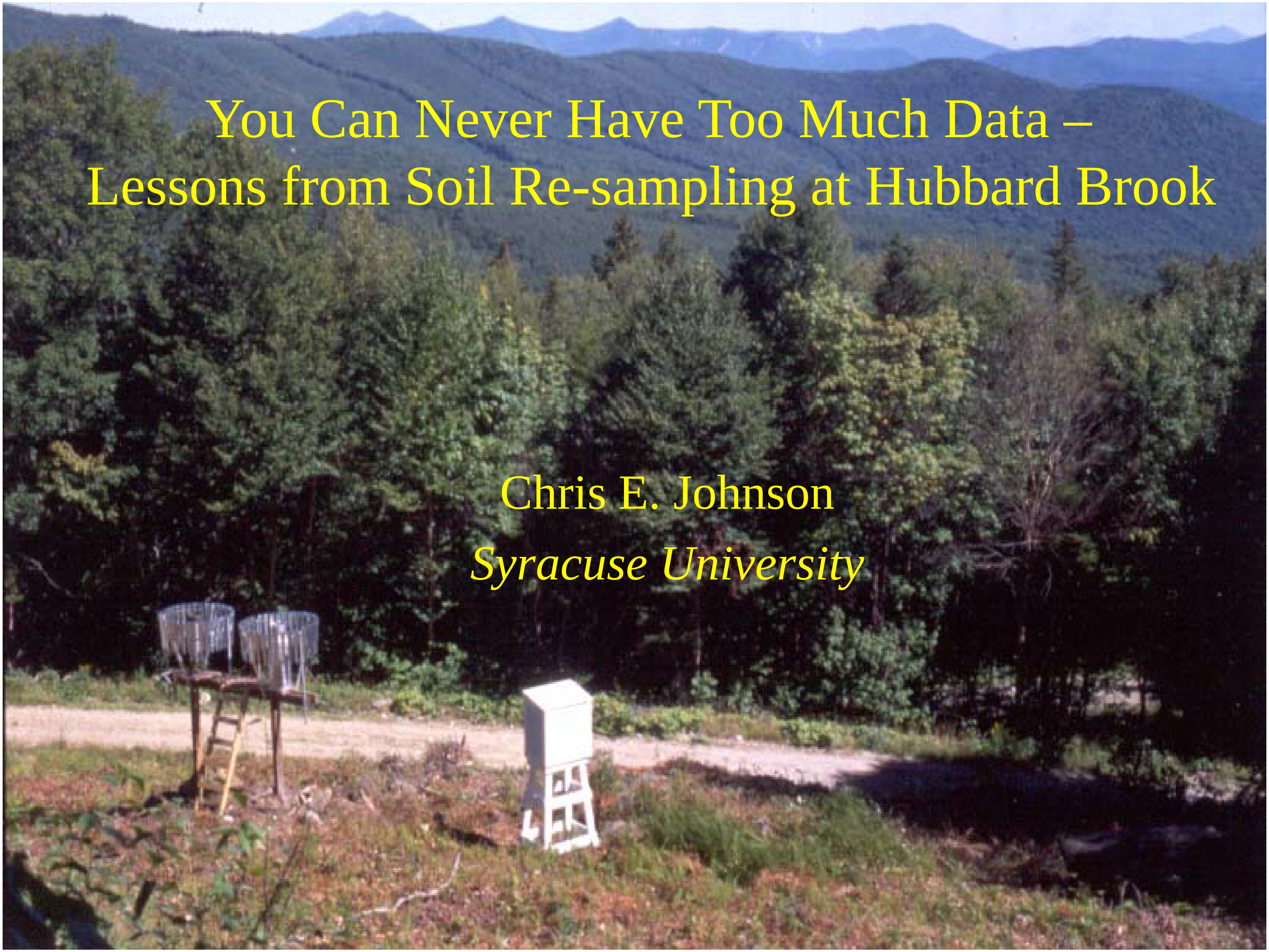
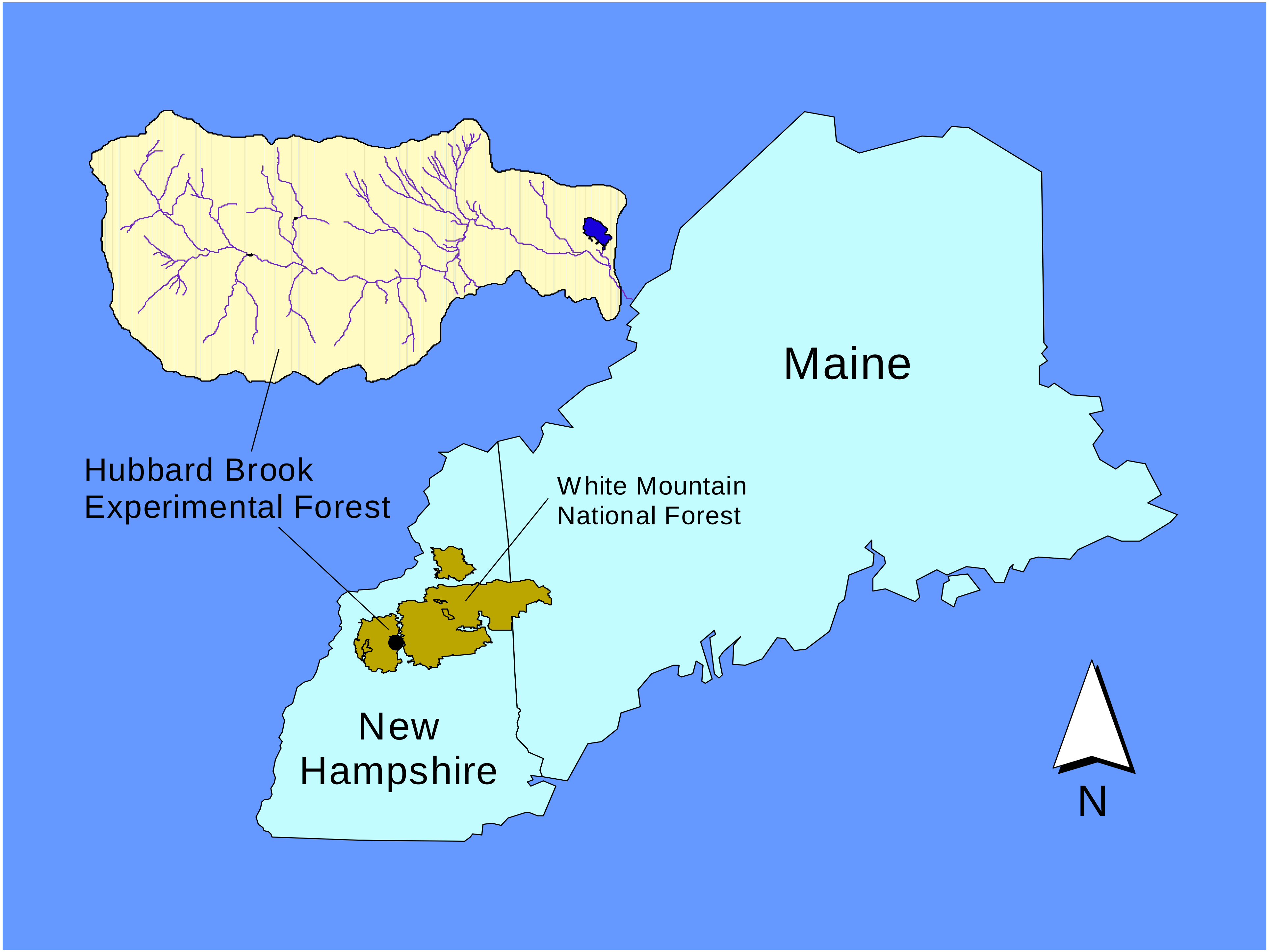


You Can Never Have Too Much Data – Lessons from Soil Re-sampling at Hubbard Brook

Chris E. Johnson

Syracuse University


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

U.S. Long-Term Ecological Research Network

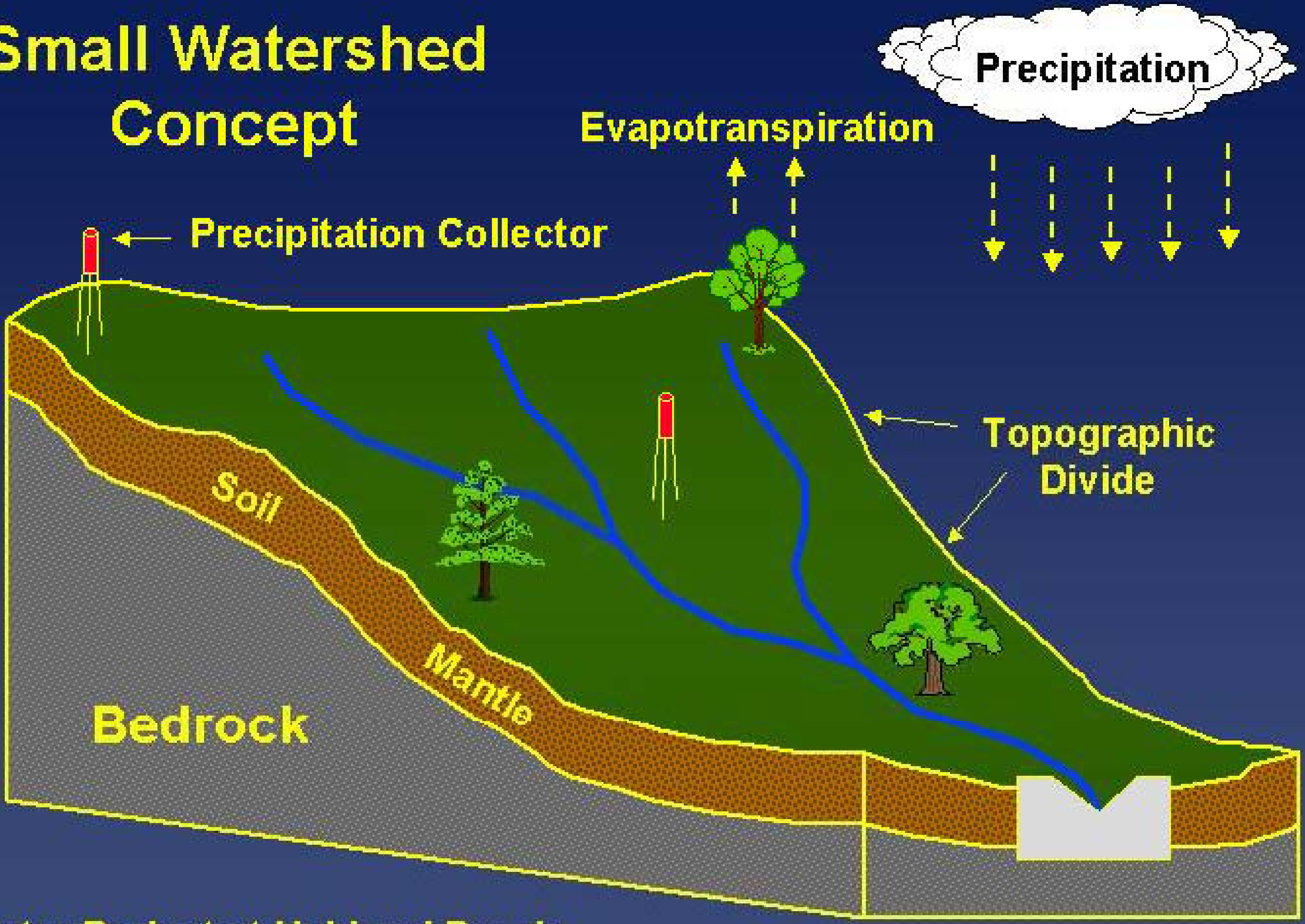
The Hubbard Brook Experimental Forest

- Established in 1955 by the USDA Forest Service for hydrologic research.

Hubbard Brook Ecosystem Study

- Initiated in 1963 using the small watershed approach to study hydrologic cycle-element interactions in small undisturbed and human-manipulated forest ecosystems.

Small Watershed Concept



Water Budget at Hubbard Brook:

Precipitation (100%) = Streamflow (60%) + Evapotranspiration (40%)

Hubbard Brook Experimental Forest

Characteristics of the Hubbard Brook Experimental Forest

Bedrock	Quartz Mica Schist and Quartzite
Landscape	Till-Mantled Glacial Valleys
Soils	Spodosols (Typic Haplorthods)

	pH_w	%BS
Oa	3.9	50
Mineral Soil	4.3	12

Vegetation	Northern Hardwood Forest; Cutting 1915-17; 80-90% Hardwoods, 10-20% Conifers
Climate	Humid Continental, Mean Precipitation 1400 mm

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.

Hubbard Brook Ecosystem Study
Why we monitor soils:

1. To support comprehensive biogeochemical studies.
    - Chemical budgets
    - Calculation of turnover time
    - Interpretation of ecological and geochemical data

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Hubbard Brook Ecosystem Study

Why we monitor soils:

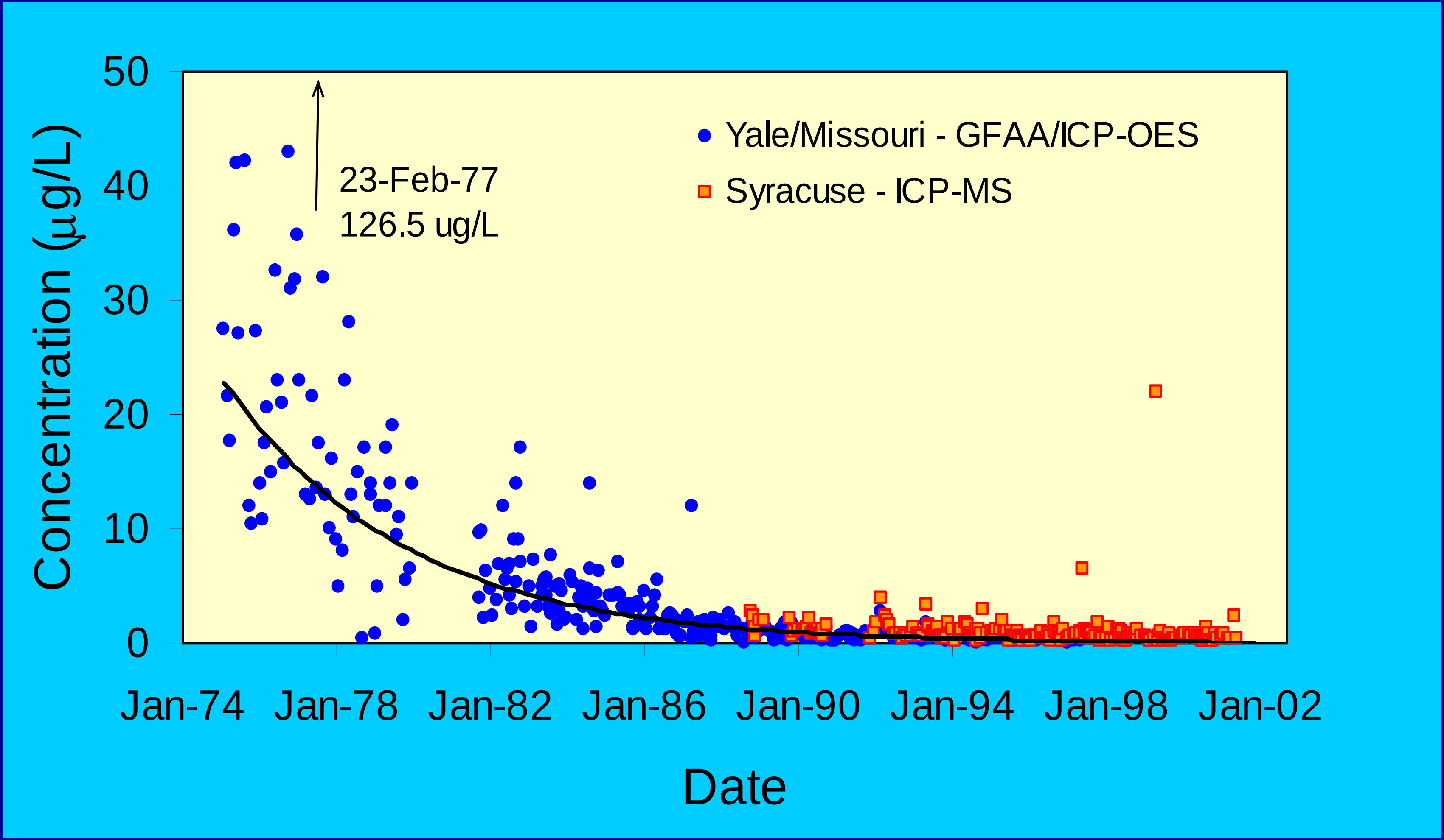
1. To support comprehensive biogeochemical studies.
   - Chemical budgets
   - Calculation of turnover time
   - Interpretation of ecological and geochemical data
2. To be prepared for serendipity.
3. To test hypotheses concerning disturbance effects on soils.
   - Forest management (clear-cutting)
   - Acid rain and recovery

Changes in Lead (Pb) Cycling with Decreasing Atmospheric Inputs

Background

- Major sources of Pb: Smelting, Battery Production, Paints, Gasoline (Petrol).
- Alkyl-Pb compounds used as anti-knock additives in gasoline beginning in 1923.
- With increasing automobile/truck traffic, gasoline became principal source of atmospheric Pb in USA.
- 1970: Clean Air Act; General Motors announces intent to comply by installing catalytic converters beginning in 1974. Other auto makers follow.
- US Pb consumption declines > 90% 1975 – 1985.
- Natural ecosystem experiment…

Pb concentration in bulk precipitation has declined to ~1% of 1975 values



Remarkably…

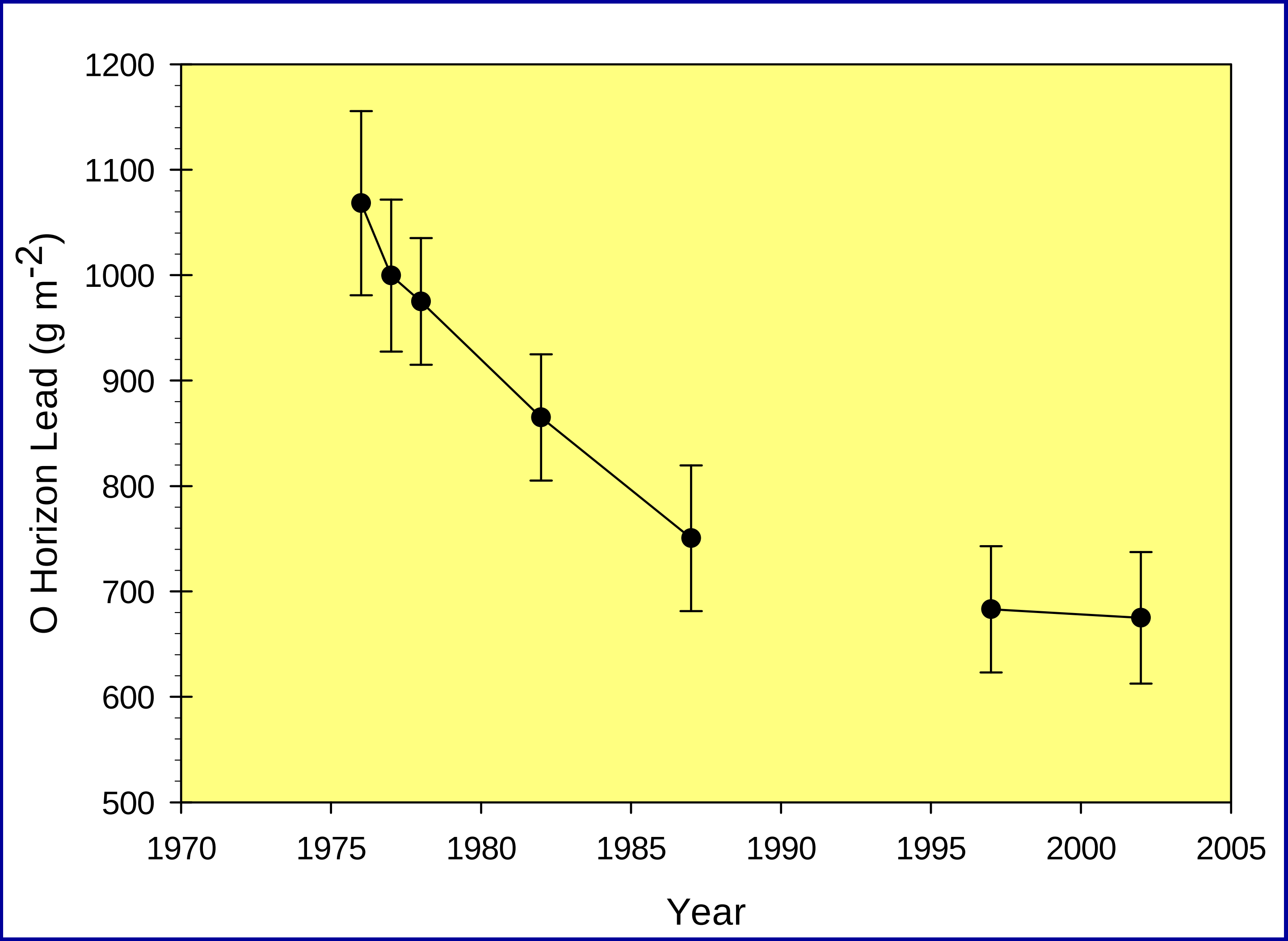
Pb input in precipitation has declined by more than 98%

BUT

Precipitation input continues to exceed stream output

So, what is happening in the soil?

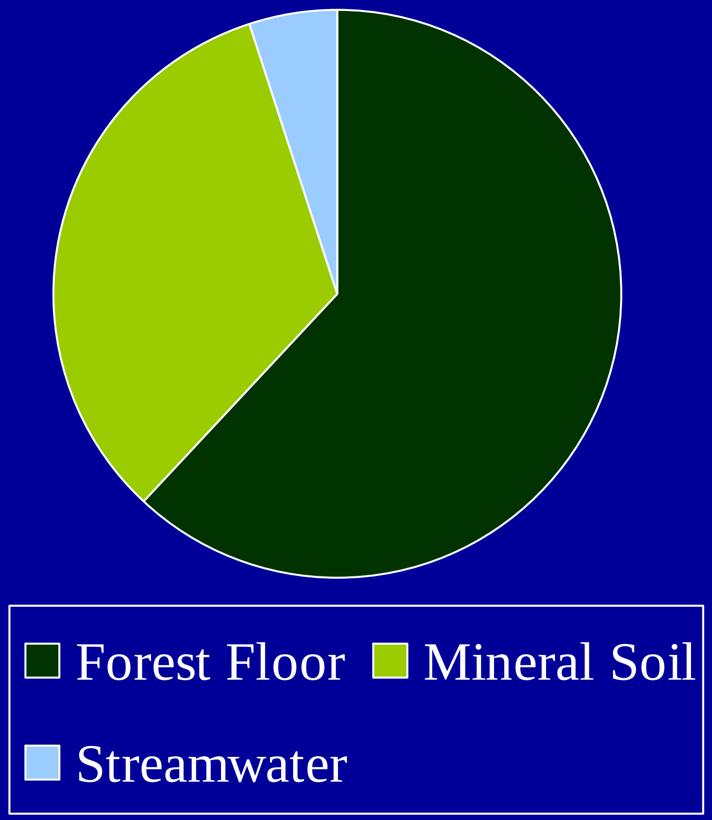
The Pb content of the O horizon has declined by 40% since 1976



Johnson et al. (1995) + unpublished data

Modern (1926-1997) Lead Budget for the HBEF
All values: kg/ha

1.	Atmospheric Deposition – 1926-1997	8.76
2.	Pb in Forest Floor - 1997	6.80
3.	Estimated Pb in Forest Floor - 1926	1.35
4.	Net Accumulation of Pb in Forest Floor (2) – (3)	5.45
5.	Estimated Stream Flux – 1926-1997 (0.7 µg/L, 87 cm yr^{-1} runoff)	0.43
6.	Flux to Mineral Soil (1) – (4) – (5)	2.88



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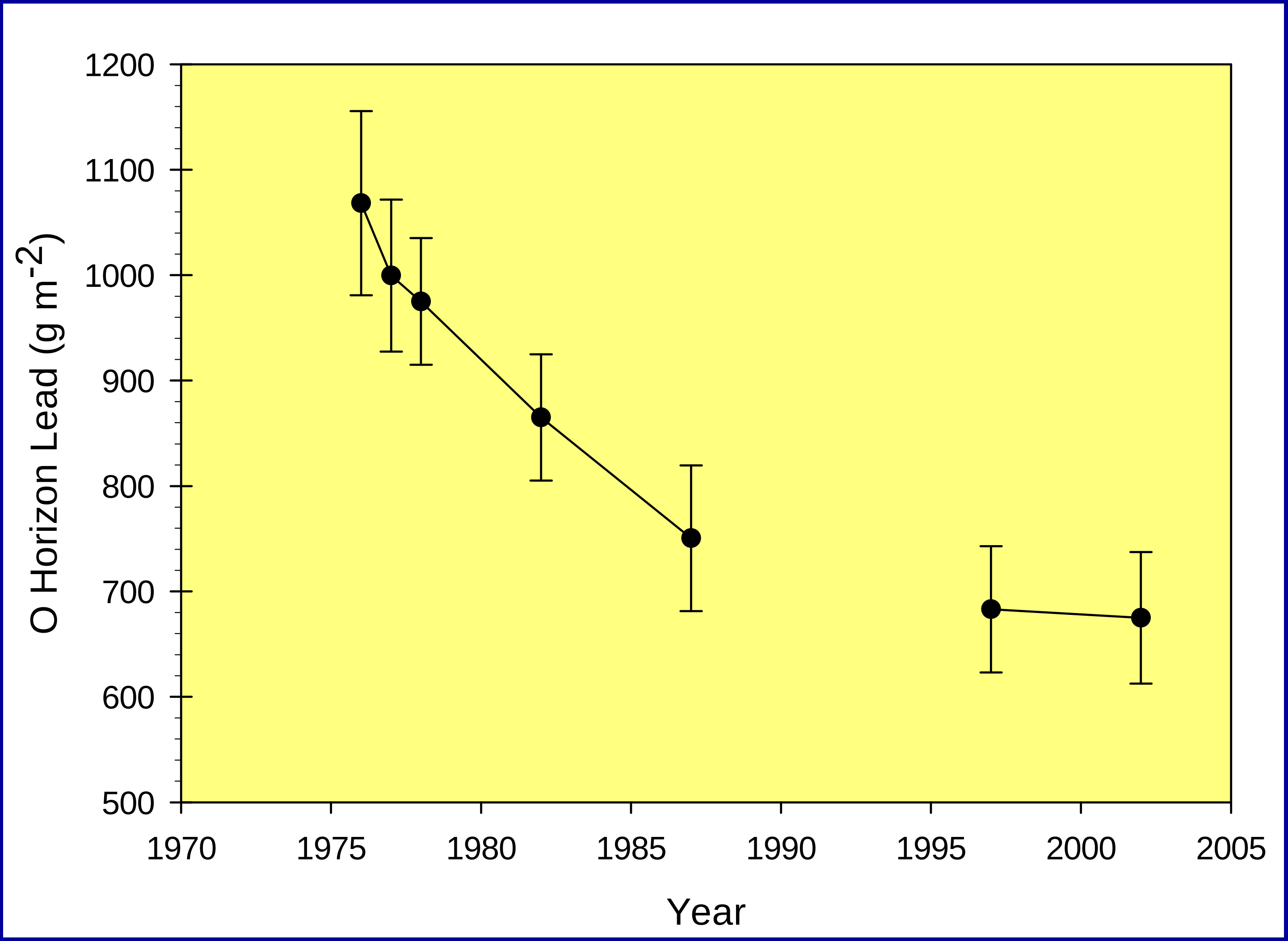
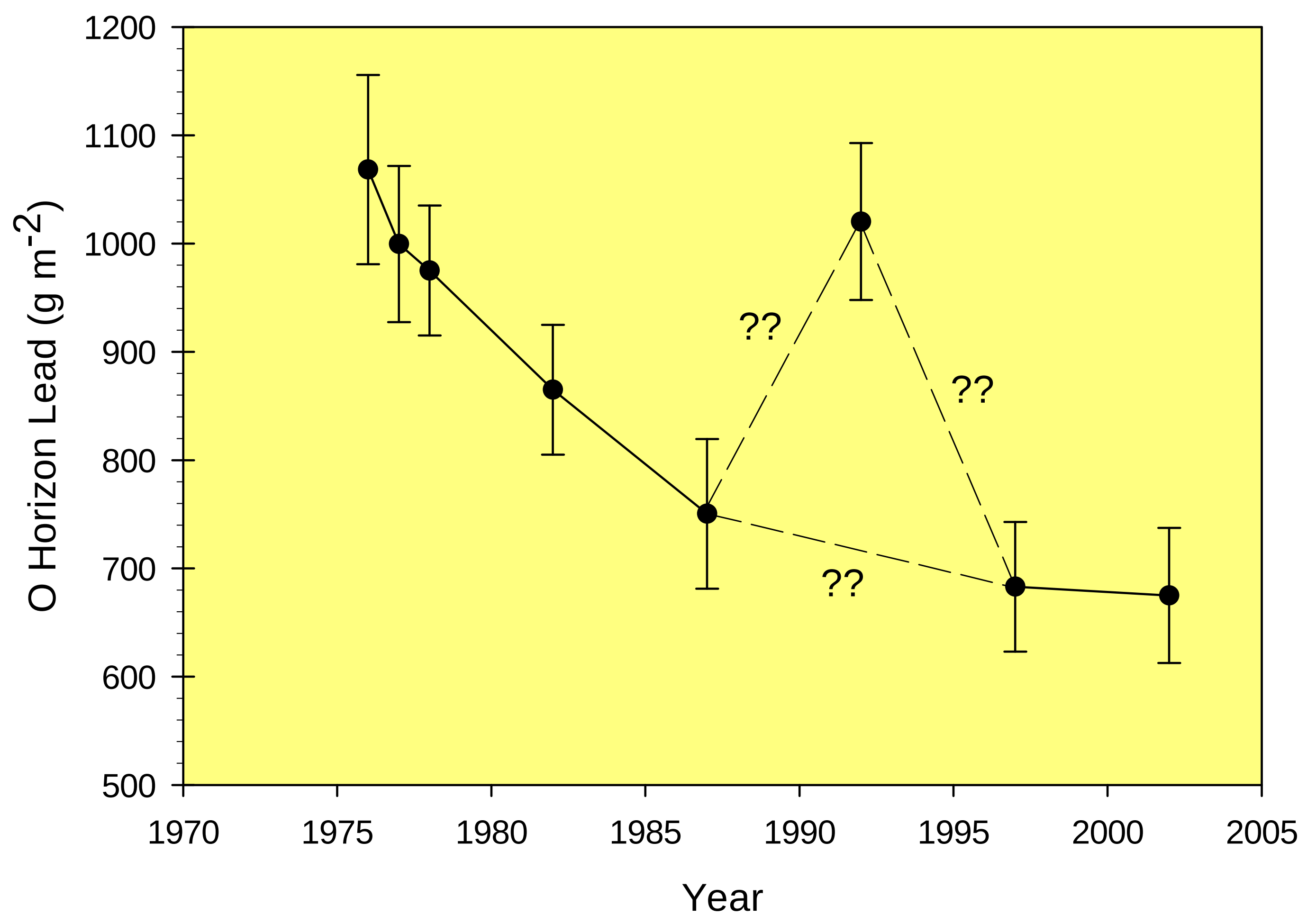


Johnson et al. (1995) + unpublished data

Maybe You CAN Have Too Much Data!



Johnson et al. (1995) + unpublished data

Changes in Soil Chemistry 15 Years after Whole-Tree Clearcutting

Nutrient Pools – Biomass vs. Soil (kg/ha)

	Calcium		Potassium		
Location	Biomass	Exch.	Biomass	Exch.	Ref.
Baie Comeau, Québec	277	45	84	132	(1)
St. Jovite, Québec	413	117	159	65	(1)
Weymouth Pt., ME	537	392	245	159	(2)
W5 - Hubbard Brook, NH	656	321	245	153	(3)

(1) Weetman & Webber, 1972
(2) Smith et al., 1986
(3) Swank & Johnson, 1994

Nutrient Release after Clear-felling

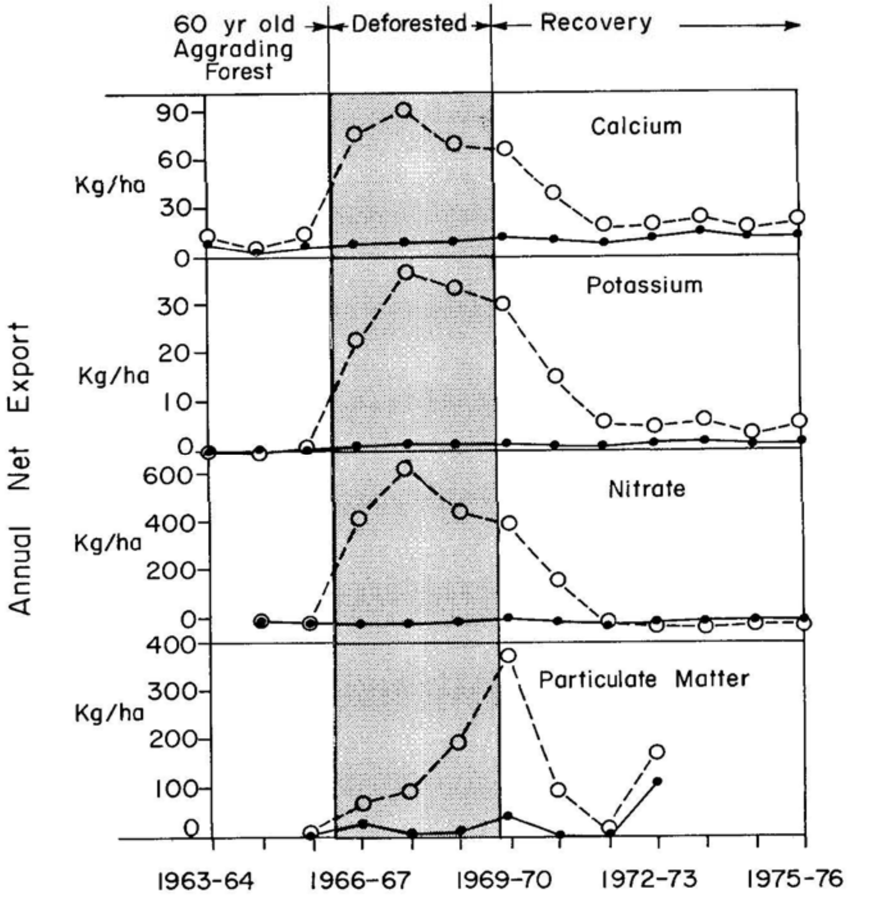


Figure 5-7. Export patterns of dissolved substances (calcium, potassium and nitrate) and particulate matter in stream water from (○--○) the experimentally clear-cut watershed (W2) and (●—●) the forested reference watershed (W6) (modified from Likens et al., 1978).

Bormann & Likens:
Pattern and Process in a Forested Ecosystem (1979)

Hypothesis

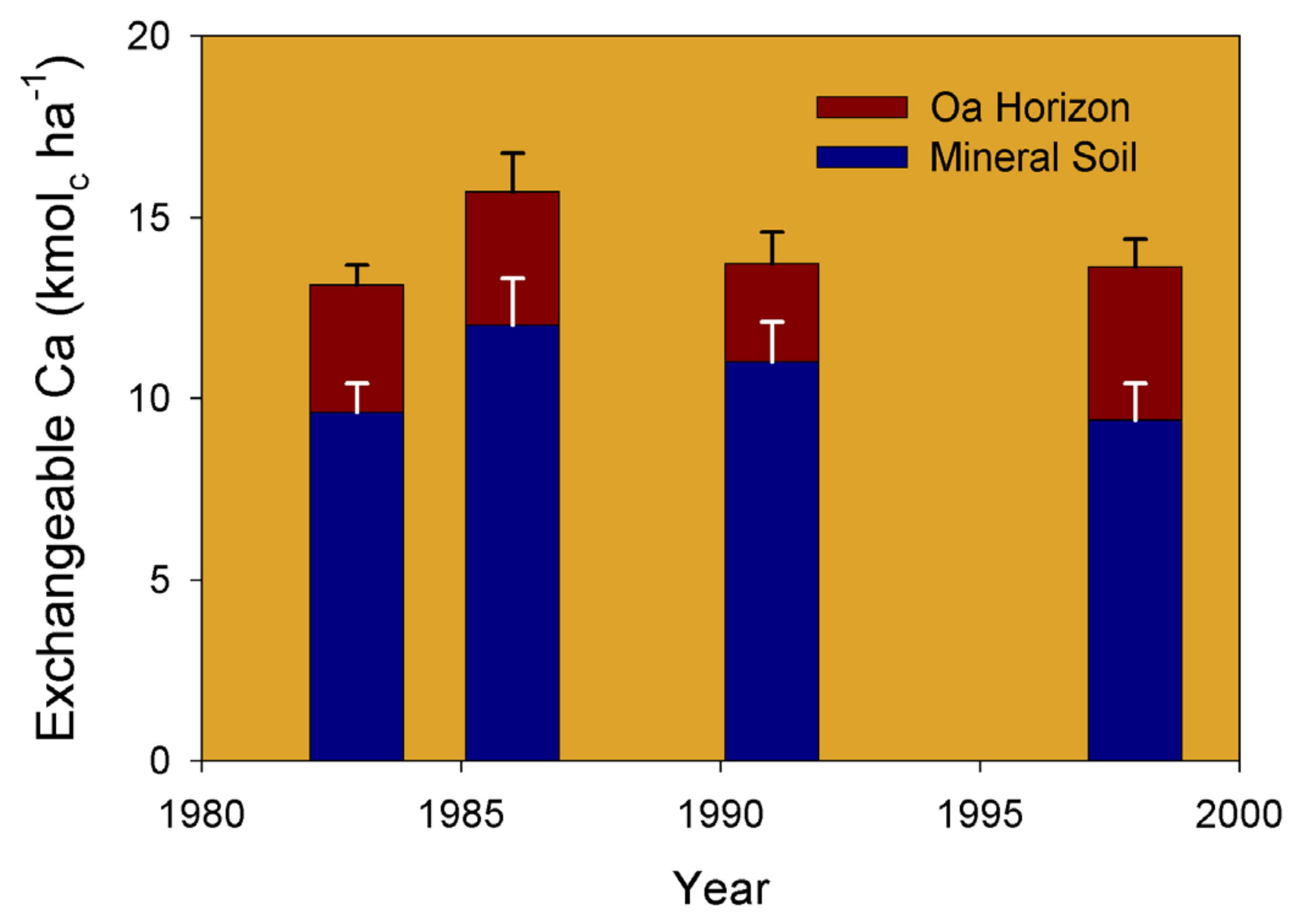
Leaching losses and uptake by regrowing vegetation result in significant decreases in exchangeable Ca (and other nutrient cations).

W5 Whole-Tree Harvest 1983-84

Hubbard Brook Experimental Forest, NH (1997)

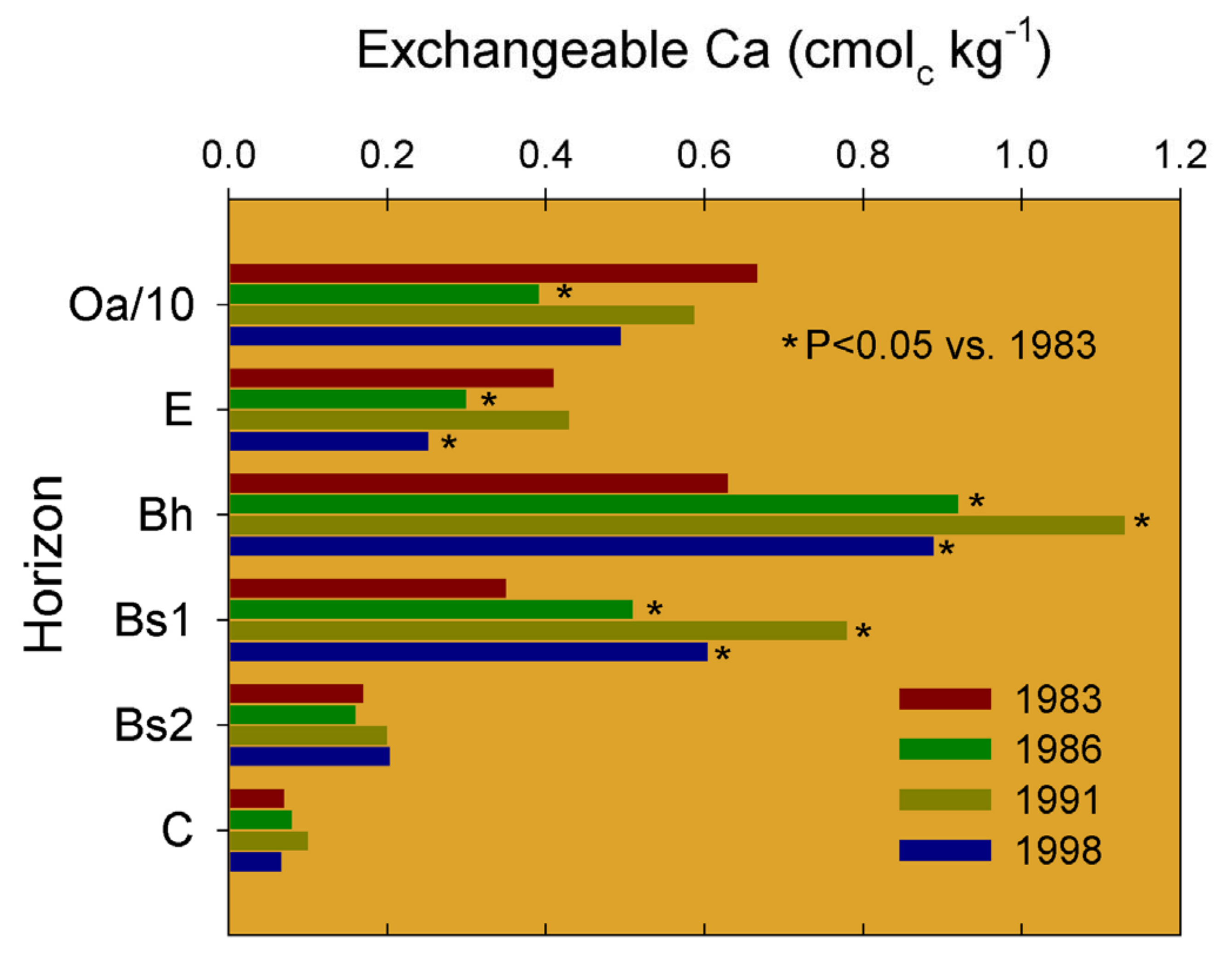
No Change in Exchangeable Ca Pools

(N = 60 0.5 m^2 pits per sampling year)



Johnson et al. (1991, 1996, unpublished data)

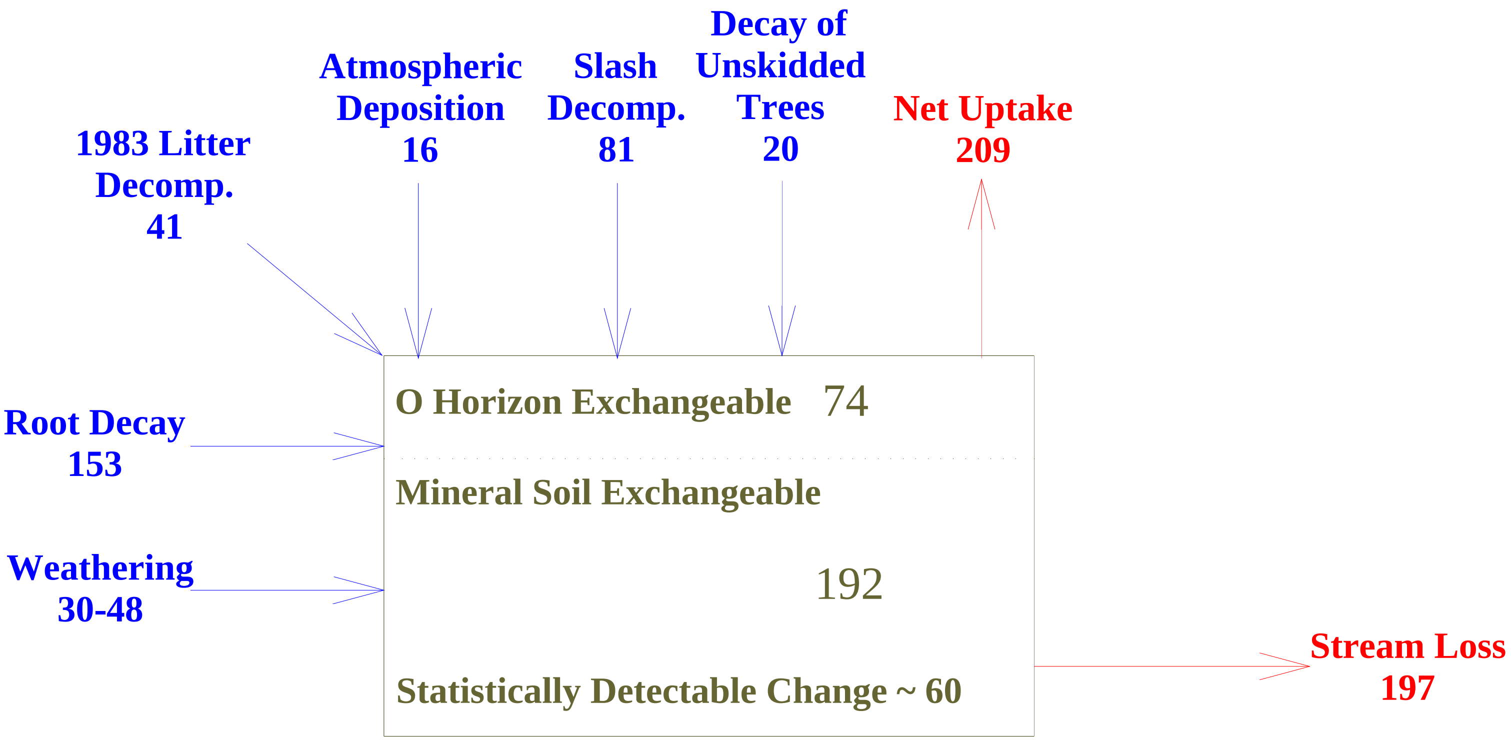
Redistribution of Ca within the Profile



Johnson et al. (1991, 1996) updated

1984-99: 15-year Cumulative Fluxes

All Values: kg/ha Calcium



1983 Litter Decomp.
41

Atmospheric Deposition
16

Slash Decomp.
81

Decay of Unskidded Trees
20

Net Uptake
209

Root Decay
153

Weathering
30-48

O Horizon Exchangeable 74

Mineral Soil Exchangeable

192

Statistically Detectable Change ~ 60

Stream Loss
197

Total In = (30-48) + 153 + 41 + 16 + 81 + 20 = 341-359 kg/ha

Total Out = 209 + 197 = 406 kg/ha

Net (Out - In) = 47-65 kg/ka

Recovery of Soils from Chronic Acidification

Background

- High inputs of acid deposition in the New England region have occurred since the early 20th century.
- Acid deposition causes accelerated acidification of soils and/or drainage waters.
- Soil acidification results in reduced base saturation, with Al and H replacing Ca in particular on soil exchange sites.
- The magnitude of Ca depletion from New England soils is not clear, but could be on the order of 50% or more of pre-industrial Ca pools.
- Acid deposition has declined significantly in the region since the 1980s. How are soils likely to recover?

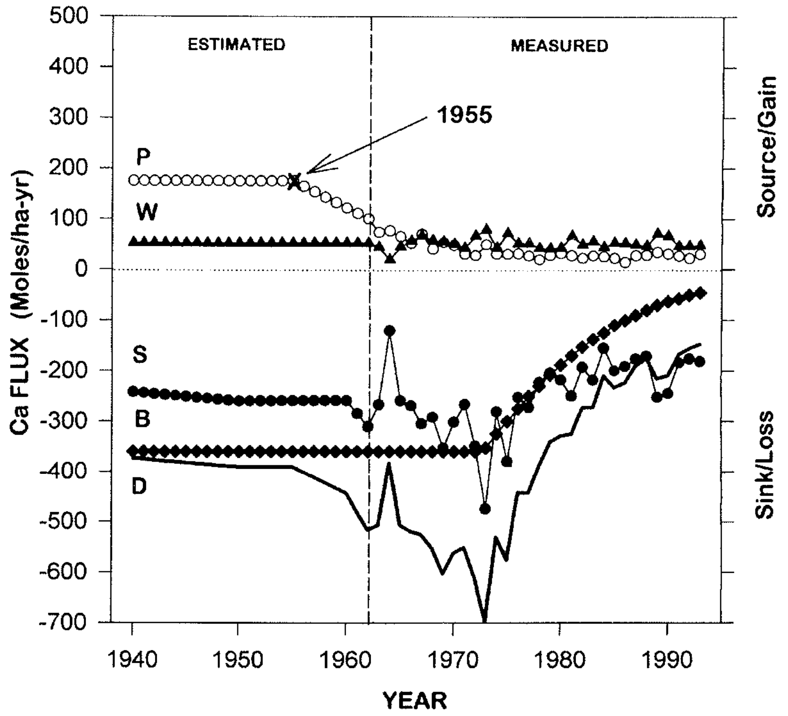


Figure 23. Annual fluxes of calcium for W6 of the HBEF during 1940–1963 (estimated) and 1963–1994 (measured). P (○) is bulk precipitation input, W (▲) is weathering release, S (●) is streamwater loss, B (◆) is net biomass storage and D (—) is net release from labile soil pools (exchangeable + organically bound), obtained by difference. Data for P during 1955–56 are from Junge & Werby (1958). (Modified from Likens et al. 1996.)

Likens et al. 1998

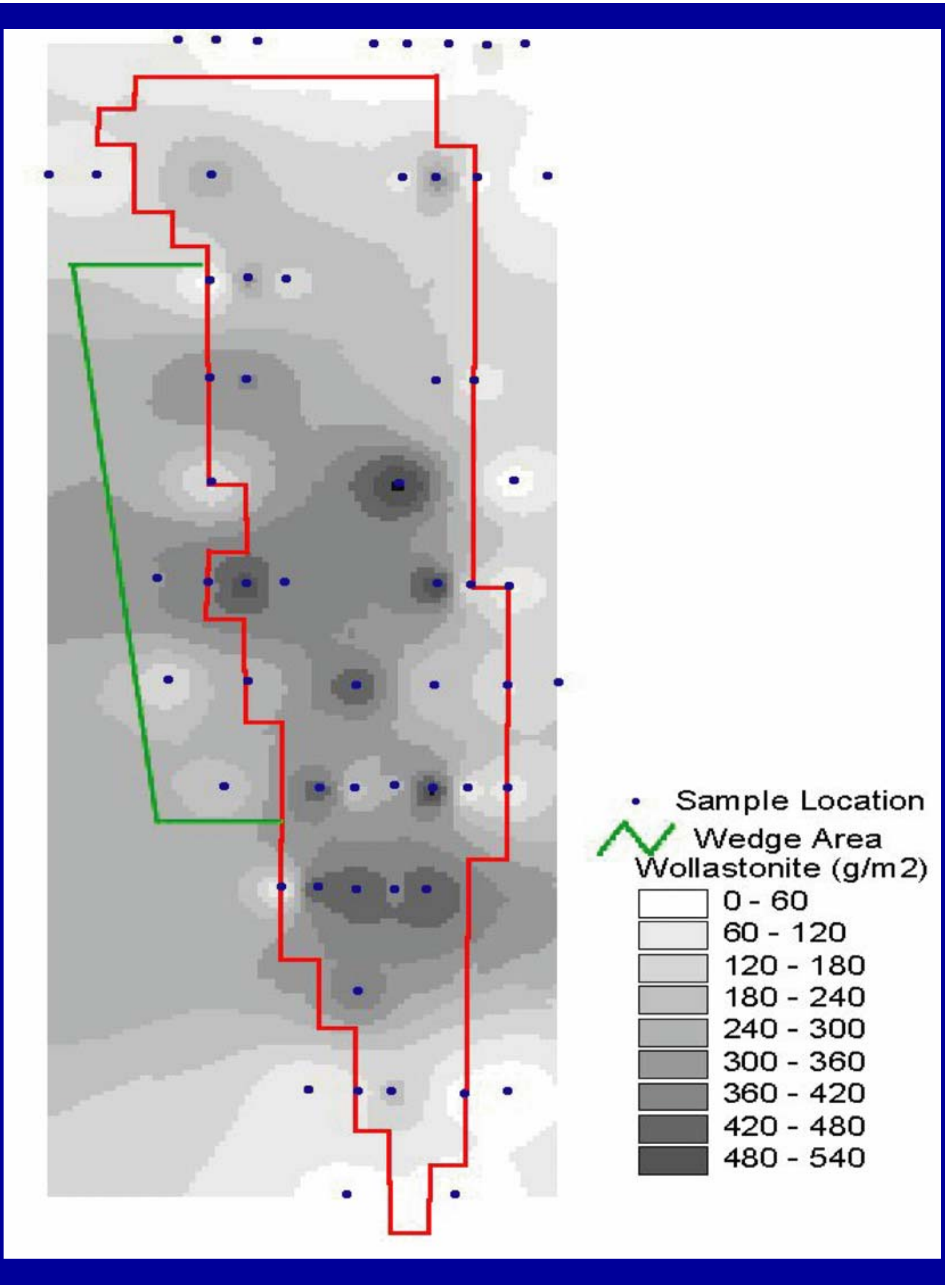
Wollastonite ($CaSiO_3$) Application to W1

October, 1999

Wollastonite Application

Target Rate: 460 g m^{-2}

Mean Rate: 350 g m^{-2}

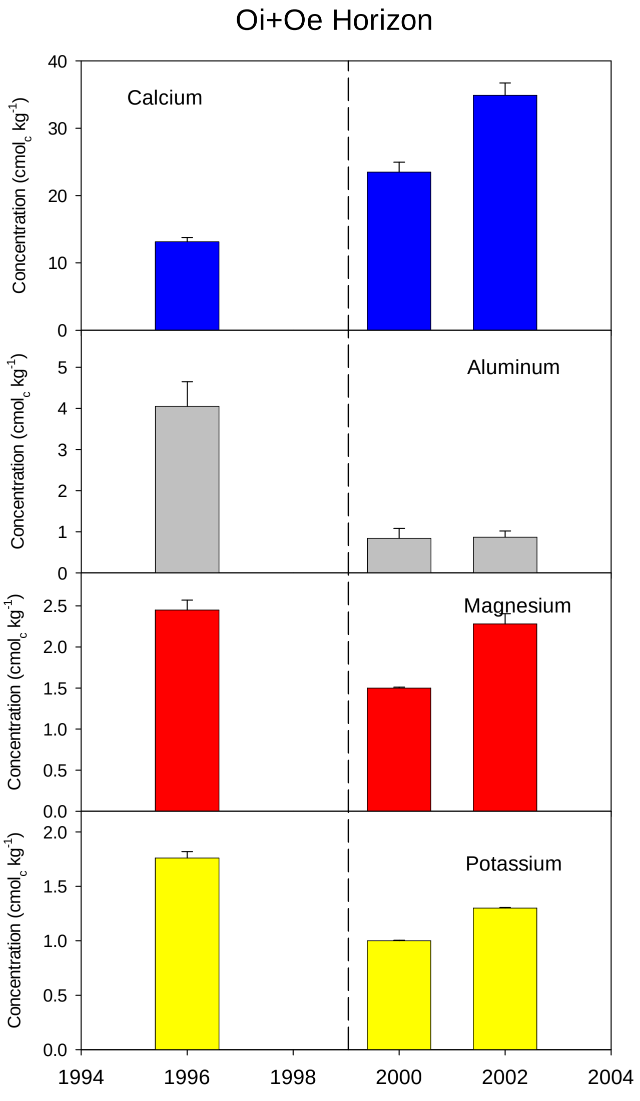


Fate of Added Wollastonite

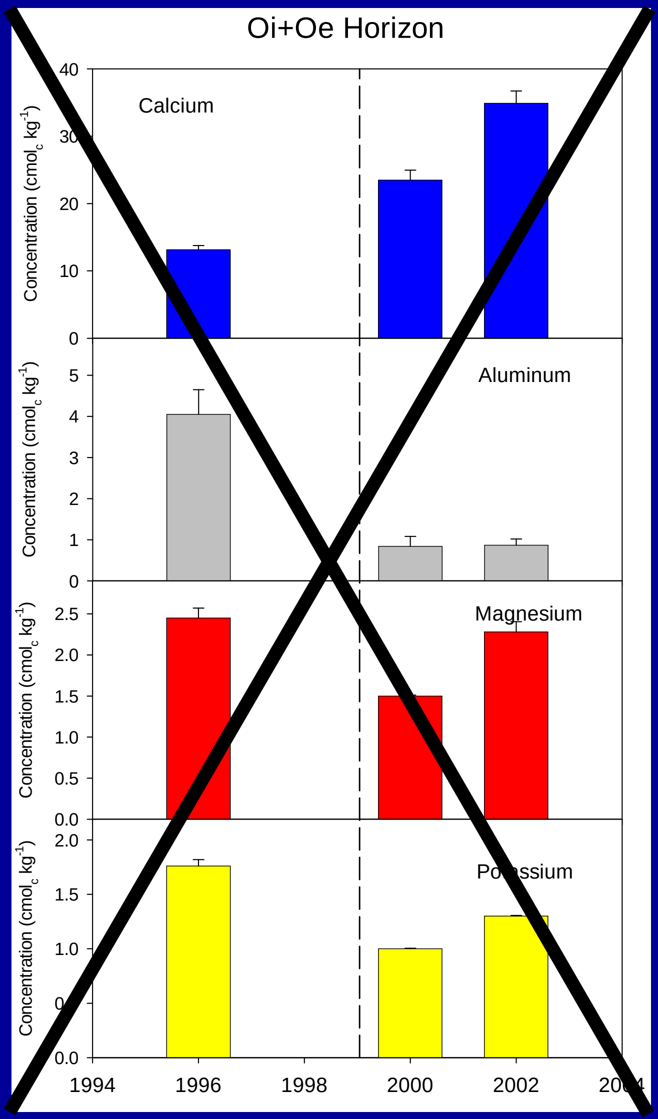
Total Calcium (HNO_3 digest) g/m^2

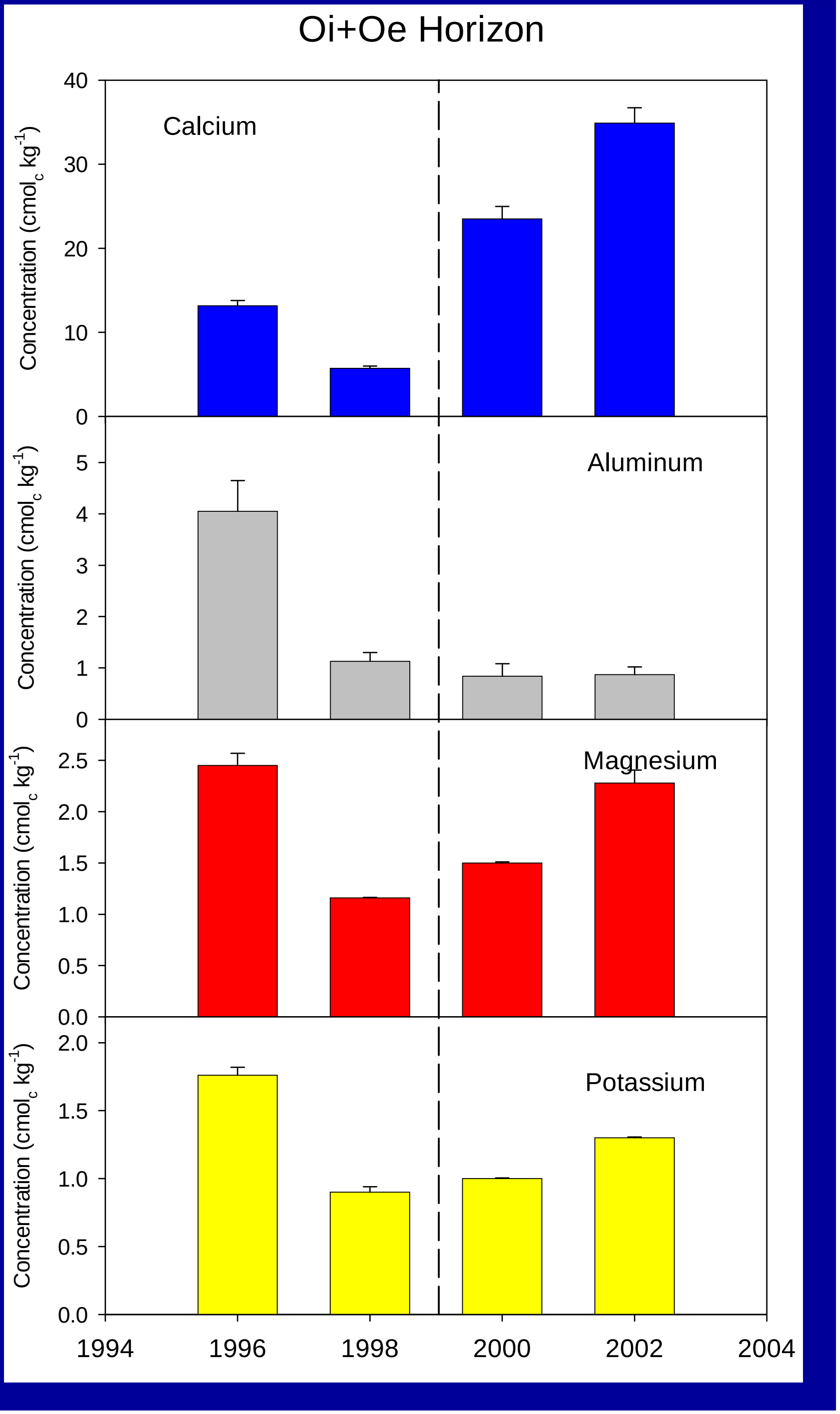
Horizon	1996	1998	2000	2002
Oi + Oe	13.0	14.2	98.9	82.5
Oa	7.1	8.8	10.8	15.9
Forest Floor Total	20.1	23.0	109.7	98.4
0-10 cm Mineral	Not Measured	9.1	8.4	7.7

Exchangeable Cations:
Oi+Oe Horizon

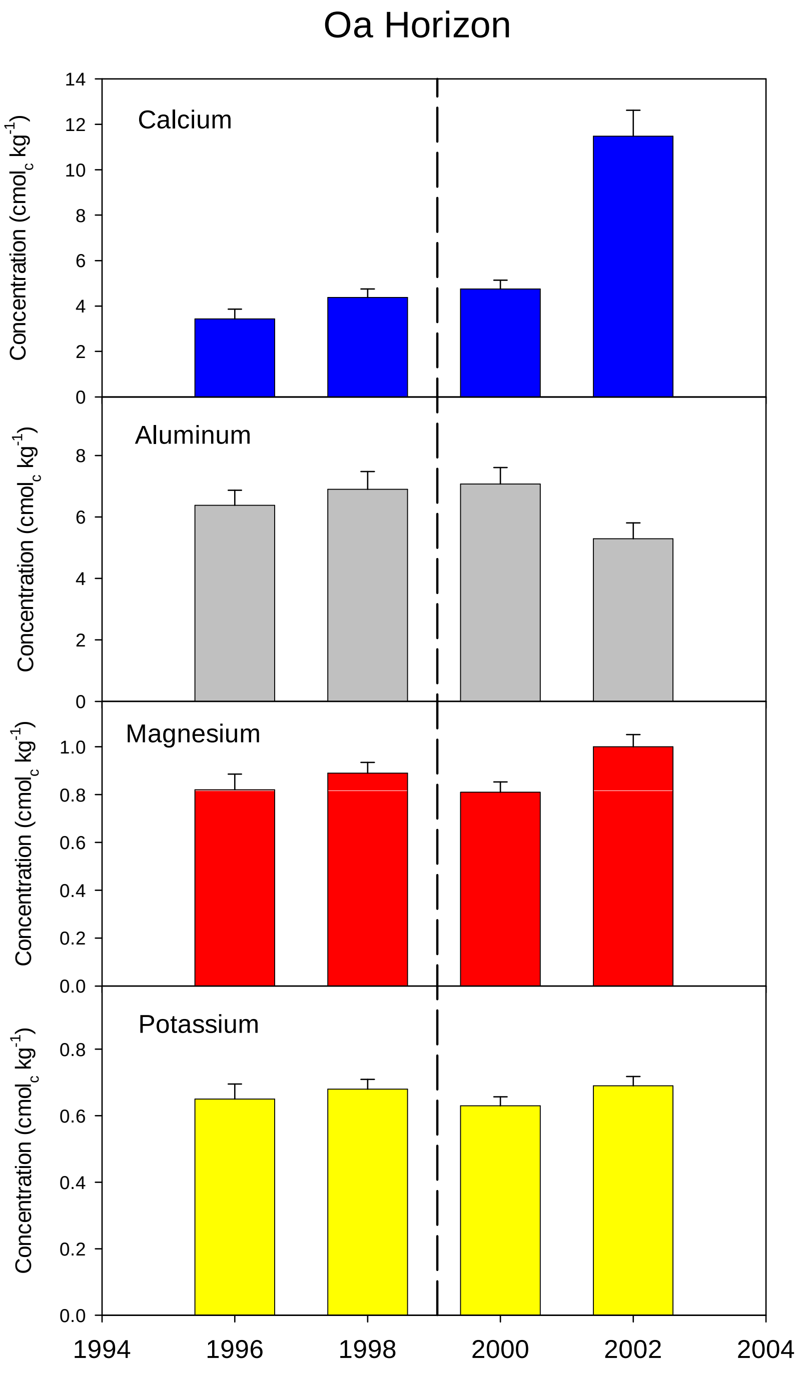


Exchangeable Cations: Oi+Oe Horizon

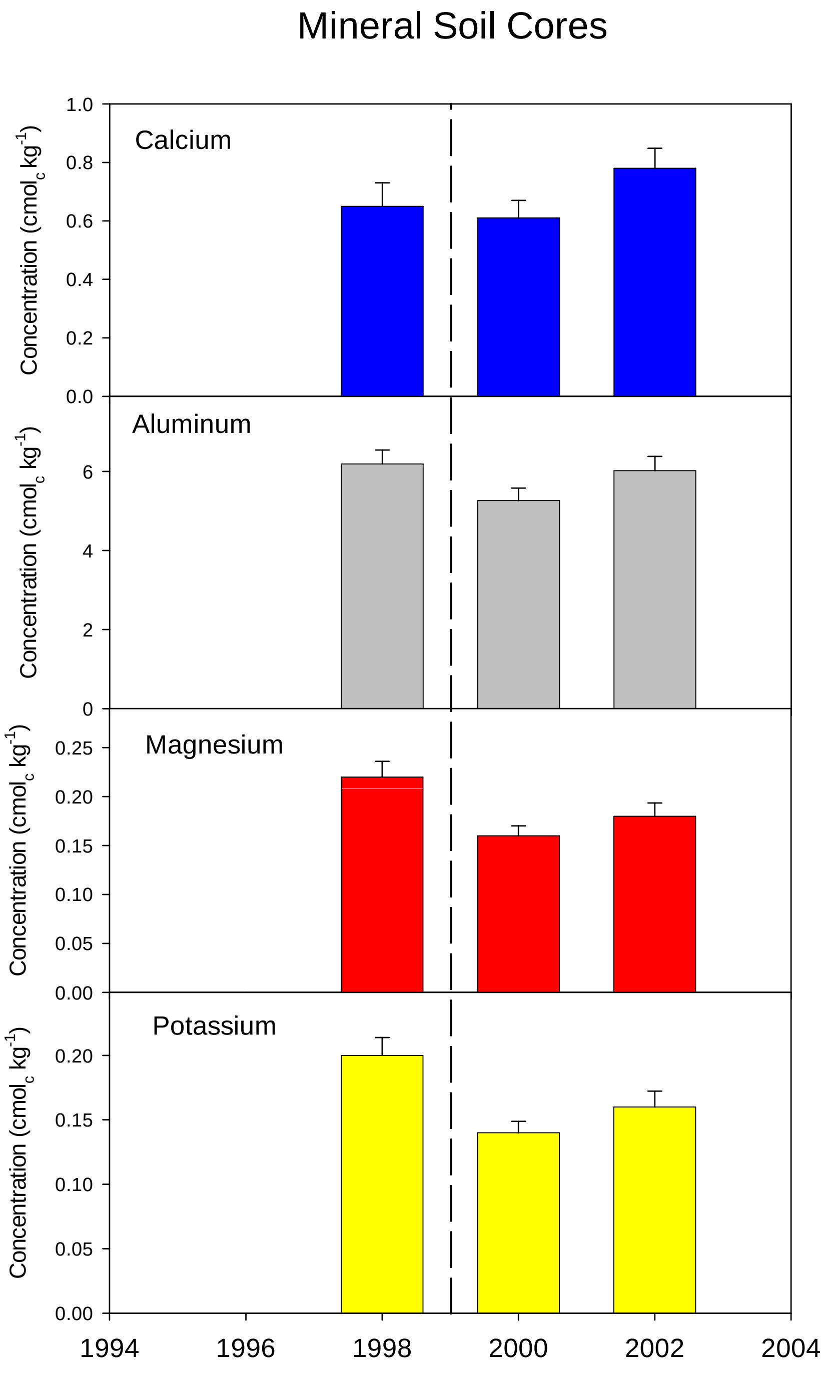




Exchangeable Cations: Oa Horizon



Exchangeable Cations: 0-10 cm Mineral Soil



Some Statistical Issues

1. Sampling from the same plots over time.
    - ‘Paired’ hypothesis tests require re-sampling of the same sample population.

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    - **SOILS CANNOT BE RE-SAMPLED.**

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1. Sampling from the same plots over time.
    - ‘Paired’ hypothesis tests require re-sampling of the same sample population.
    - **SOILS CANNOT BE RE-SAMPLED.**
    - Use two-sample or repeated measures tests to assess significance of soil change over time.

Some Statistical Issues

2. Composite Sampling.
   - ‘Compositing’ or ‘bulking’ samples reduces variability.

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    - Very sparse literature on hypothesis testing with composited samples.
    - Geostatistical concept of ‘support’: The support is the physical shape and size of the area represented by a ‘sample’ – auger, soil pit, etc.

Some Statistical Issues

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    - ‘Compositing’ or ‘bulking’ samples reduces variability.
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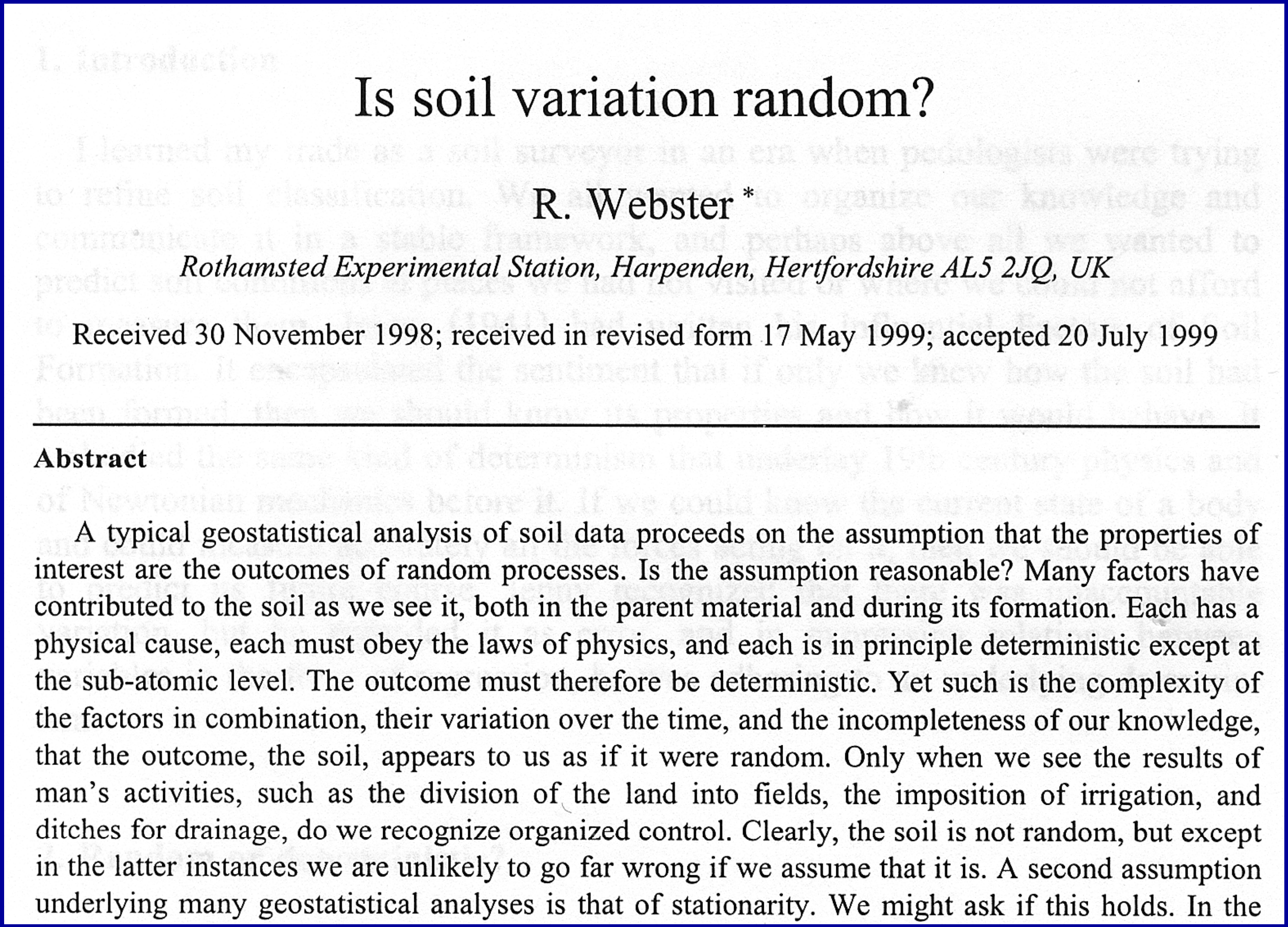
   - Very sparse literature on hypothesis testing with composited samples.
   - Geostatistical concept of ‘support’.
   - When you composite, you lose interpretive power at spatial scales less than the support.
   - Lab analyses are generally far more expensive than sampling – composite if you must, **but do it in the lab, not in the field!**

Some Statistical Issues

3. Embracing Soil Variation



Is soil variation random?

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Abstract

A typical geostatistical analysis of soil data proceeds on the assumption that the properties of interest are the outcomes of random processes. Is the assumption reasonable? Many factors have contributed to the soil as we see it, both in the parent material and during its formation. Each has a physical cause, each must obey the laws of physics, and each is in principle deterministic except at the sub-atomic level. The outcome must therefore be deterministic. Yet such is the complexity of the factors in combination, their variation over the time, and the incompleteness of our knowledge, that the outcome, the soil, appears to us as if it were random. Only when we see the results of man's activities, such as the division of the land into fields, the imposition of irrigation, and ditches for drainage, do we recognize organized control. Clearly, the soil is not random, but except in the latter instances we are unlikely to go far wrong if we assume that it is. A second assumption underlying many geostatistical analyses is that of stationarity. We might ask if this holds. In the

Geoderma 97: 149-163 (2000)

Conclusion

You can never have too much data!

Conclusion

~~You can never have too much data.~~

You can never have too many samples!