Thirty Years of Change in Forest Soils of the Allegheny Plateau, Pennsylvania

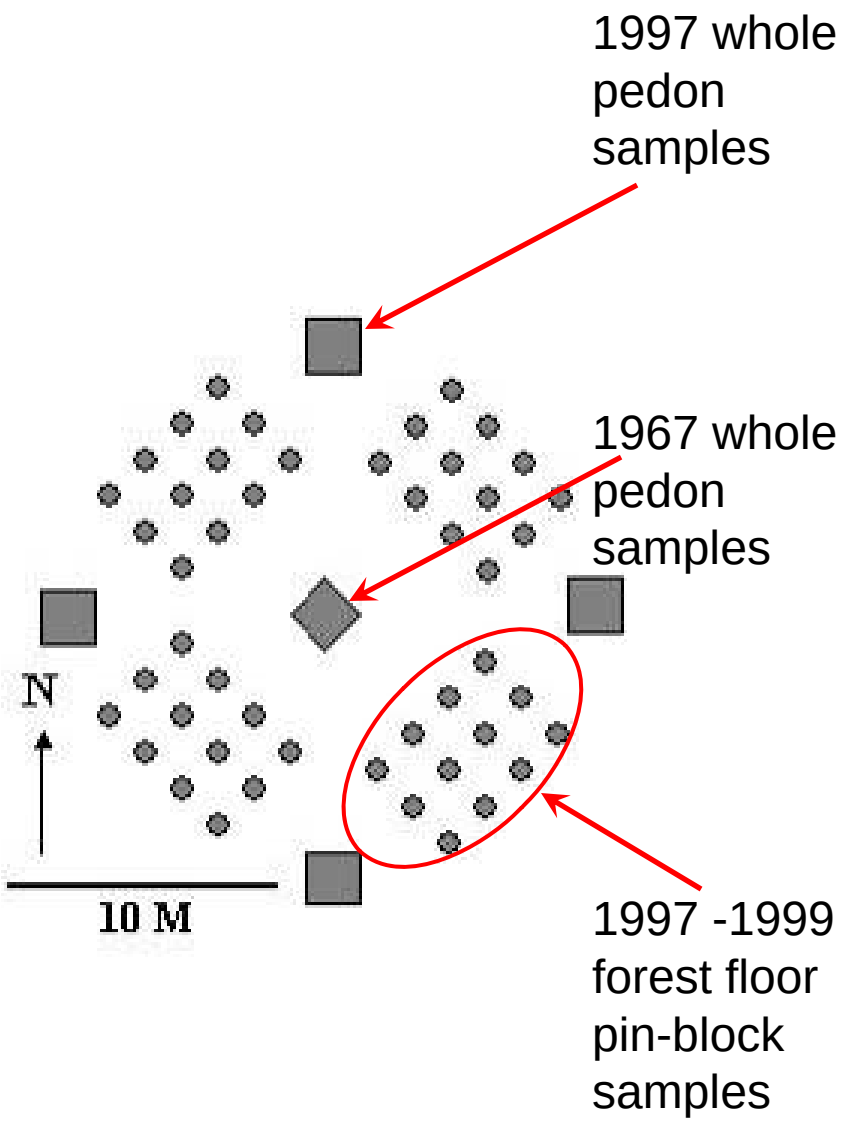
S. W. Bailey,* S. B. Horsley, and R. P. Long

ABSTRACT

Numerous studies have investigated the potential depletion of available base cation pools from forest soils in regions impacted by acid deposition. However, these studies mostly used indirect methods. Retrospective studies, providing direct evidence of chemical changes in forest soils, are relatively rare due to a lack of appropriate sampling, documentation, and archiving of samples over decadal or longer periods. We were provided an unusual opportunity to conduct such a retrospective study with relocation of four sites on the Allegheny Plateau in Pennsylvania. Detailed soil sampling and analyses were conducted in 1967. An original investigator was available to insure field sampling protocol consistency during resampling in 1997, and the original samples had been archived and were available for reanalysis. At all four sites there were significant decreases in exchangeable Ca and Mg concentrations and pH at all depths. Exchangeable Al concentrations increased at all depths at all sites, however increases were only significant in upper soil horizons. Short-term temporal changes, estimated by sampling the Oa/A horizon annually for 3 yr, were insignificant, suggesting that the differences between 1967 and 1997 are part of a long-term trend. At most of the sites losses of Ca and Mg on a pool basis were much larger than could be accounted for in biomass accumulation, suggesting leaching of nutrients off-site.

THERE IS MUCH INTEREST in possible depletion of base cations, particularly Ca, from forest soils (Federer atmospheric acid deposition is supported on theoretical grounds (Reuss, 1983), by laboratory experiments (Lawrence et al., 1999), by observational mass balance studies (Bailey et al., 1996; Likens et al., 1996; Huntington et al., 2000) and by experimental acidification studies (Fernandez et al., 2003). Retrospective studies commonly have not shown reductions in exchangeable bases, often in contrast to concurrent mass balance studies (Johnson et al., 1997; Likens et al., 1998). One retrospective study, which has documented base cation depletion was performed at the Calhoun Experimental Forest in South Carolina in a loblolly pine stand on postagricultural (previously limed) land. Here, Markewitz et al. (1998) used a hydrogen budget approach to determine that 38% of the observed base cation depletion was due to acid deposition.

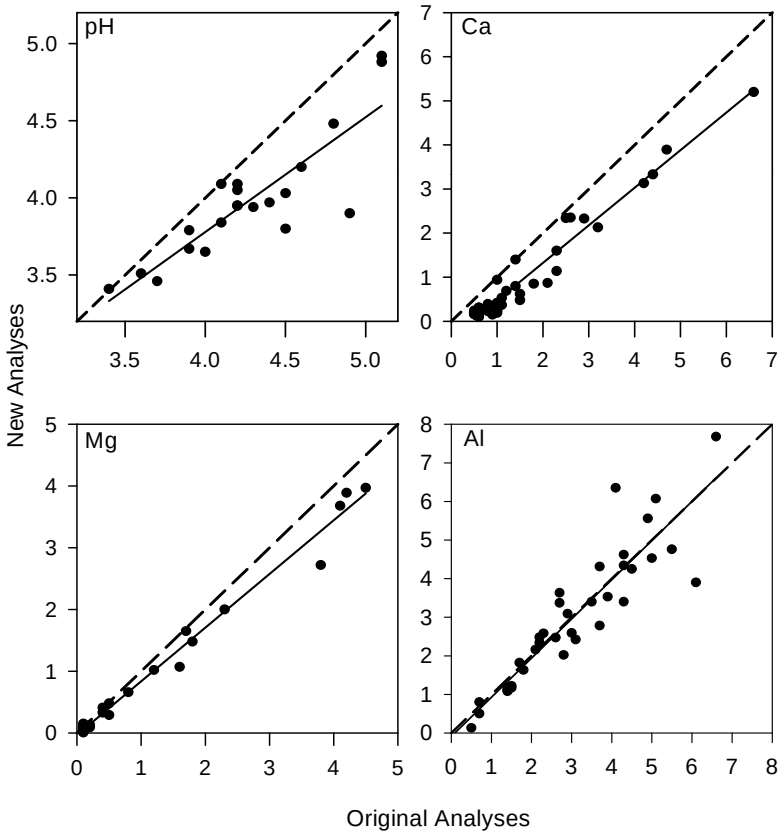
There are several possible explanations for the rare documentation of exchangeable base depletion in retrospective studies. Most retrospective studies are relatively recent, limiting the chance of detecting modest changes in a large pool in the face of spatial variability. Acid deposition is thought to have been widespread across the northeastern USA by the mid-1950s (Cogbill and Likens, 1974; Driscoll et al., 2001). The long-term mass balance model for the Hubbard Brook Experimen-


1997 whole pedon samples
1967 whole pedon samples
N
10 M
1997 -1999 forest floor pin-block samples

Strategies to Minimize Noise

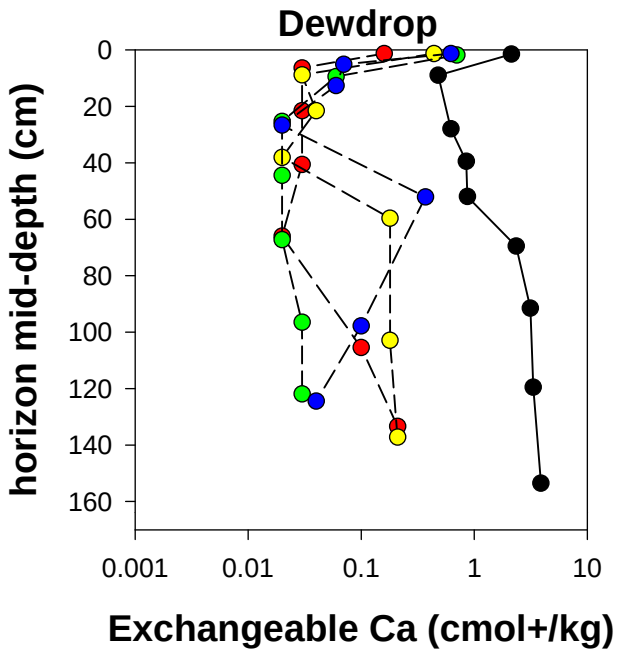
- Sample by carefully defined genetic horizons
- Collect large samples
- Maintain sample homogenization

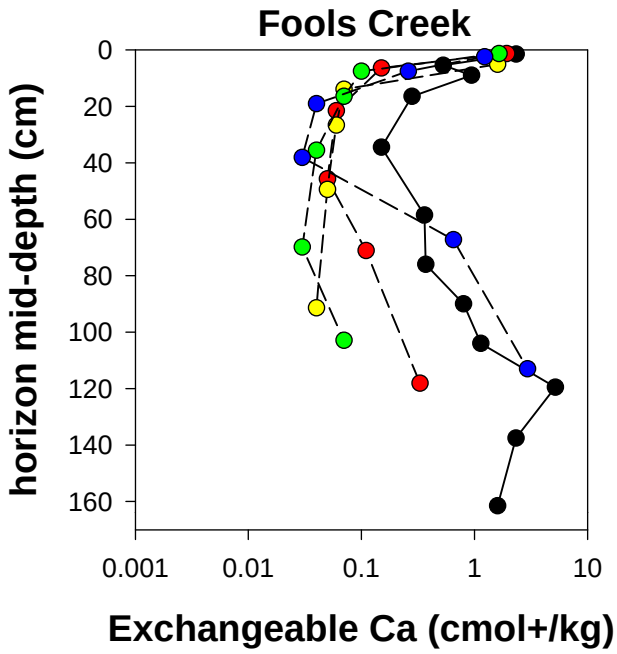
Reanalysis of Archived Samples

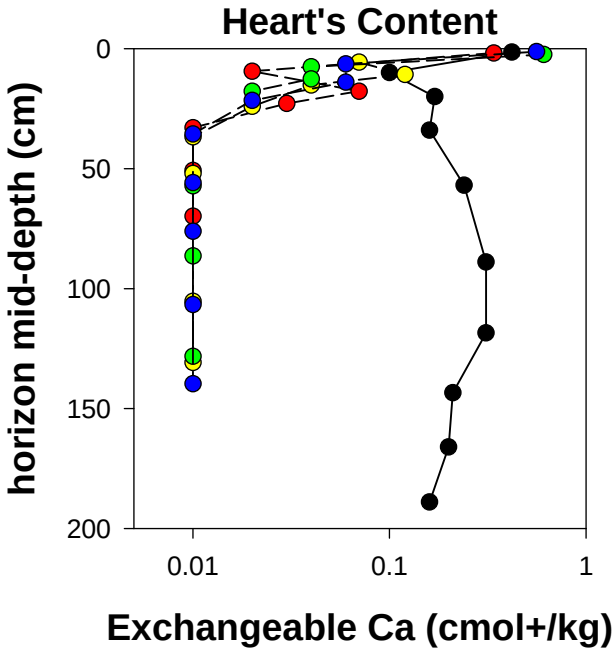


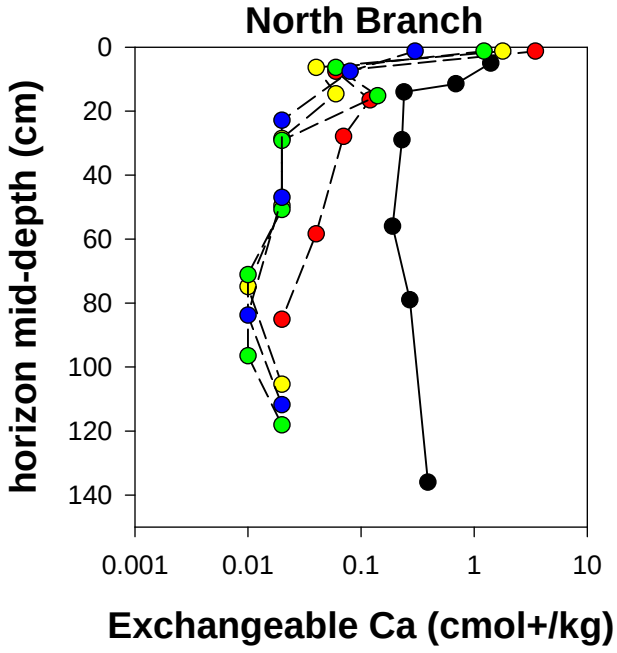
- New and original analyses highly correlated
- pH (7% lower) less well preserved than Ca, Mg, Al

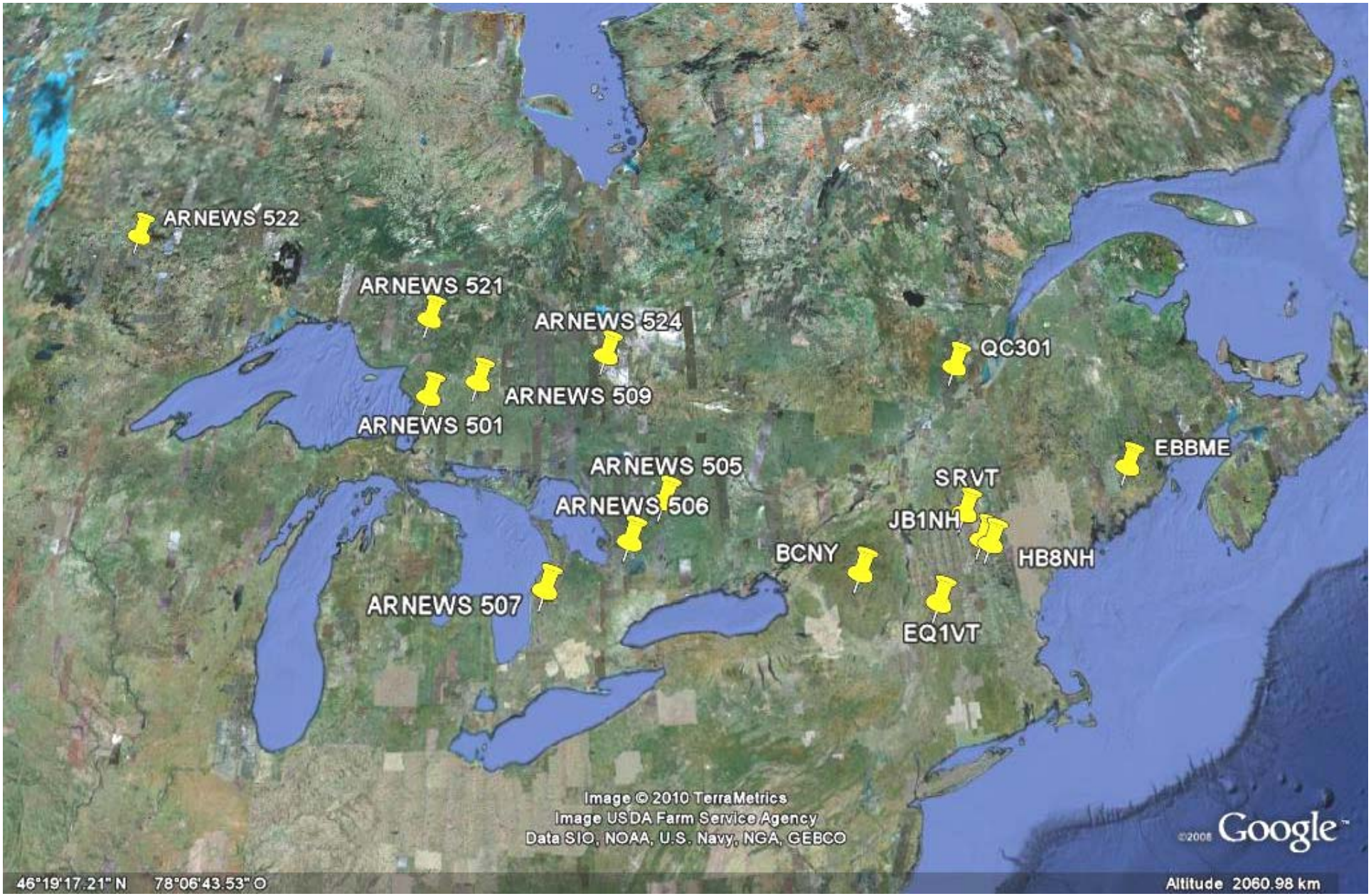
Variation in Exchangeable Calcium 1967 (black) – 1997 (colors)

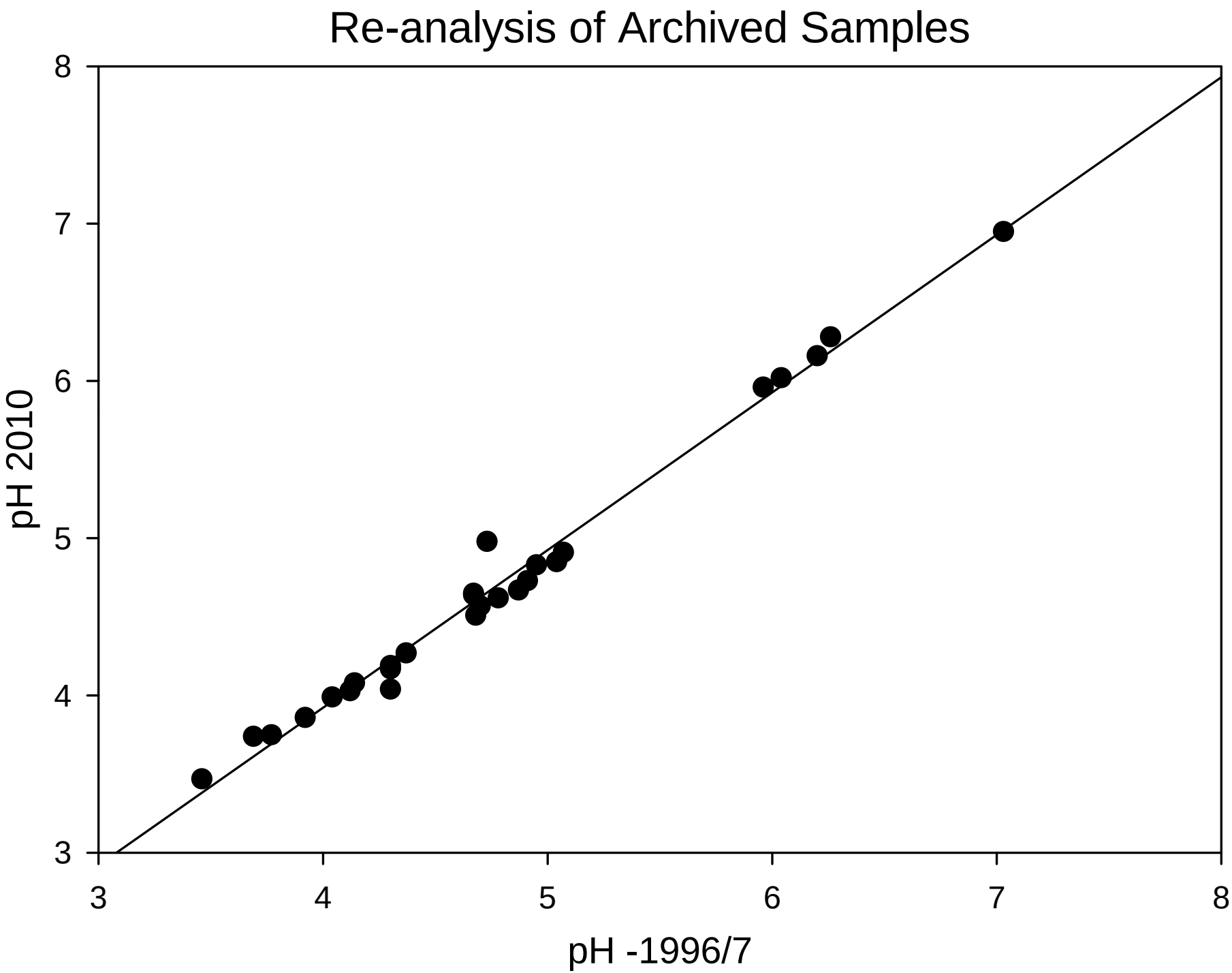


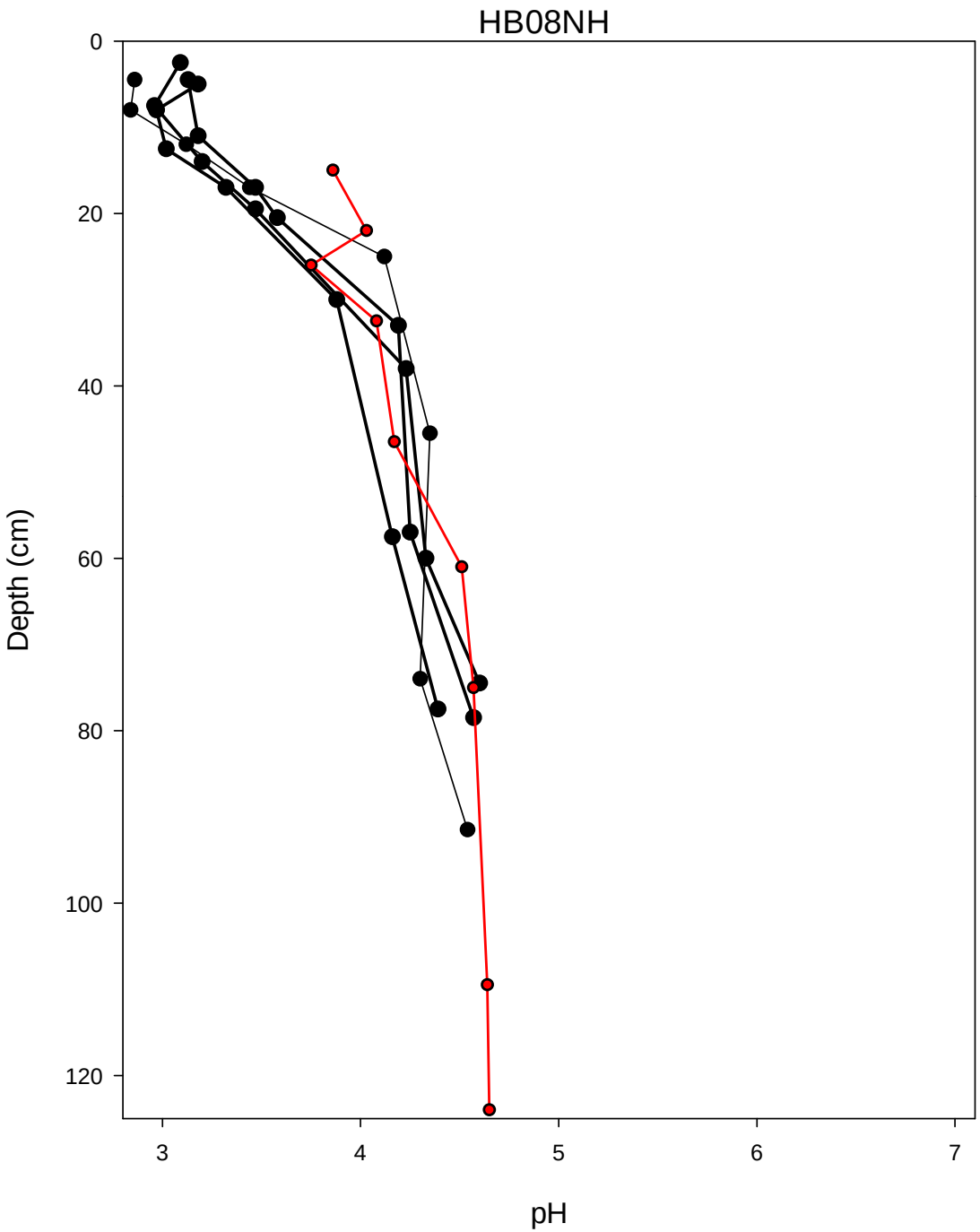


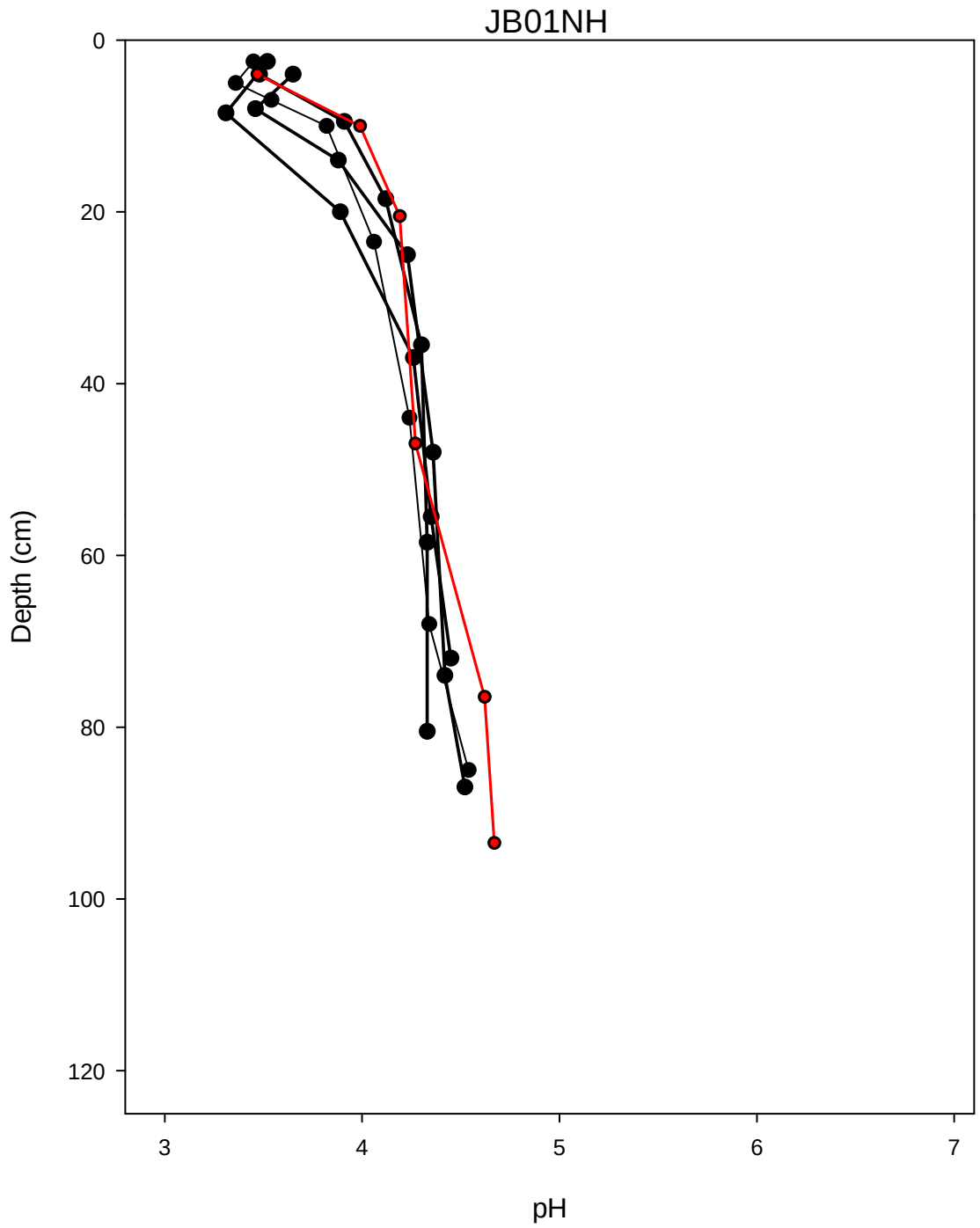


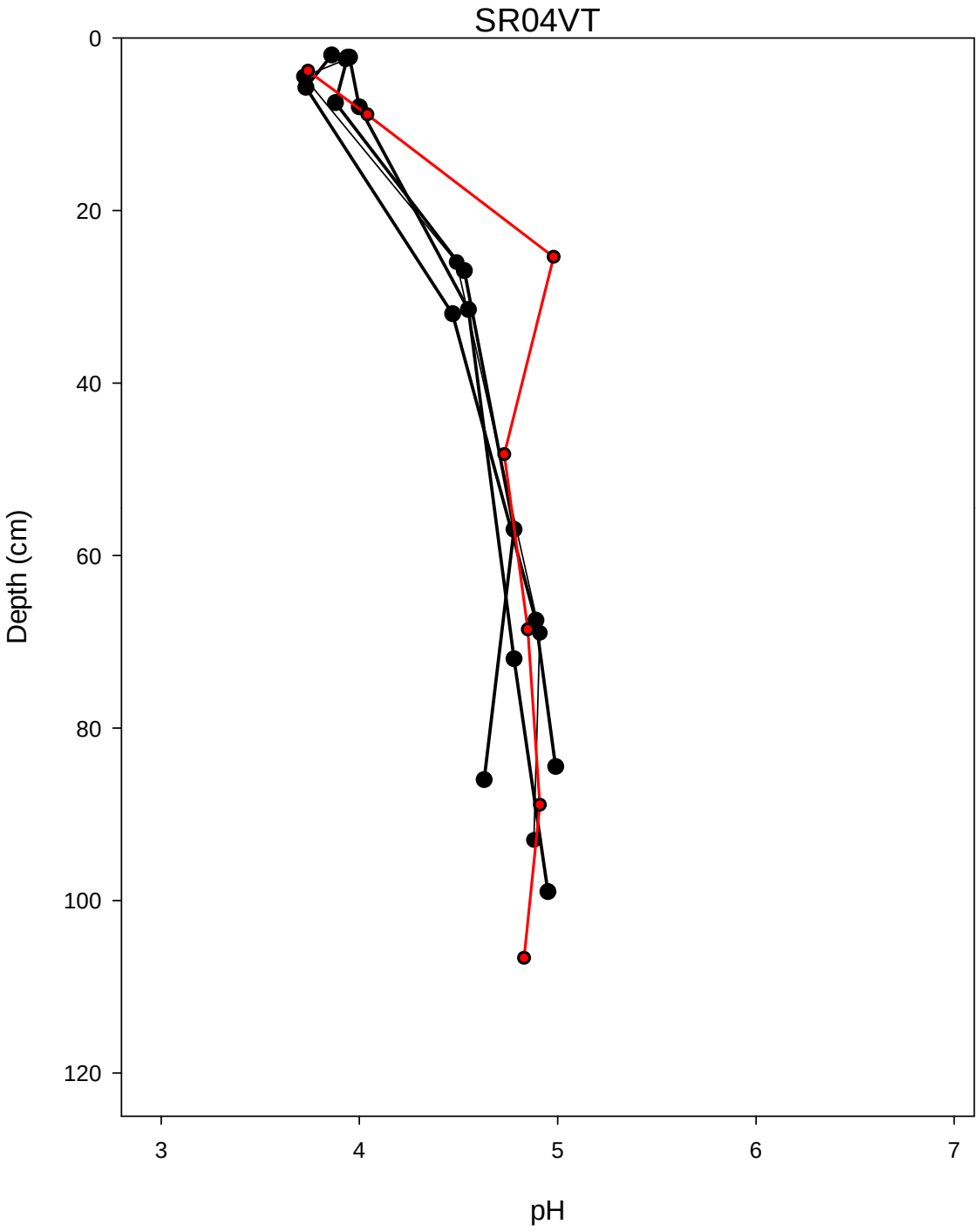


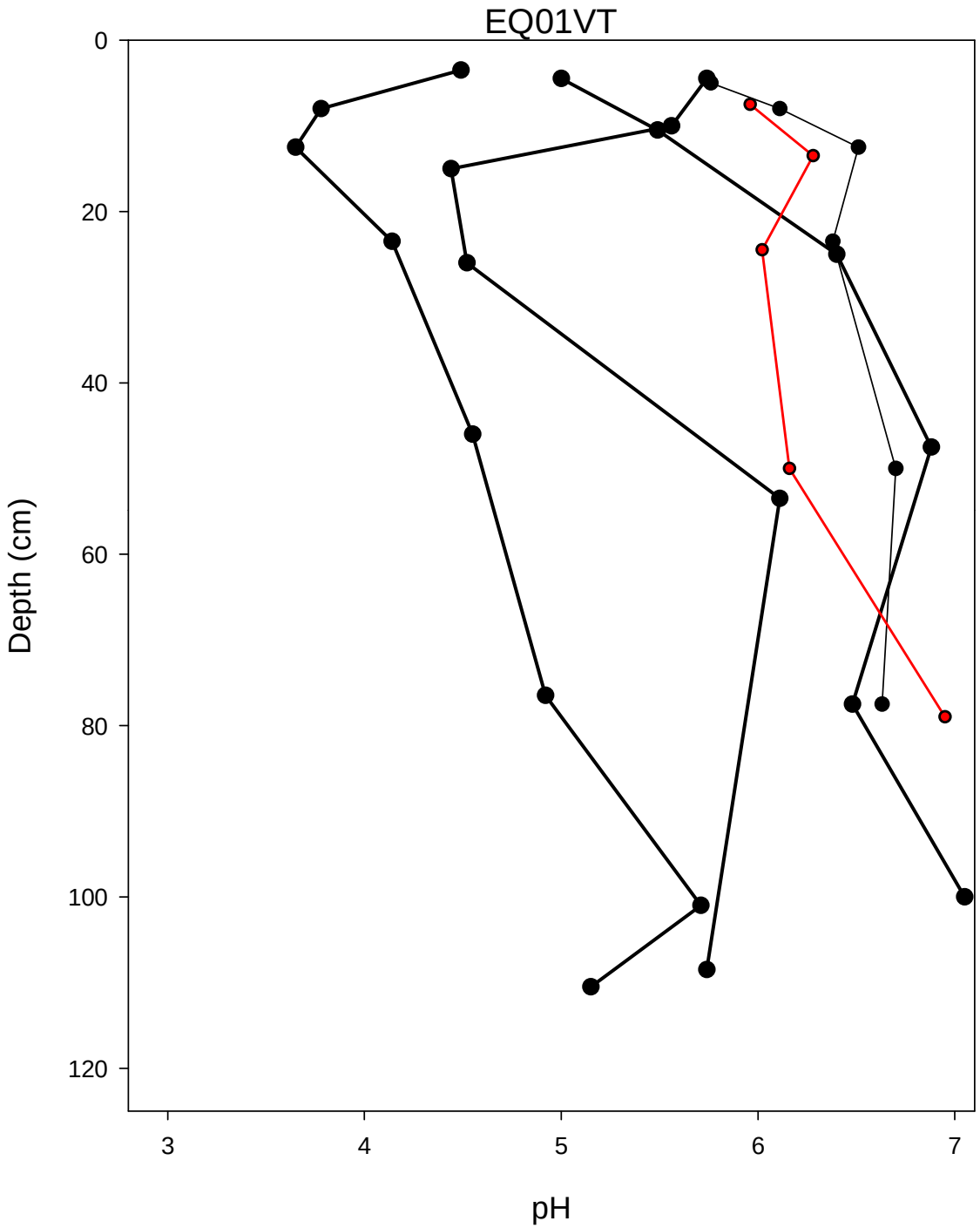

ARNEWS 522
ARNEWS 521
ARNEWS 524
QC301
ARNEWS 509
ARNEWS 501
EBBME
ARNEWS 505
SRVT
ARNEWS 506
JB1NH
HB8NH
BCNY
ARNEWS 507
EQ1VT
Image © 2010 TerraMetrics
Image USDA Farm Service Agency
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
©2008 Google
46°19'17.21" N 78°06'43.53" O
Altitude 2060.98 km


Re-analysis of Archived Samples
pH 2010
pH -1996/7
3
4
5
6
7
8


HB08NH
Depth (cm)
0
20
40
60
80
100
120
3
4
5
6
7
pH


JB01NH
Depth (cm)
0
20
40
60
80
100
120
3
4
5
6
7
pH


SR04VT
Depth (cm)
0
20
40
60
80
100
120
3
4
5
6
7
pH

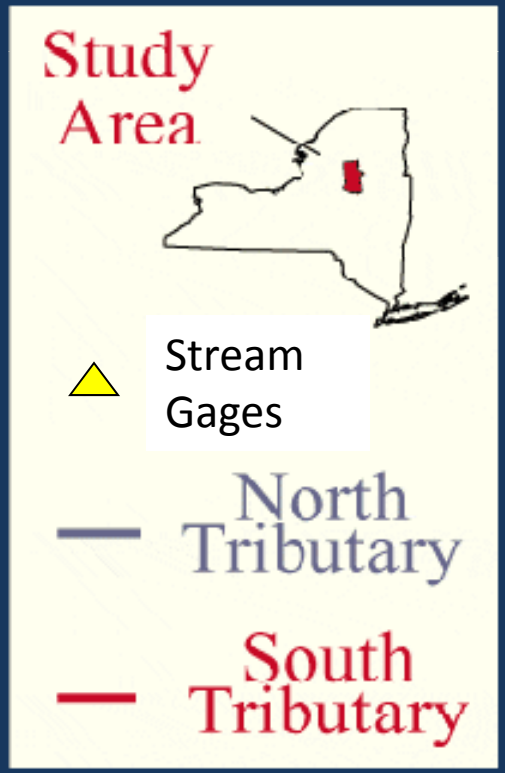

EQ01VT
Depth (cm)
0
20
40
60
80
100
120
3
4
5
6
7
pH

Buck Creek:

NYSERDA

ALSC

USGS

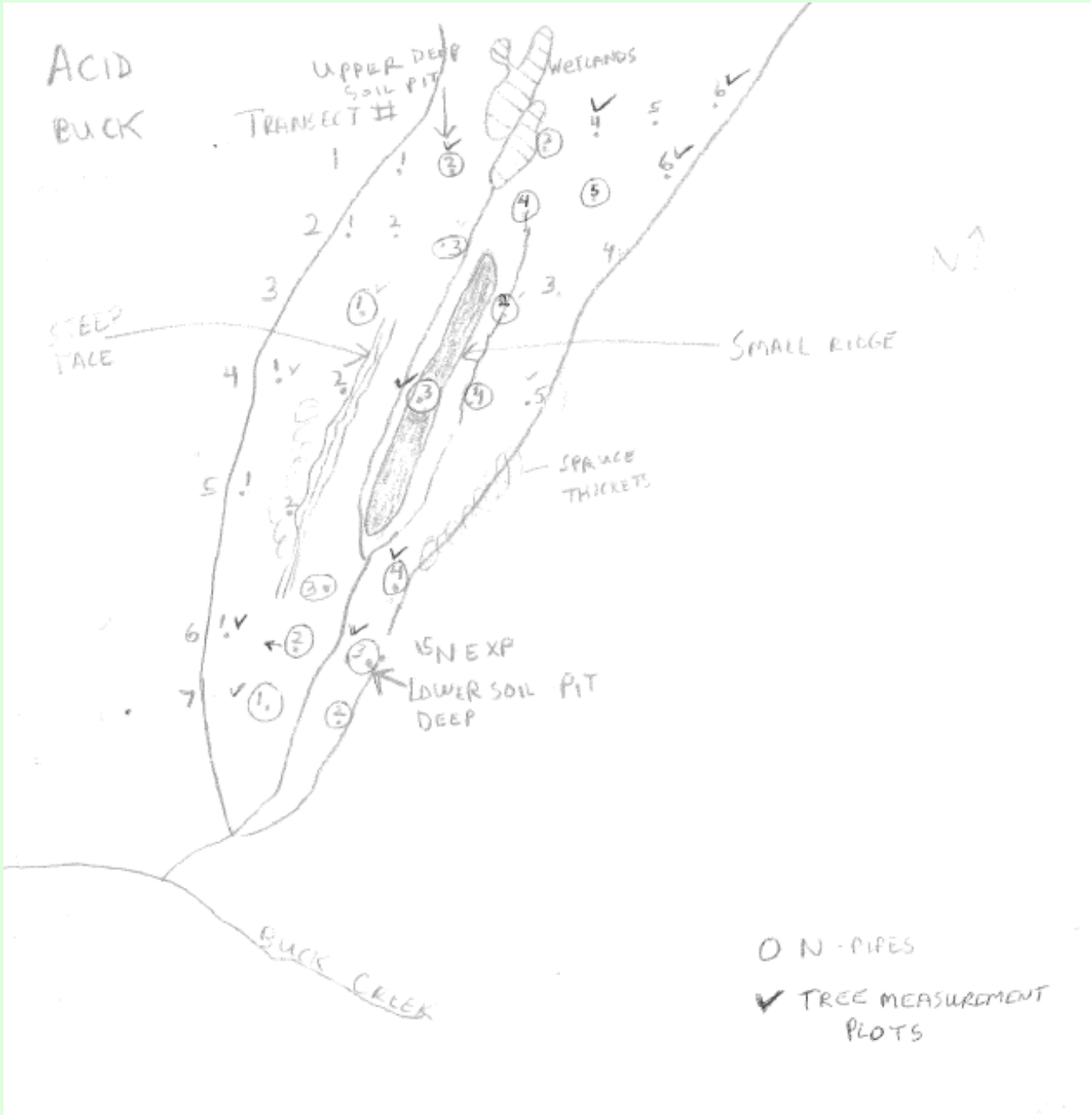


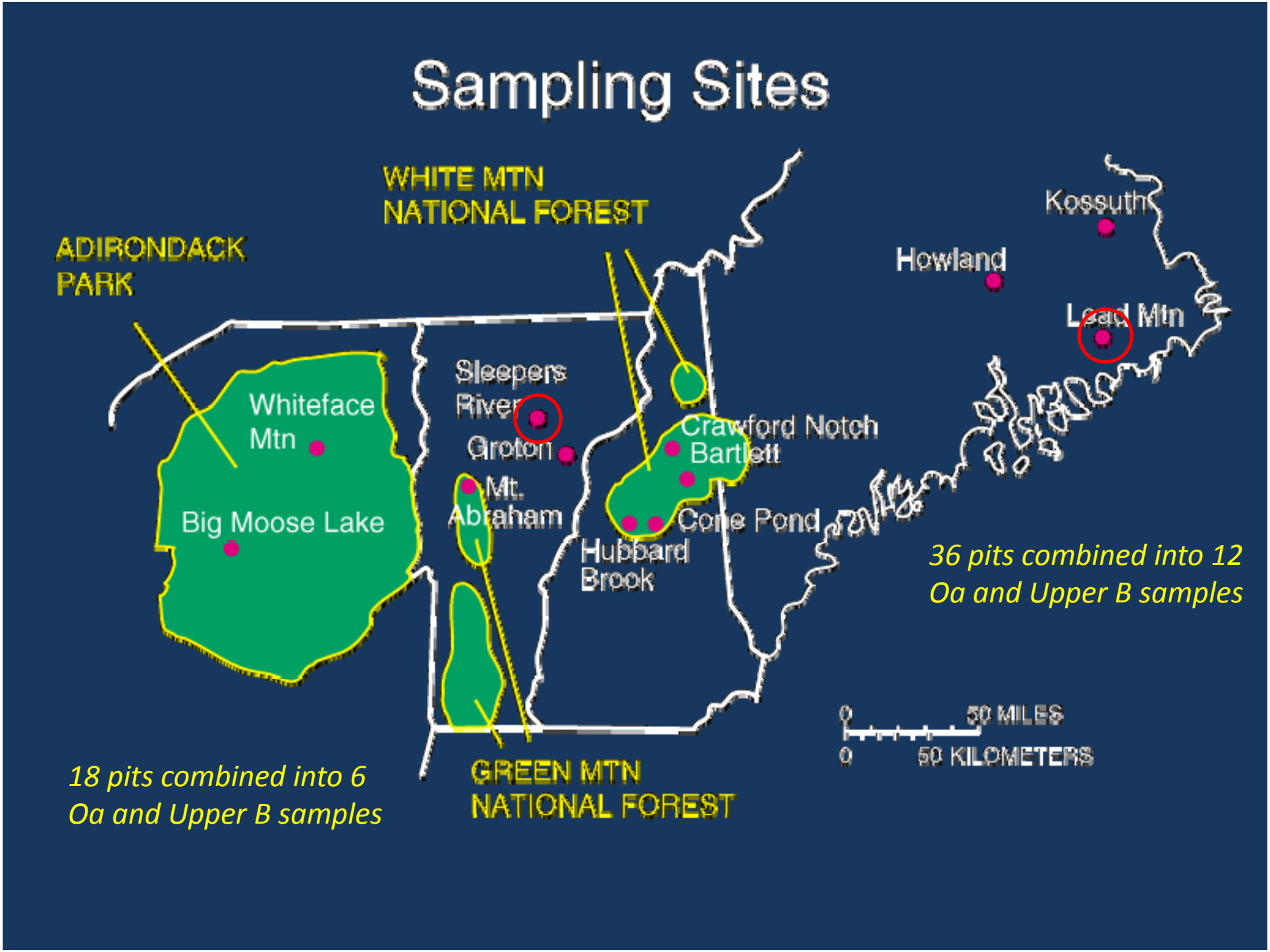

Freezing Injury of Red Spruce Needles, Buck Creek, 2003

Sampling Design

1. Oa and Upper 10 cm of B at 30 locations.

2. 5 replicate pits at 3 locations.




Sampling Sites
WHITE MTN
NATIONAL FOREST
ADIRONDACK
PARK
Kossuth
Howland
Lead Mtn
Whiteface
Mtn
Sleepers
River
Groton
Mt.
Abraham
Big Moose Lake
Crawford Notch
Bartlett
Cone Pond
Hubbard
Brook
36 pits combined into 12
Oa and Upper B samples
0 30 MILES
0 50 KILOMETERS
18 pits combined into 6
Oa and Upper B samples
GREEN MTN
NATIONAL FOREST

Government of Canada | Gouvernement du Canada
Canadian Forestry Service | Service canadien des forêts

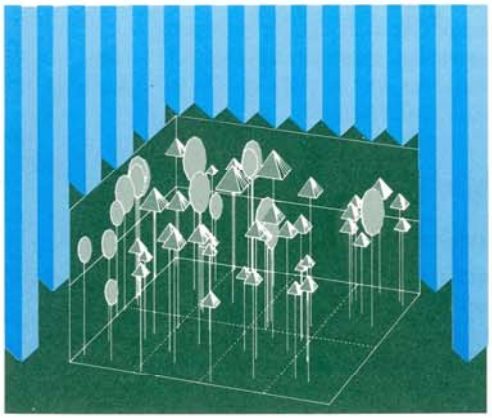
ACID RAIN NATIONAL EARLY WARNING SYSTEM

Manual on Plot Establishment and Monitoring

L.P. Magasi

Information Report DPC-X-25
Forest Science Directorate

The Acid Rain National Early Warning System (ARNEWS): Canada's National Forest Health Monitoring Network



Forestry Canada Forêts Canada

Canada

Figure 1. Location of ARNEWS plots in Canada.

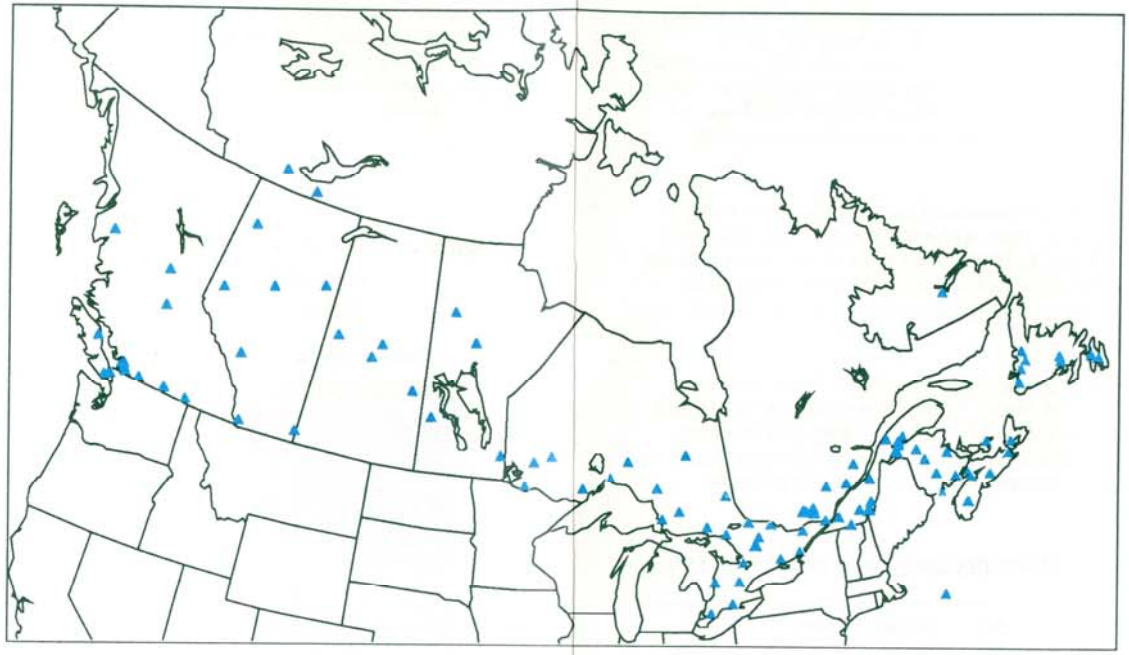


Table 2. Parameters monitored in Canada's ARNEWS plots.

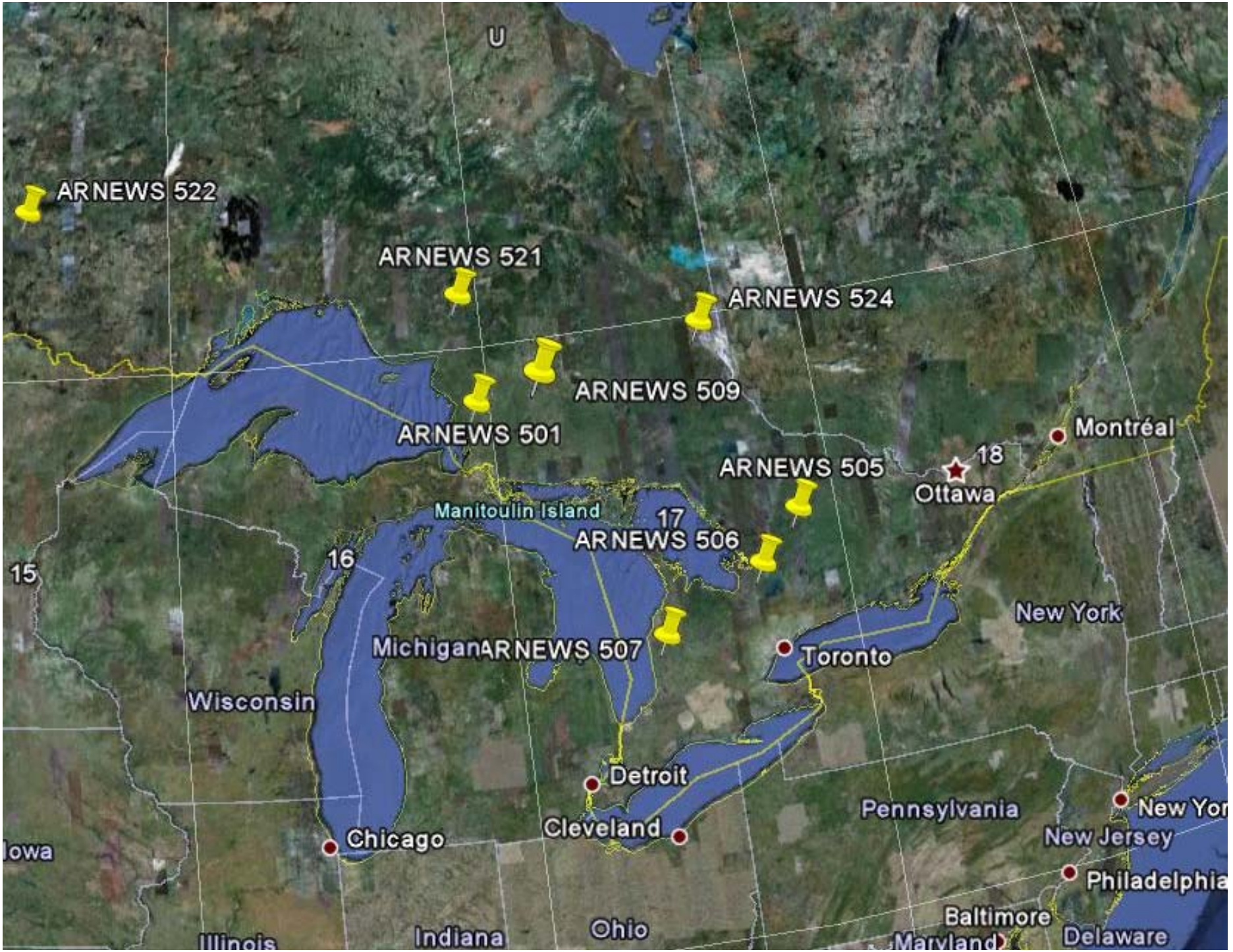
Parameters assessed annually
Tree mortality
Crown and foliage condition
Visible foliar symptoms
Parameters assessed several times per growing season
Insect and disease conditions
Visible foliar symptoms
Seed production
Parameters assessed at 5-year intervals
Radial tree growth
Vertical tree growth
Crown structure and density
Foliage sampling for chemical analysis
Soil sampling for chemical analysis

soil and foliage chemistry, tree growth, and crown structure are assessed (Table 2). Destructive sampling procedures (for example, cutting a branch) that may affect the natural conditions are done on trees adjacent to the plot.

The experience and expertise of trained FIDS staff to judge deviations from a "normal" healthy tree are essential for accurate assessments of crown and foliage conditions. When damage is detected, a search is made for organisms and nonliving factors known to cause the damage. If an agent is found and cannot be identified in the field, samples may be collected or photographs taken to aid in diagnosing the cause later in the laboratory.

Results

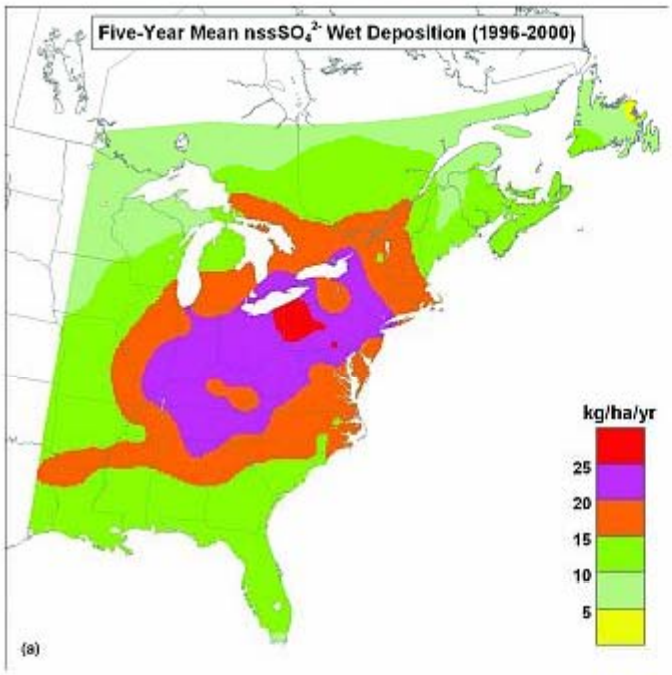
Within normal forest conditions some trees die from a variety of causes, including competition by neighboring trees for sunlight, water, and nutrients. Trees that die from competition are usually in a suppressed crown position, that is, they are smaller and overtopped by their neighbors.

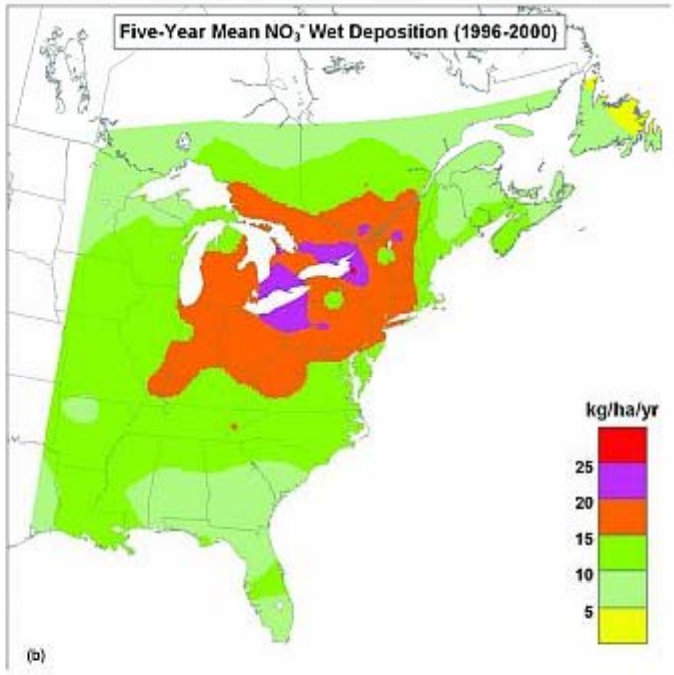

ARNEWS 522
ARNEWS 521
ARNEWS 524
ARNEWS 509
ARNEWS 501
ARNEWS 505
ARNEWS 506
ARNEWS 507
Montréal
18
Ottawa
Manitoulin Island
17
16
15
New York
Toronto
Michigan
Wisconsin
Detroit
Pennsylvania
Chicago
Cleveland
New Jersey
Philadelphia
Baltimore
Indiana
Ohio
Delaware

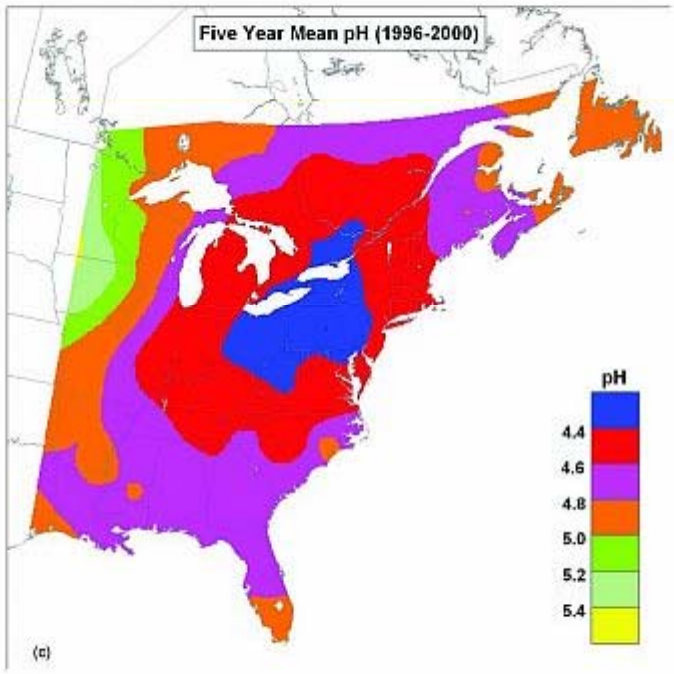

521

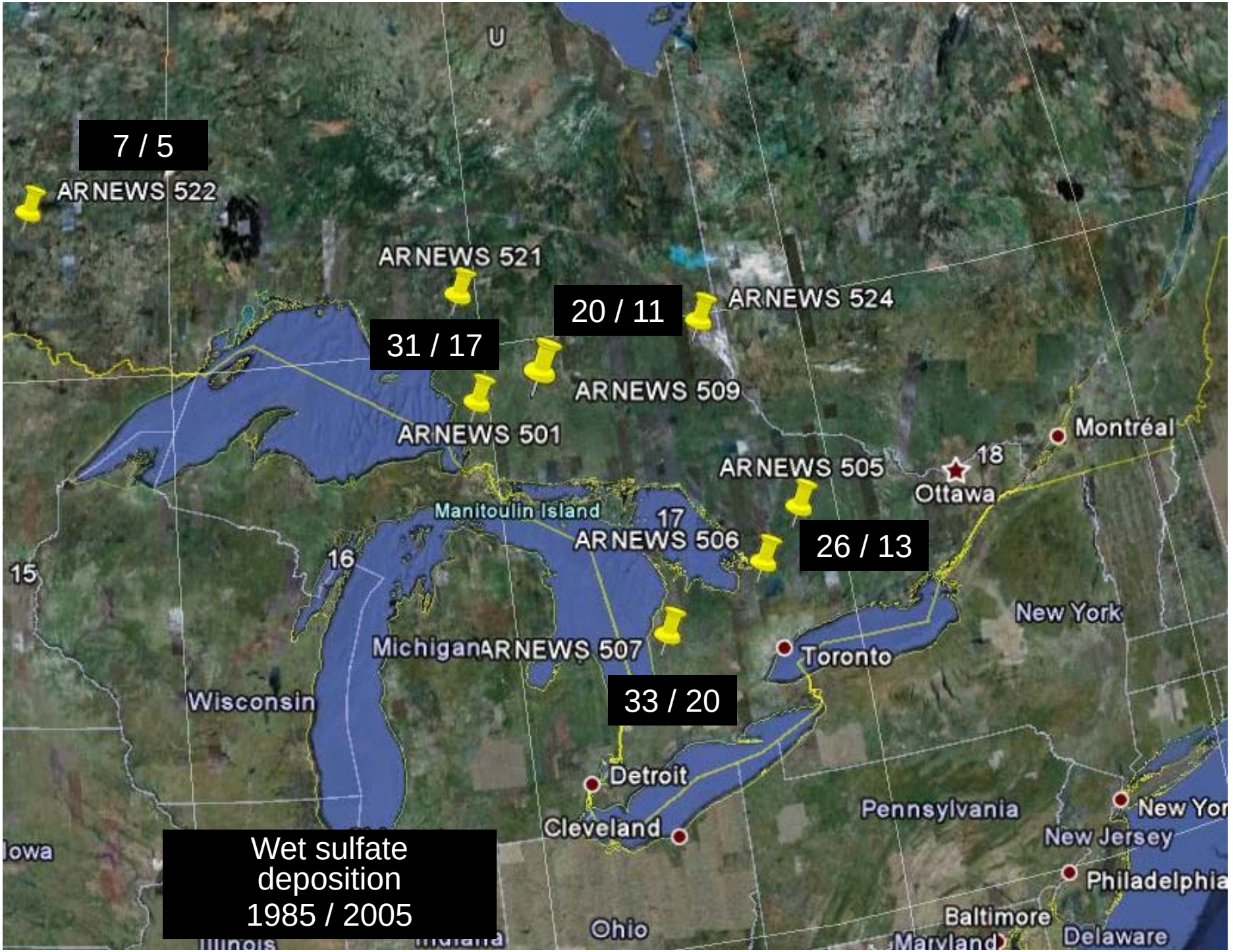

507

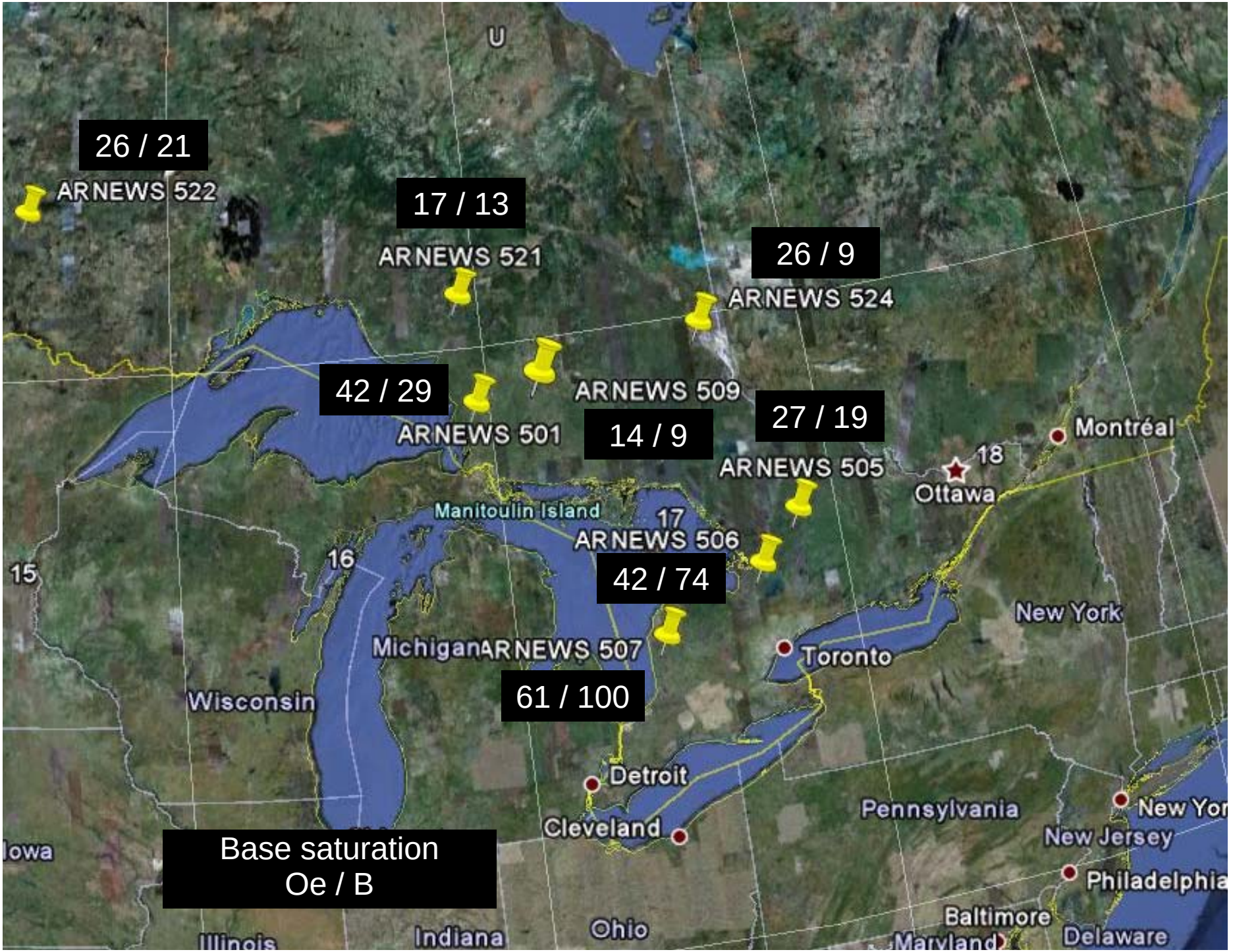

505

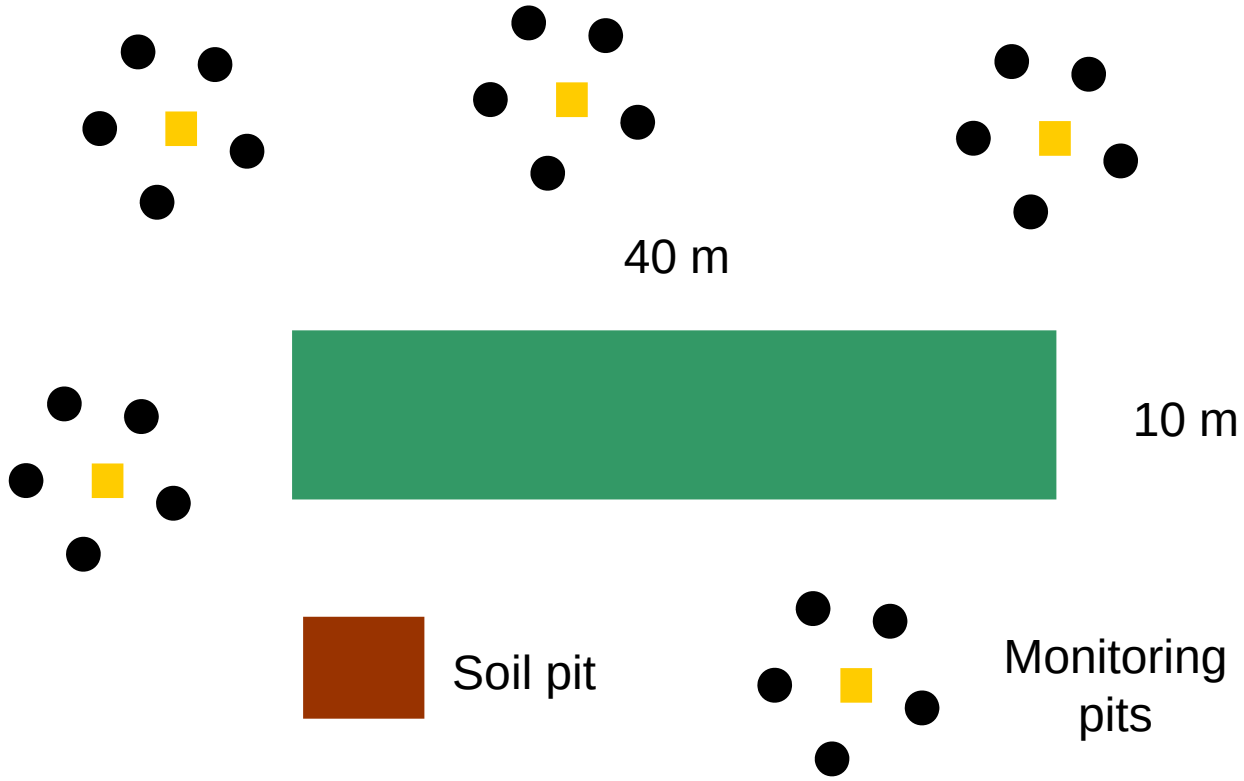

Five-Year Mean nssSO_4^{2-} Wet Deposition (1996-2000)
kg/ha/yr
25
20
15
10
5
(a)

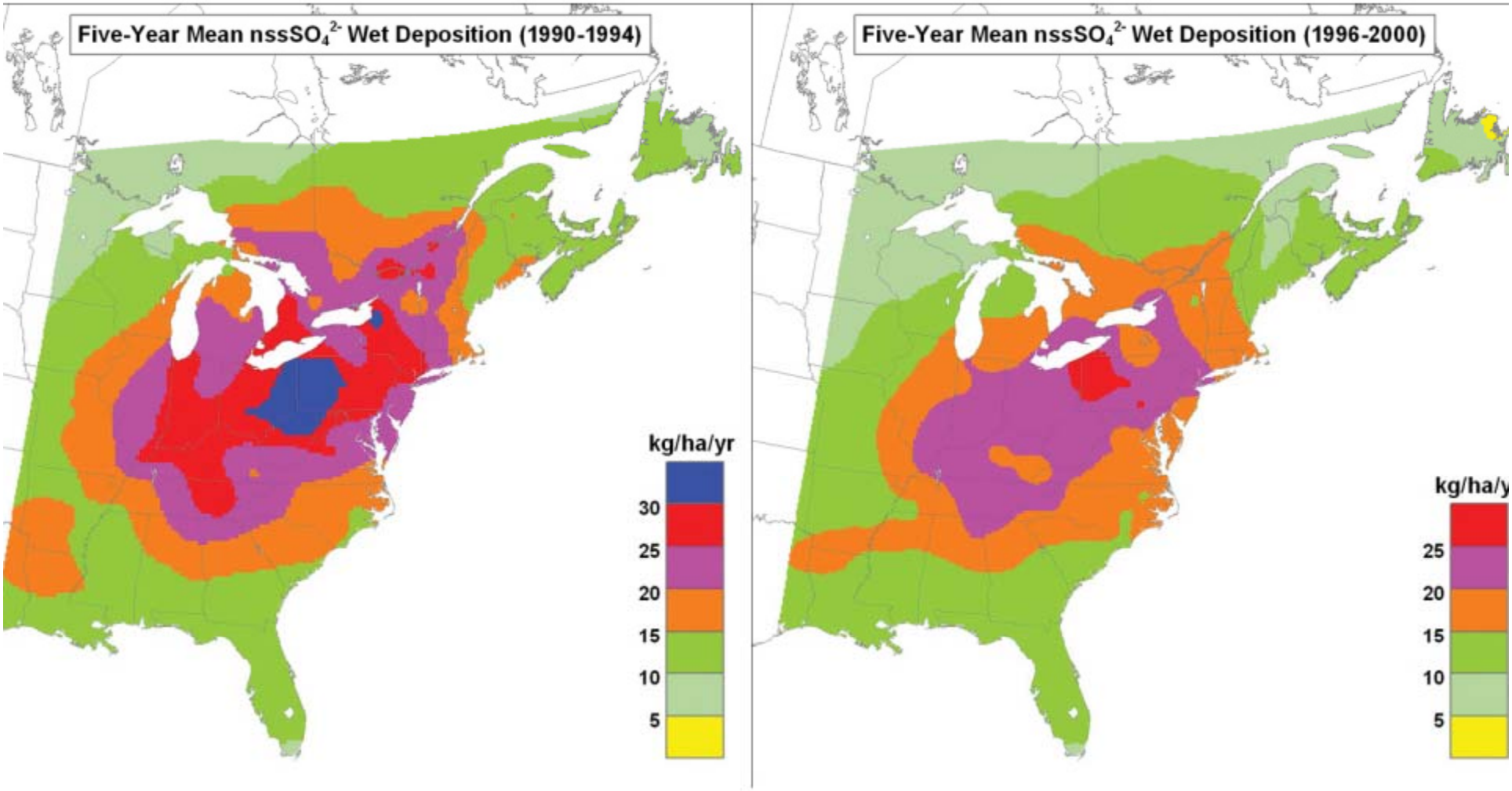

Five-Year Mean NO_3^- Wet Deposition (1996-2000)
kg/ha/yr
25
20
15
10
5
(b)

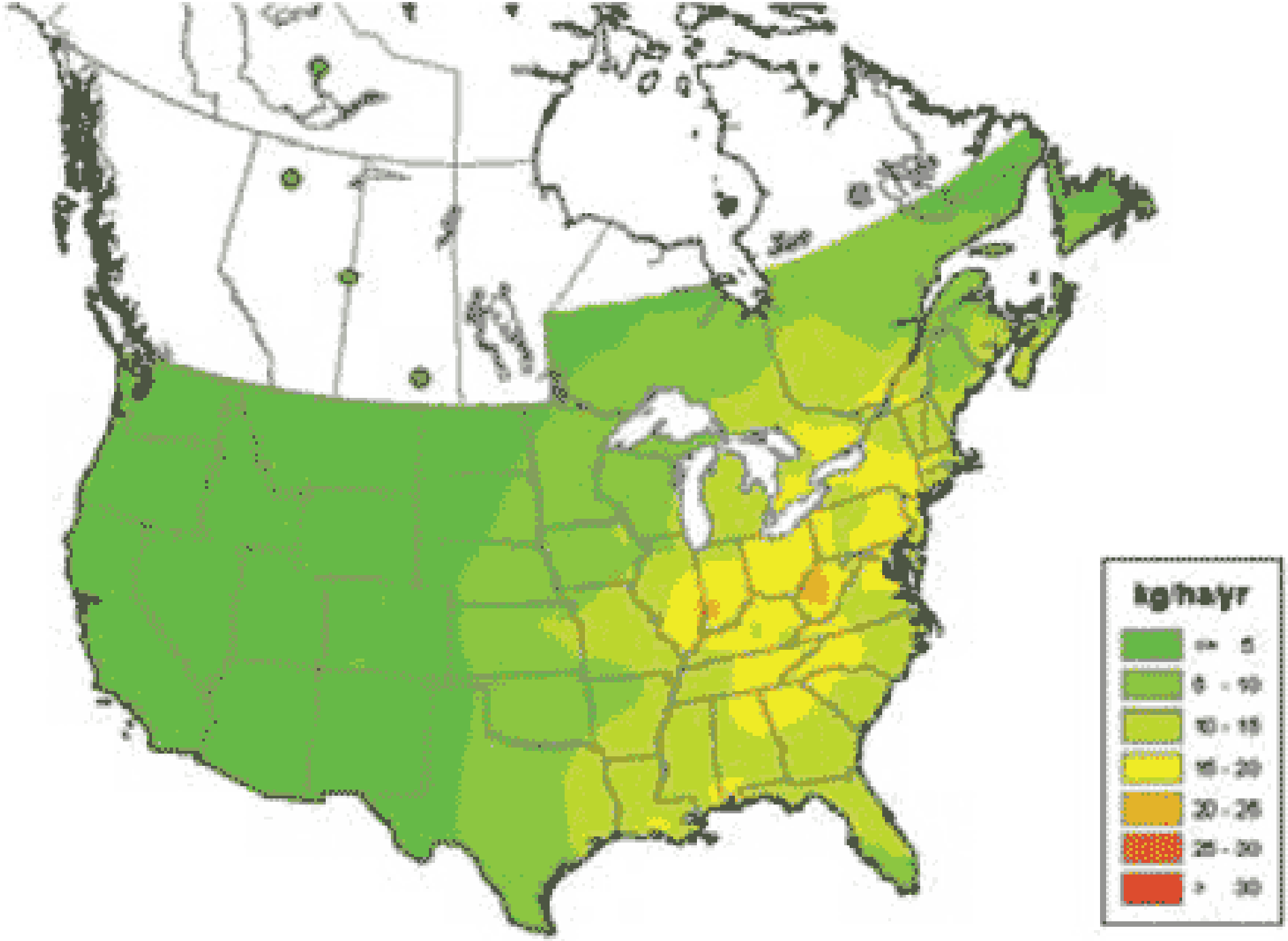

Five Year Mean pH (1996-2000)
pH
4.4
4.6
4.8
5.0
5.2
5.4
(c)


7 / 5
ARNEWS 522
ARNEWS 521
20 / 11
ARNEWS 524
31 / 17
ARNEWS 509
ARNEWS 501
Montréal
ARNEWS 505
18
Ottawa
Manitoulin Island
17
ARNEWS 506
26 / 13
16
15
New York
Michigan
ARNEWS 507
Toronto
Wisconsin
33 / 20
Detroit
Pennsylvania
Cleveland
New Jersey
Philadelphia
Baltimore
Ohio
Maryland
Delaware
Wet sulfate deposition 1985 / 2005


26 / 21
ARNEWS 522
17 / 13
ARNEWS 521
26 / 9
ARNEWS 524
42 / 29
ARNEWS 501
ARNEWS 509
14 / 9
27 / 19
ARNEWS 505
Montréal
18
Ottawa
Manitoulin Island
17
ARNEWS 506
16
15
42 / 74
New York
Michigan
ARNEWS 507
Toronto
61 / 100
Wisconsin
Detroit
Pennsylvania
Cleveland
New Jersey
Philadelphia
Baltimore
Maryland
Delaware
Indiana
Ohio
Base saturation
Oe / B


40 m
10 m
Soil pit
Monitoring pits


Five-Year Mean nssSO_4^{2-} Wet Deposition (1990-1994)
kg/ha/yr
30
25
20
15
10
5
Five-Year Mean nssSO_4^{2-} Wet Deposition (1996-2000)
kg/ha/y
25
20
15
10
5


kg/ha/yr