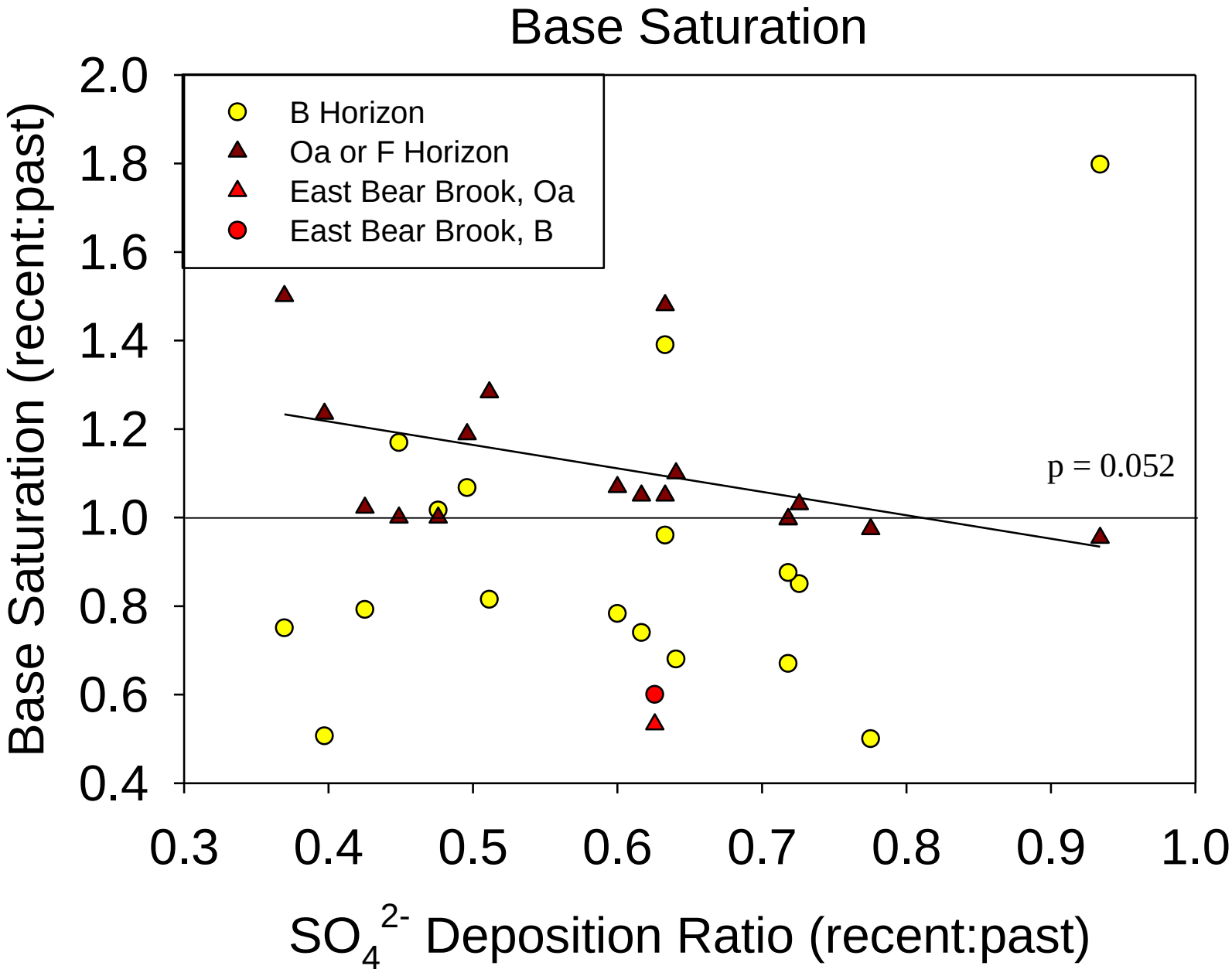

pH in fresh versus archived samples
re-analysis, 2010
original analyses, 1990's
3
4
5
6
7
3
4
5
6
7


Exchangeable Al in fresh versus archived samples
100
10
1
0.1
re-analysis, 2010
0.1
1
10
100
original analyses, 1990's


Exchangeable Ca in fresh versus archived samples
100
10
1
0.1
0.01
re-analysis, 2010
0.01
0.1
1
10
100
original analyses, 1990's


Soil pH
Oa horizon
pH Ratio (recent:past)
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
SO4 2- Deposition Ratio (recent:past)


Exchangeable Al
Oa Horizon
Exchangeable Al (resample:original)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.2
0.4
0.6
0.8
1.0
Deposition Ratio (resample:original)


Base Saturation
B Horizon
Oa or F Horizon
East Bear Brook, Oa
East Bear Brook, B
p = 0.052
Base Saturation (recent:past)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
SO4 2- Deposition Ratio (recent:past)

Implications and applications in the Northern Forest region

- Decreasing trends of acidic deposition were generally related to decreased acidity in organic soil horizons across the region.
- However, general increases in acidity not related to acidic deposition trends were found in the B horizon of most sites.
- Decreased acidity in organic horizons was likely tied to more effective uptake and recycling of nutrient base cations by vegetation under lowered deposition levels.
- Decreased base saturation of the B horizon suggests that base cation leaching rates continued to exceed inputs from weathering under the deposition rates that occurred between samplings.

Future Directions

- Forests with low-calcium soils are common throughout the NERC region.
- The importance of the forest floor in providing nutrient base cations has grown in these soils, making nutrient cycling more dependent on organic carbon dynamics.
- The effects of substantial decreases in acidic deposition on forest floor carbon is not well understood, and effects of climate change even less so.
- Further research is also needed to determine the capacity of the mineral soil and deeper substrates to supply nutrient base cations to the rooting zone.

List of Products

- Data analysis for a journal article on results of this study is partially completed. The manuscript will be ready for journal submission by January 2013.
- To support the goals of this project, The New York State Energy Research and Development Authority (NYSERDA) provided $25,000 for the soil resampling and chemical analysis of the Buck Creek watershed.
- Data collected through this project will be added to a database that has been constructed for the purpose of providing publicly accessible information on changes in soils in the Northeastern Forest.
- Results of this project will be presented at the Northeast Soil Monitoring Cooperative, March 2013.