Ca decline and implications for forestry in Central Ontario

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August 19th, 2010

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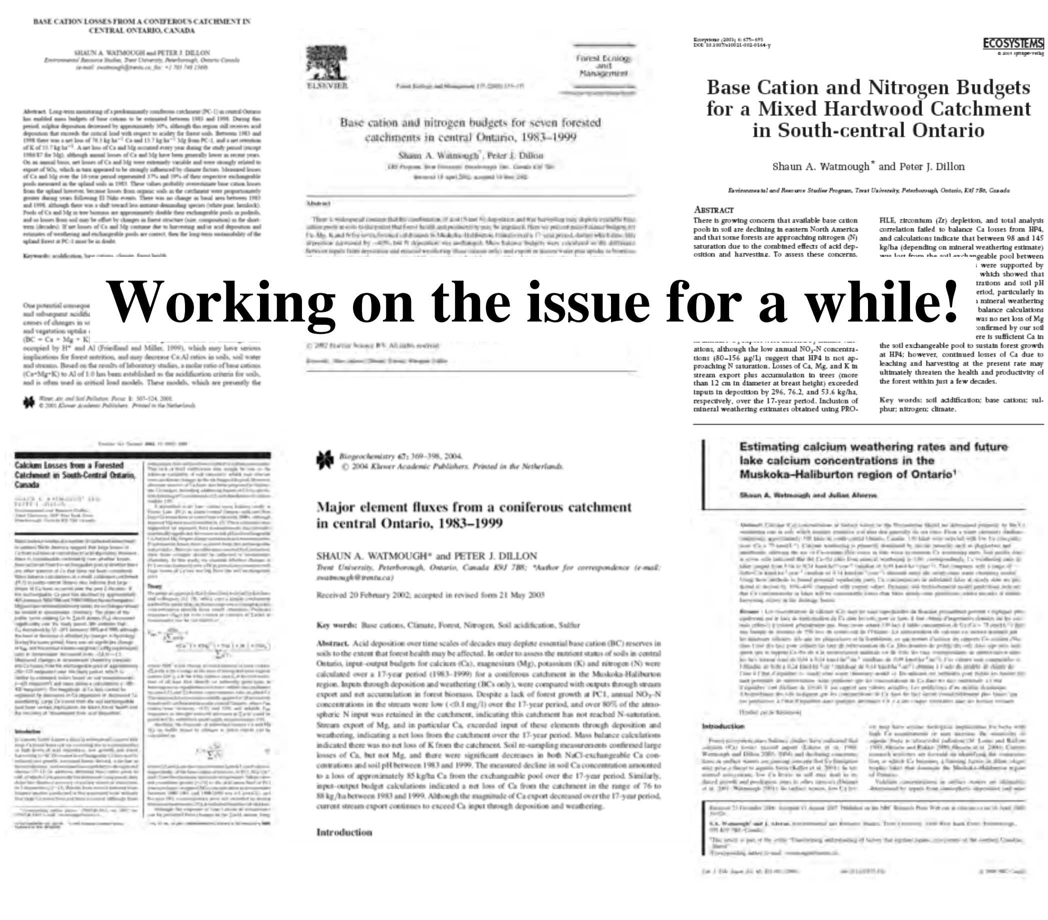
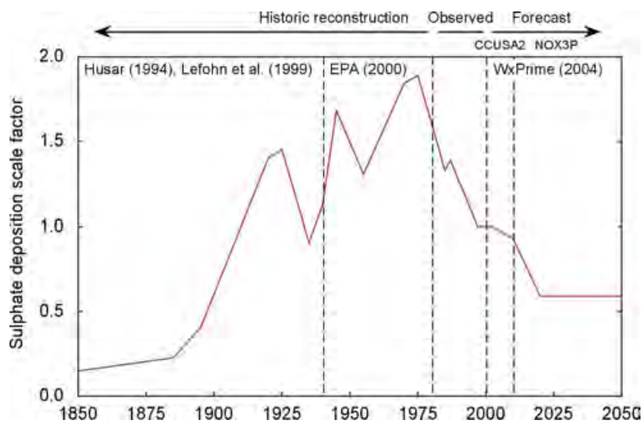
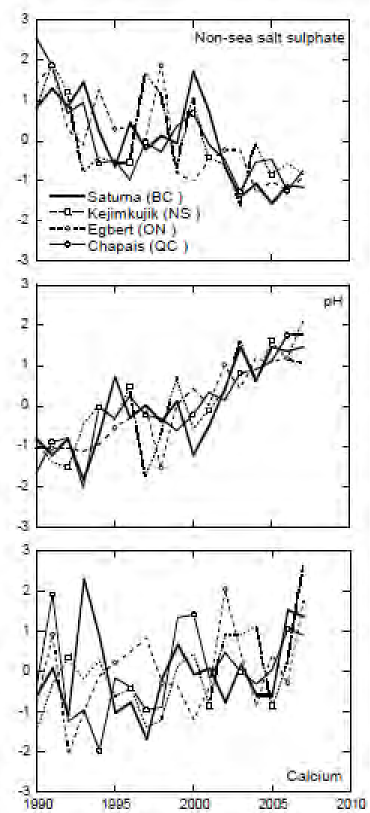


Working on the issue for a while!

Good news - Acid (S) deposition has decreased by ~50 % since the late 1970s





But…

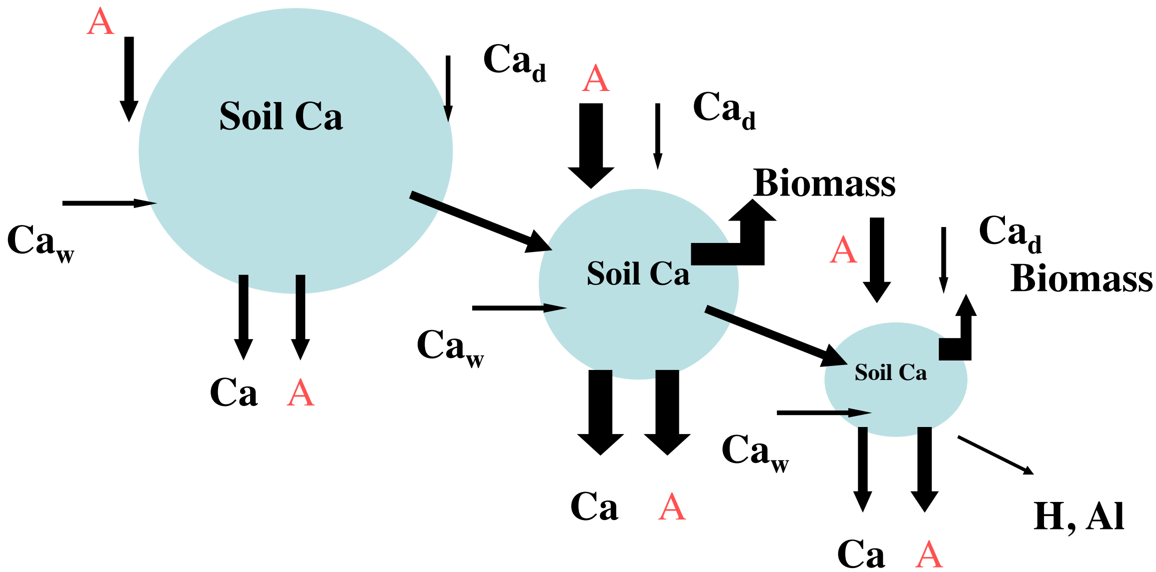
- ‘Canadian lakes suffering aquatic version of osteoporosis’ – Globe and Mail, 2008.

The Widespread Threat of Calcium Decline in Fresh Waters

Adam Jeziorski,[1] Norman D. Yan,[2,3] Andrew M. Paterson,[3] Anna M. DeSellas,[1,3] Michael A. Turner,[4] Dean S. Jeffries,[5] Bill Keller,[6] Russ C. Weeber,[7] Don K. McNicol,[7] Michelle E. Palmer,[2] Kyle McIver,[1] Kristina Arseneau,[1] Brian K. Ginn,[1] Brian F. Cumming,[1] John P. Smol[1]*

Calcium concentrations are now commonly declining in softwater boreal lakes. Although the mechanisms leading to these declines are generally well known, the consequences for the aquatic biota have not yet been reported. By examining crustacean zooplankton remains preserved in lake sediment cores, we document near extirpations of calcium-rich *Daphnia* species, which are keystone herbivores in pelagic food webs, concurrent with declining lake-water calcium. A large proportion (62%, 47 to 81% by region) of the Canadian Shield lakes we examined has a calcium concentration approaching or below the threshold at which laboratory *Daphnia* populations suffer reduced survival and fecundity. The ecological impacts of environmental calcium loss are likely to be both widespread and pronounced.

In eastern North America and Europe, acid deposition and harvesting continue to deplete soil Ca reserves:



What are the implications of declining Ca levels in soil?

Ca concentrations in plants decrease √

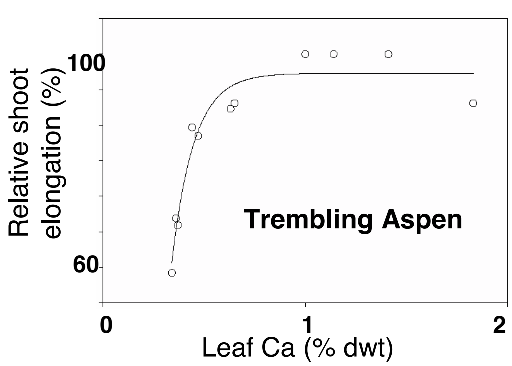
Negative effects on plant physiology √

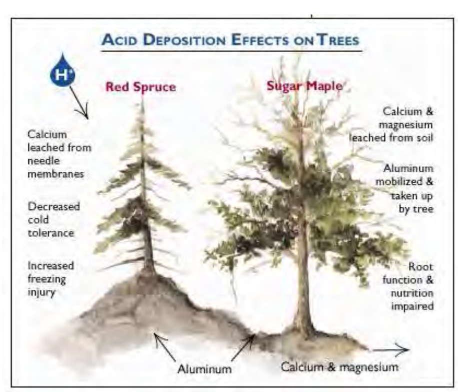
Reduced plant growth √

Reduced Ca availability/cycling √

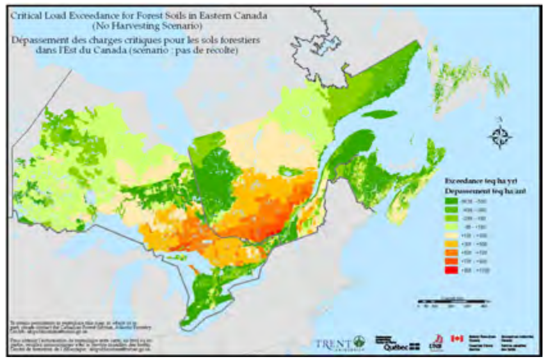
Altered species composition **?**

Altered carbon/nitrogen dynamics **?**





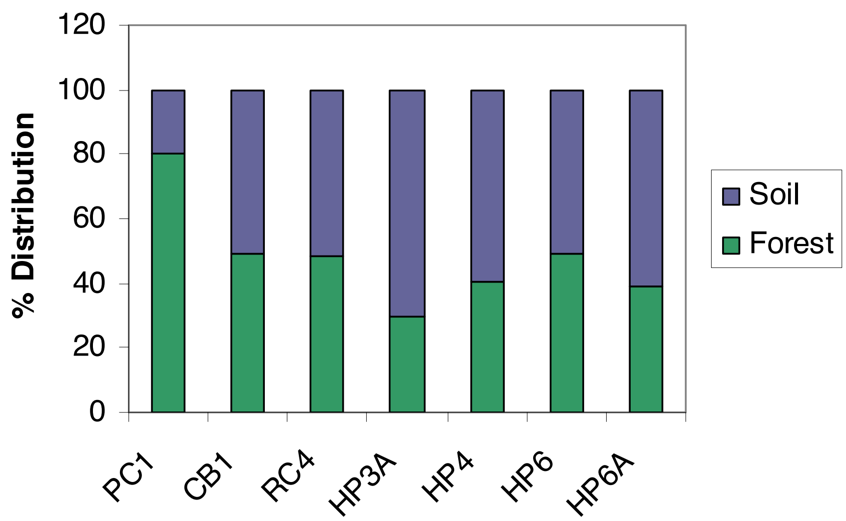
Areas prone to acid deposition/calcium limitation..



..are characterized by:

- Inherently low soil Ca levels
- High rates of Ca losses (through acid-leaching and harvesting)

Where is the Calcium in Central Ontario?



Is there evidence of Ca decline in soil – in Ontario?

- Examination of stream water chemistry
- Catchment mass balances
- Soil resurveys

Weathering rate is a key input:

- Zr-depletion
- PROFILE
- %Clay
- Ca:Na ratios
- Sr isotopes
- Mass balance
- Models: SSWC,
- MAGIC etc.

Estimating base cation weathering rates in Canadian forest soils using a simple texture-based model

Ina S. Koseva · Shaun A. Watmough · Julian Aherne

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A comparison of weathering rates for acid-sensitive catchments in Nova Scotia, Canada and their impact on critical load calculations

C.J. Whitfield [a,*], S.A. Watmough [b], J. Aherne [b], P.J. Dillon [b]
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J. Aherne and D.P. Shaw (Guest Editors)
Impacts of sulphur and nitrogen deposition in western Canada
J. Limnol., 69(Suppl. 1): 201-208, 2010 - DOI: 10.3274/JL10-69-S1-20

Estimating the sensitivity of forest soils to acid deposition in the Athabasca Oil Sands Region, Alberta

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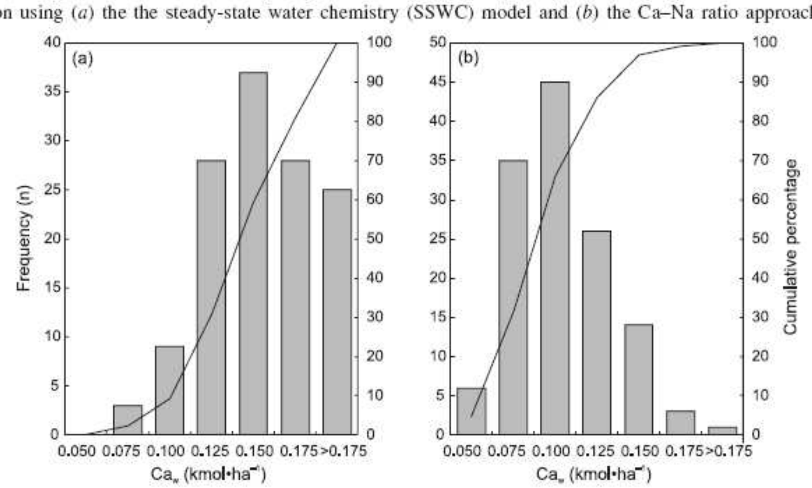
Potential impact of forest harvesting on lake chemistry in south-central Ontario at current levels of acid deposition

S.A. Watmough, J. Aherne, and P.J. Dillon

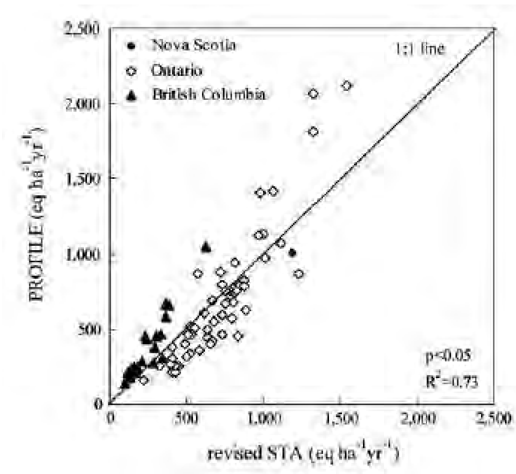
Abstract: The potential impact of harvesting on lake chemistry was assessed for ~1300 lakes in south-central Ontario using a critical loads approach based on the steady-state water chemistry (SSWC) model. The critical load of acidity is currently only exceeded by bulk sulphate deposition in 9% of the lakes if harvesting does not occur. However, the percentage increases to 23%, 56%, and 72% under potential harvesting scenarios that assume wood-only (stem without bark), stem-only, or whole-tree harvesting, respectively. This increase in exceedance of critical load is due to the much lower base cation concentrations in lakes resulting from base cation removals during harvest. For example, only 0.3% of lakes will have Ca^{2+} concentrations <50 μequiv·L^{-1} if harvesting does not occur, whereas 52% of lakes will have Ca^{2+} concentrations <50 μequiv·L^{-1} if whole-tree harvesting occurs. Harvesting clearly has an enormous potential impact on lake chemistry, which will become more apparent as exchangeable base cation pools in soil decline and acid inputs can no longer be buffered.

Number of methods used: Ca weathering rates are low

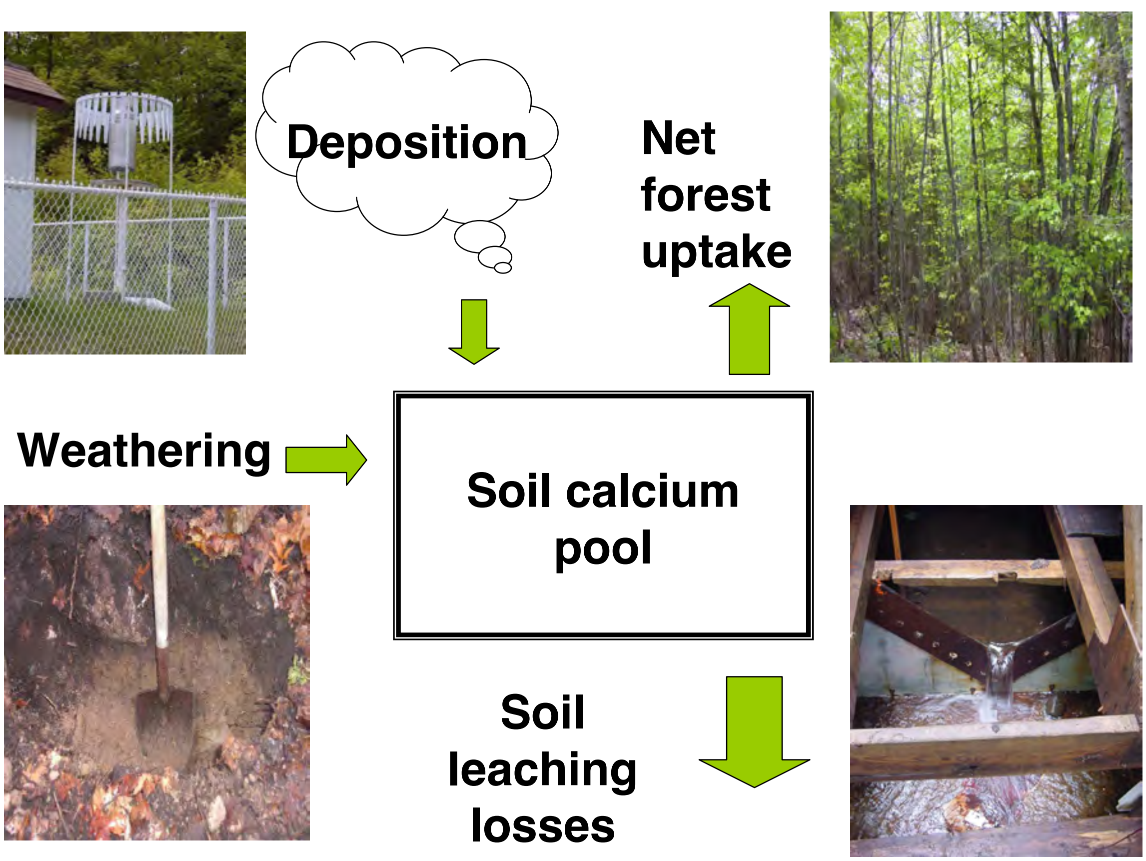
Fig. 3. Distribution (histogram and cumulative frequency) of calcium weathering (Ca_w) rates estimated for 130 lakes in Muskoka–Haliburton using (*a*) the the steady-state water chemistry (SSWC) model and (*b*) the Ca–Na ratio approach.



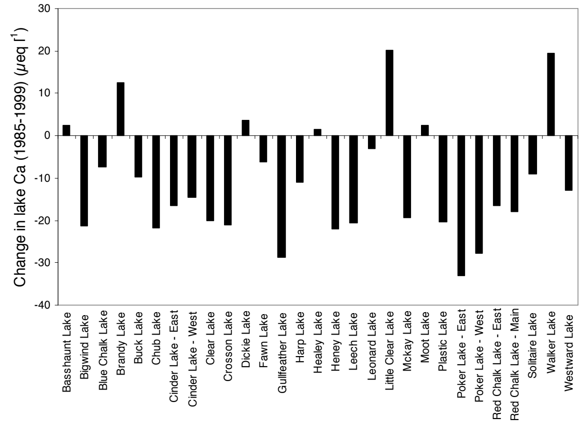
We have developed a simple method for use in Ontario

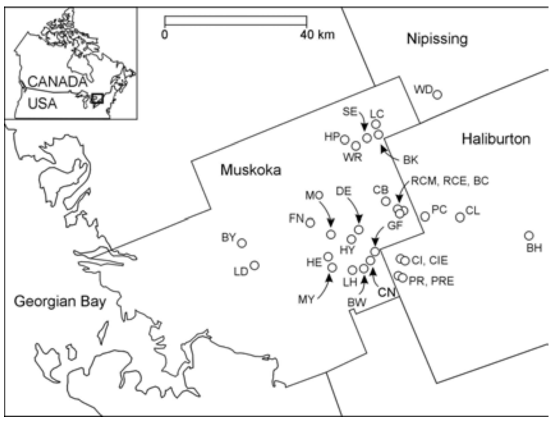


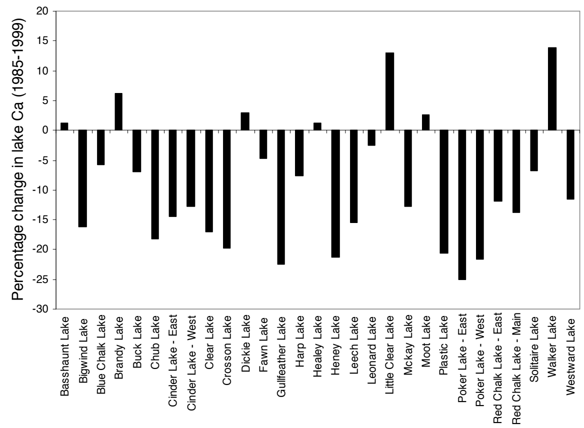
Koseva, I., Watmough, S., Aherne, J. Biogeochemistry (in press)



‘*Decline in Lake Ca concentration is a widespread occurrence in central Ontario*’:

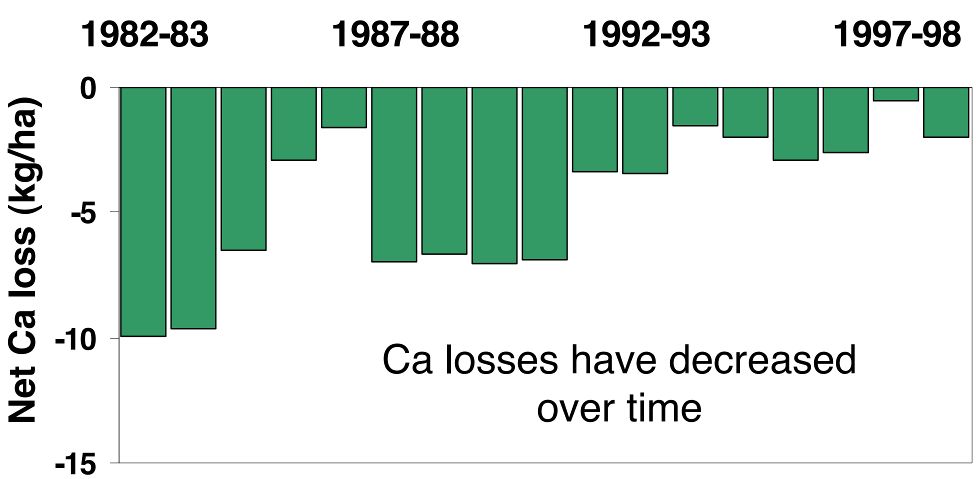




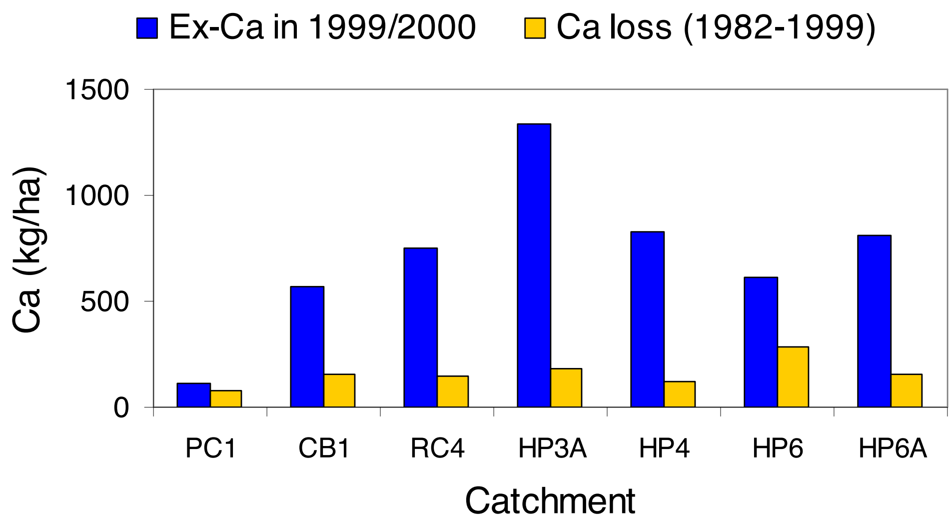


Comparison of inputs with outputs indicates

<u>NET Ca DEPLETION</u> at central Ontario forests

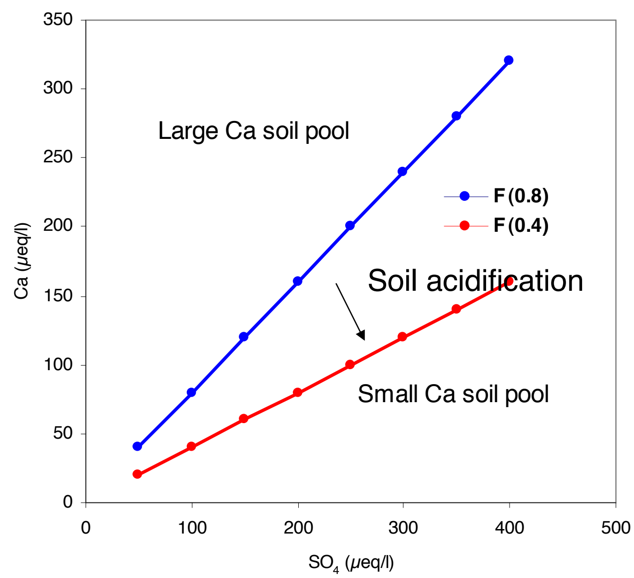


Cumulative (20-yr) losses are LARGE COMPARED TO PLANT-AVAILABLE Ca POOL in soil

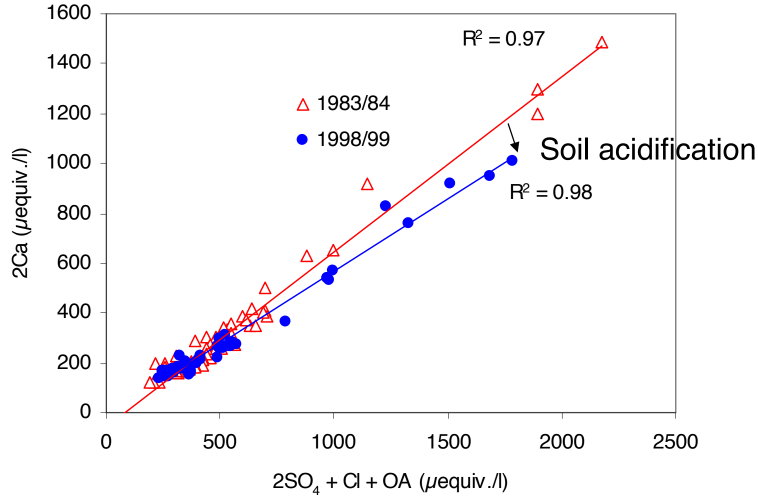


Watmough and Dillon 2003 For. Ecol. Manage.

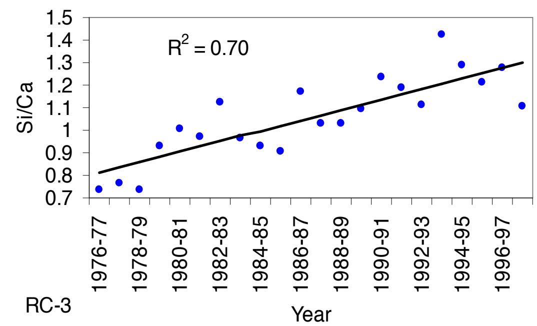
Ca inputs to lakes from soils are determined by the size of the exchangeable Ca pool and the amount of acid leaching.

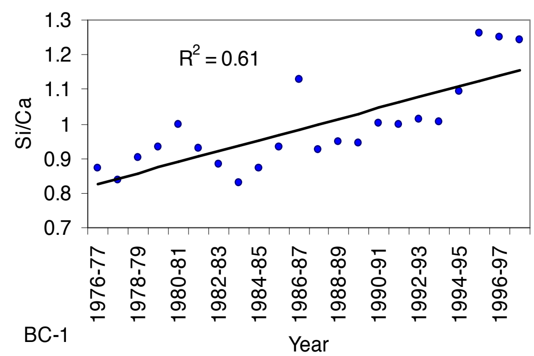


Relationship between acid anions and Ca at PC1

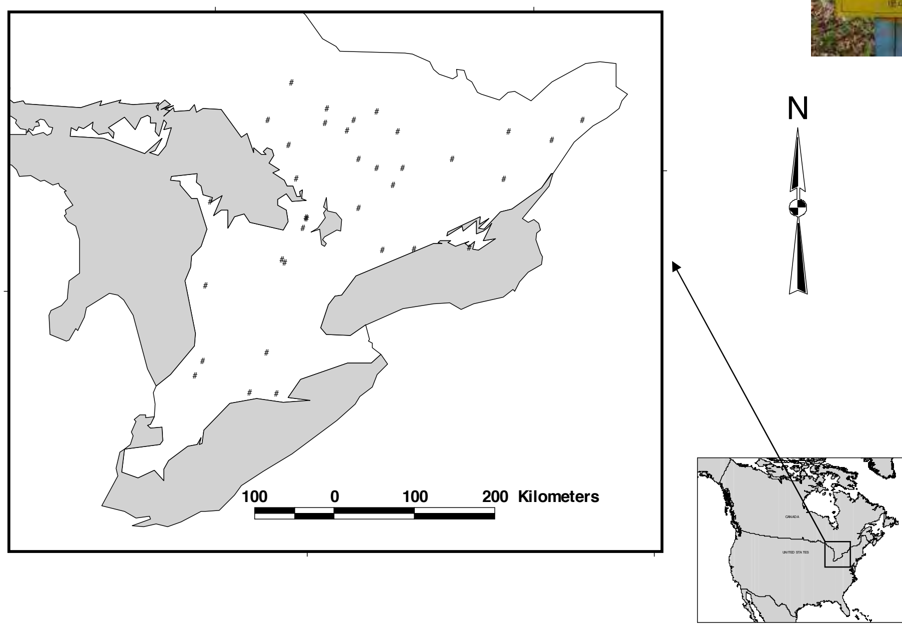


Elemental ratios (Si/Ca; Na/Ca) in many streams are indicative that decline in Ca is not due to changes (decreased) mineral weathering.

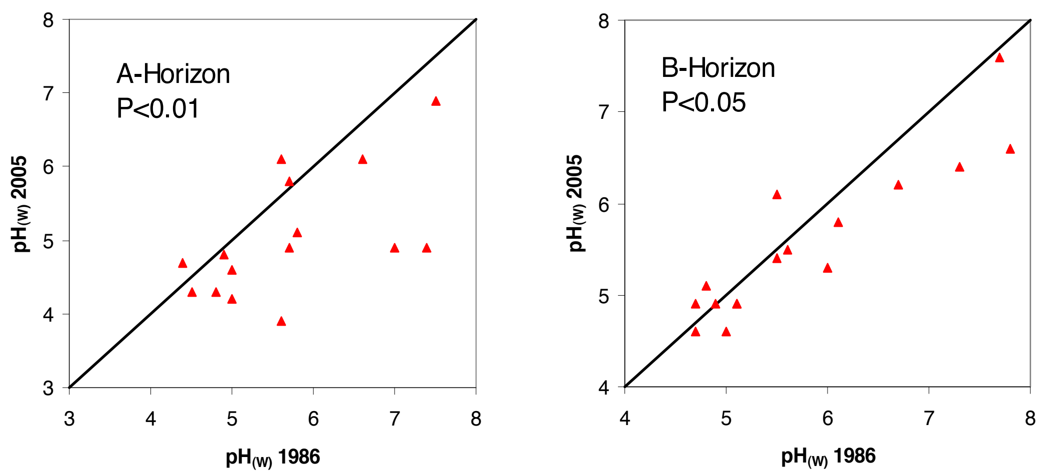




OFBN plot locations: southern Ontario



Change in soil pH at Ontario (OME) Hardwood Sites

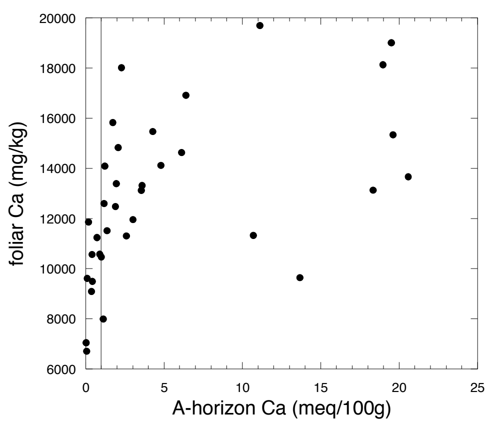


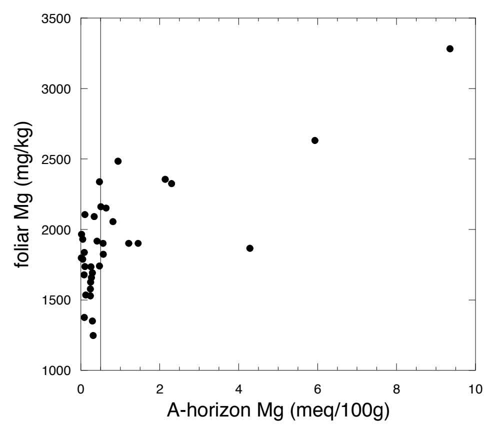
	Ca - Foliar (ppm) /Soil (meq/100g) Chemistry						
	1985			2005			
	Mean	S.E.	Range	Mean	S.E.	Range	P value
Foliage	14,870	1240	7330-27,120	12,180	680	6700-18100	0.015
A-horizon	13.3	2.2	1.7-28.1	5.1	1.7	0.1-19.6	0.006
B-horizon	6.9	1.9	0.5-21.0	2.4	1.0	<0.1-10.6	0.041

Miller and Watmough, 2009, Environmental Pollution

Link between soil and tree chemistry

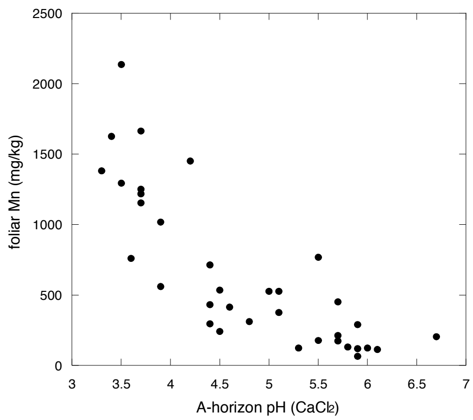
- soil Ca → foliar Ca;
- soil Mg → foliar Mg



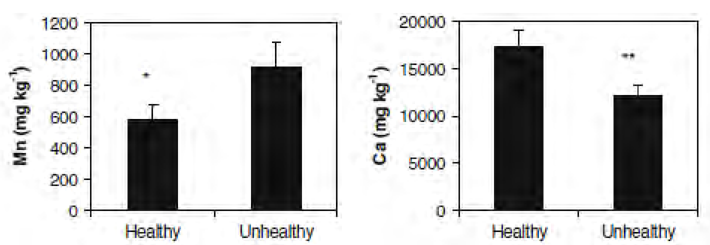


- as soil ex [Ca, Mg] increase, foliar [Ca, Mg] increase, to a point
- foliar Ca (6000 mg/kg), foliar Mg (1000 mg/kg)
  - soil reaches level associated with precipitous drop in foliar levels
    - Ca = 1 meq /100 g, Mg = 0.5 meq /100 g

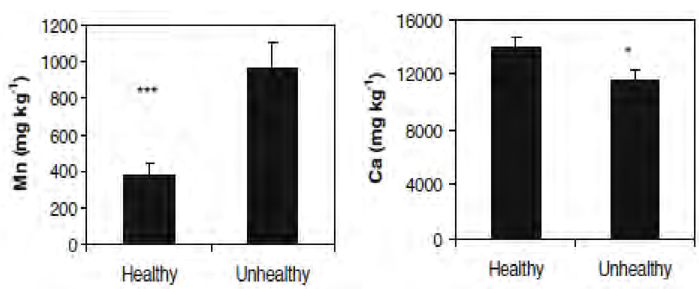
- foliar Mn was negatively related with soil pH
- foliar Mn levels were highest on the most acid soils
    - increase toward levels considered to be phytotoxic (1900 mg/kg) when pH was < 4.5



Sugar Maple crown condition and..



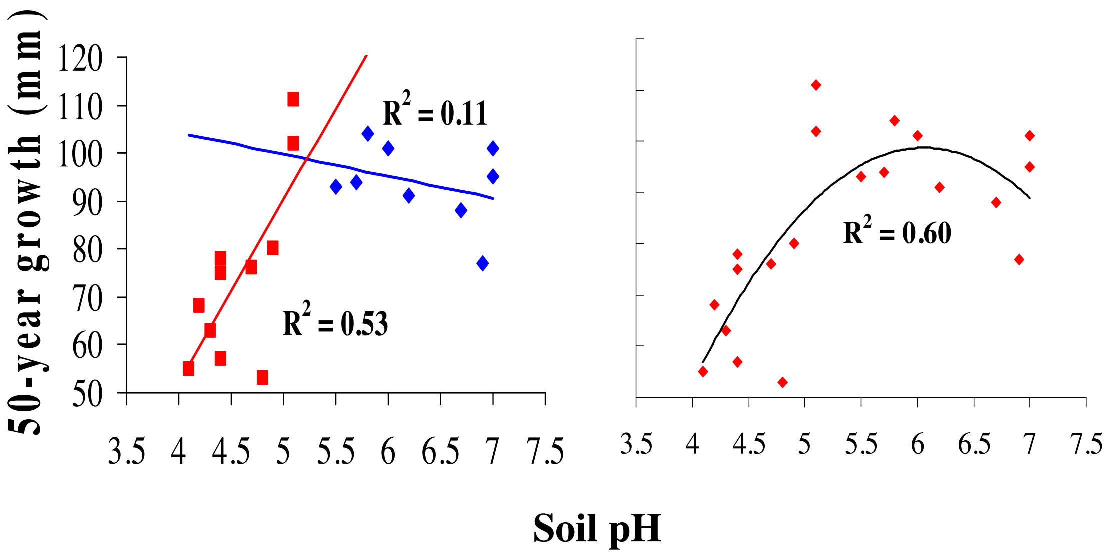
Forest floor Ca and Mn concentrations: Healthy DI<10 (n=18), Unhealthy DI>10 (n=17)



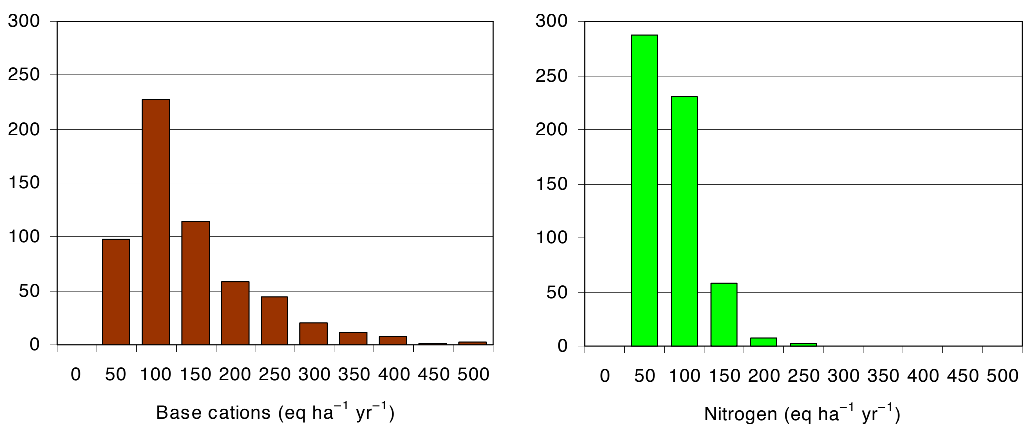
Foliar Ca and Mn concentrations: Healthy DI<10 (n=18), Unhealthy DI>10 (n=17)

Watmough, Plant and Soil, 332: 463-474 (2010)

Sugar maple growth vs. soil pH : Ontario forests

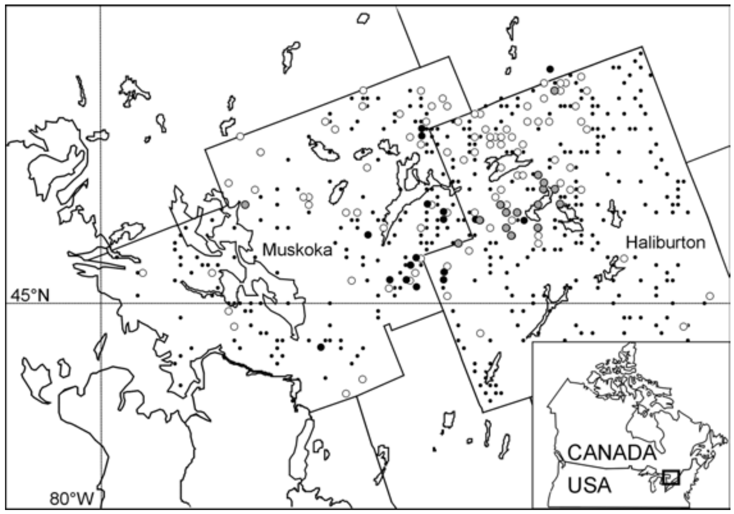


What about harvesting?

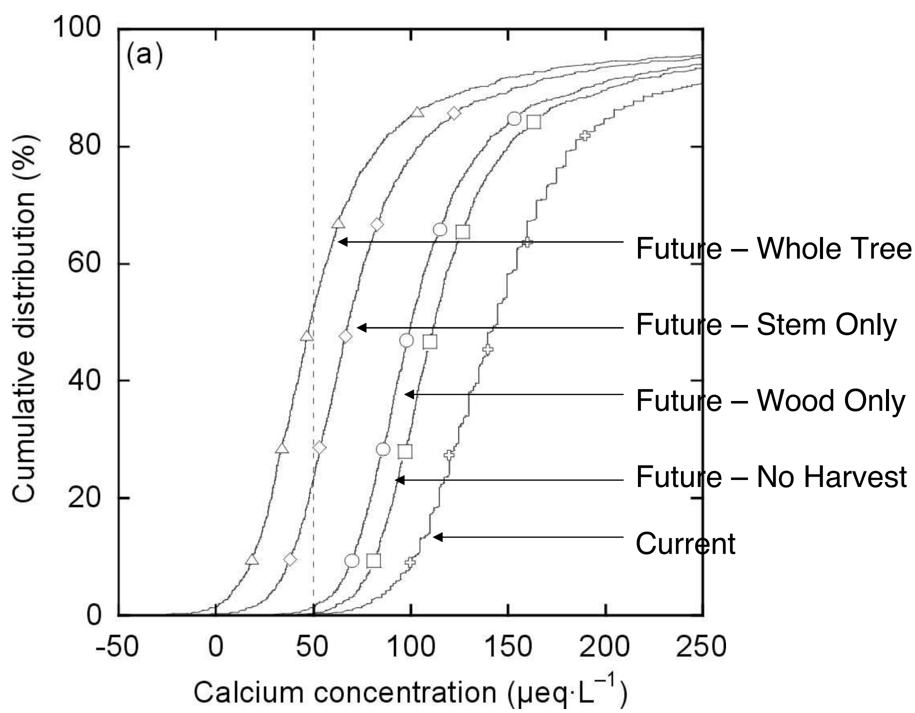


Distribution of forest base cation and nitrogen uptake values (harvest removals) in Ontario

Hypothetical harvest removals applied to predict future lake Ca levels in 1300 central Ontario lakes

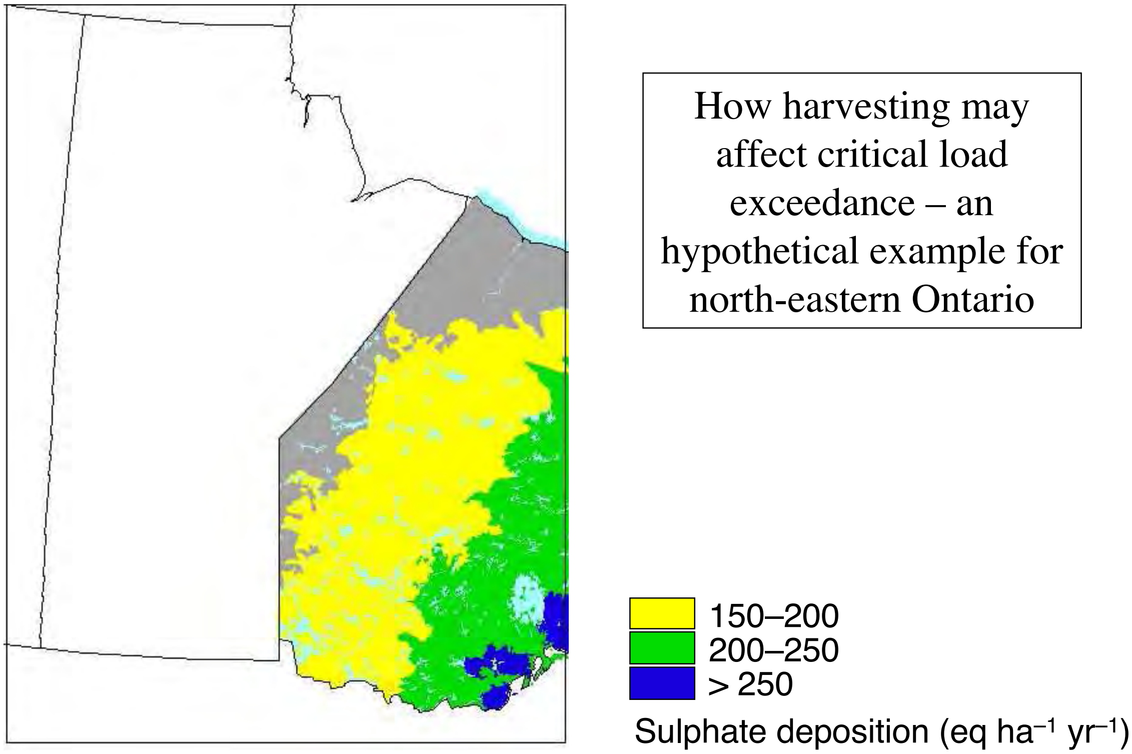


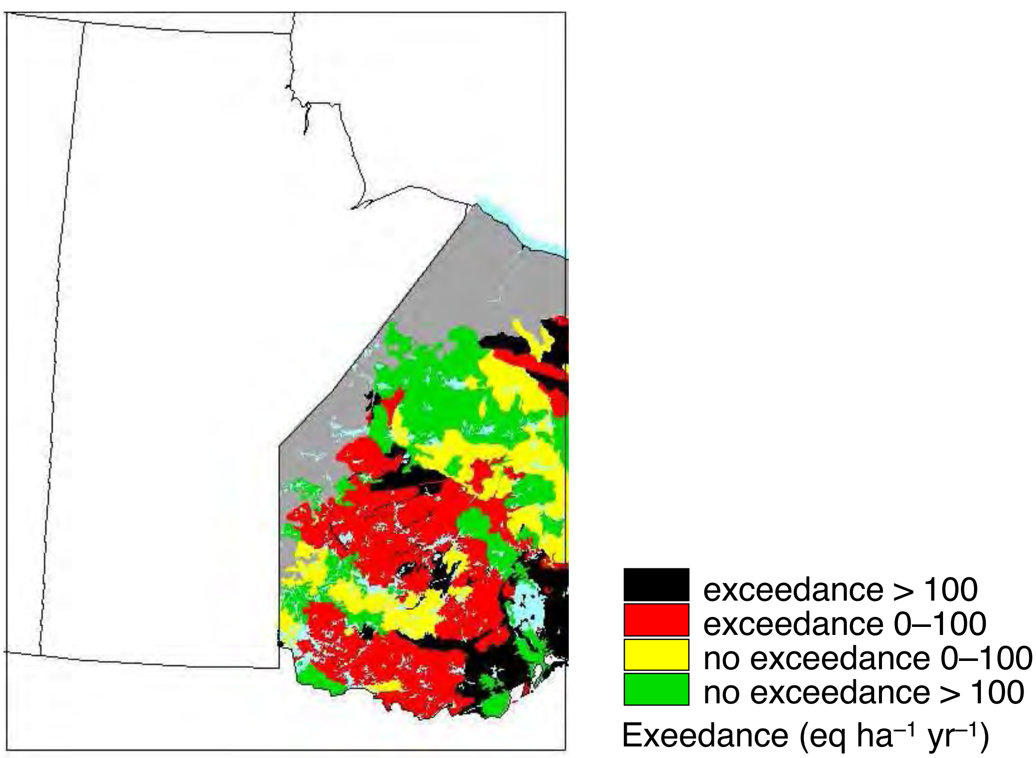
Current and Predicted Cumulative lake Ca concentration distribution (~1300 lakes)

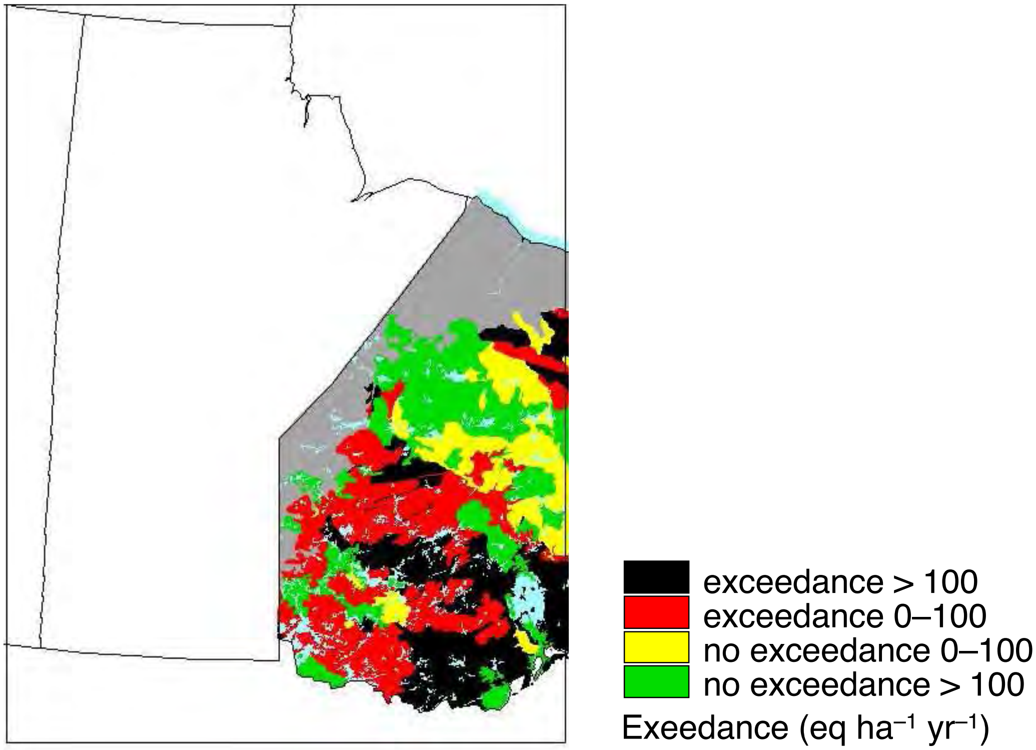


Watmough et al. 2003 CJFAS

How harvesting may affect critical load exceedance – an hypothetical example for north-eastern Ontario







Case Study in Haliburton Forest

Haliburton Forest

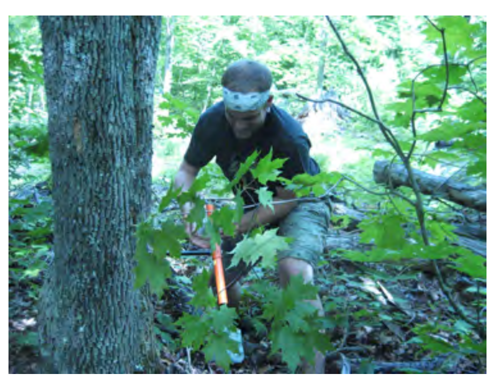
- 70,000 acre privately owned forest
- first certified "sustainable" logging operation in Canada
- practice selective low grade stem only harvesting on a 15-25 year rotational cycle
- horse drawn and mechanized logging
- target mainly Sugar Maple

Why study here?

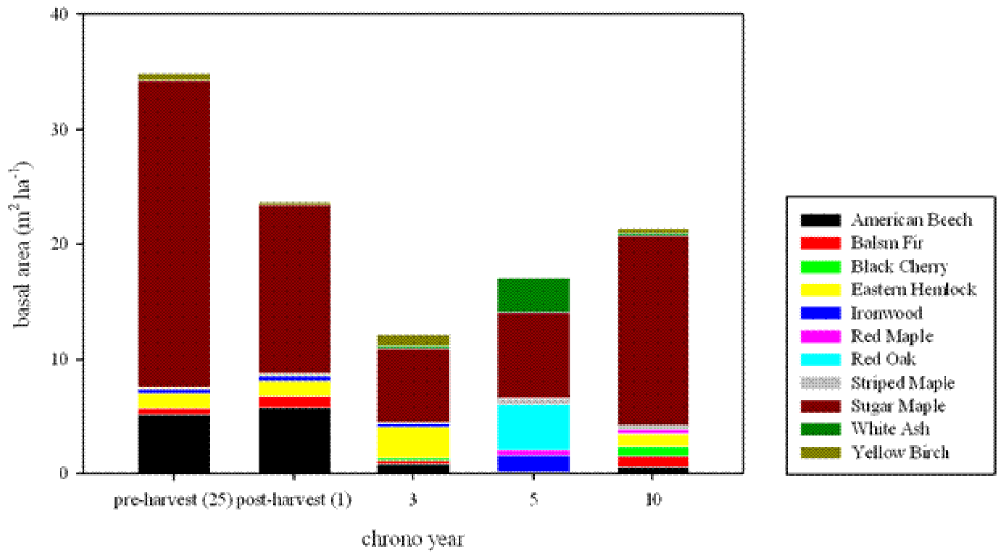
- easy access
- detailed harvesting records

Study Approach

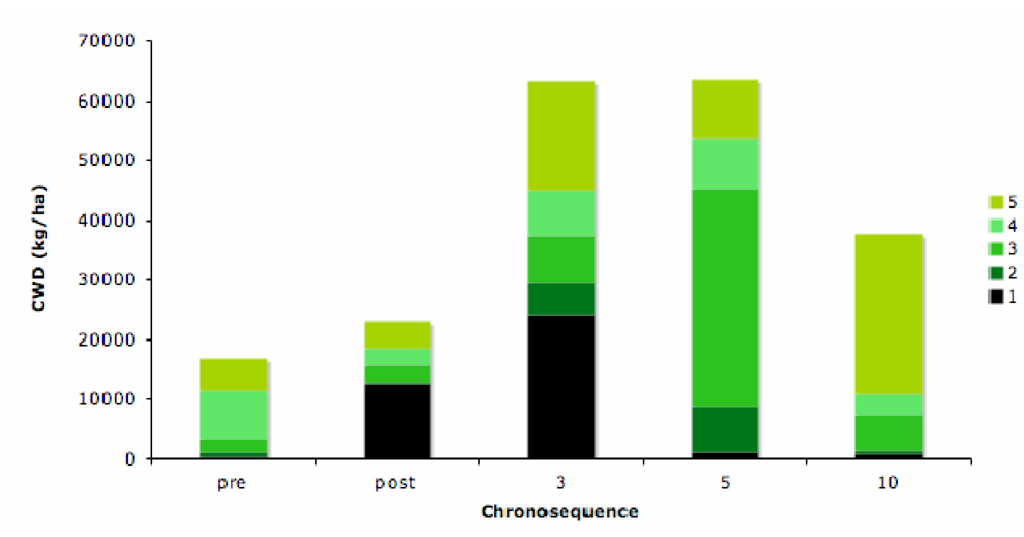
- Space For Time
- Use Chronosequence (Pre, Post, 3, 5 and 10)



Basal Area in Haliburton Forest by Harvesting treatment



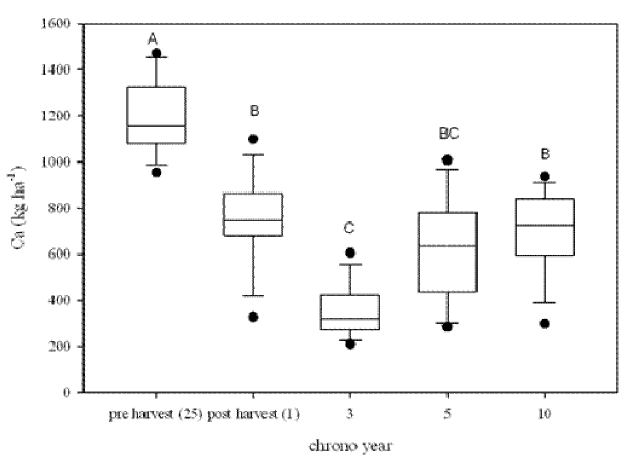
Coarse Woody Debris



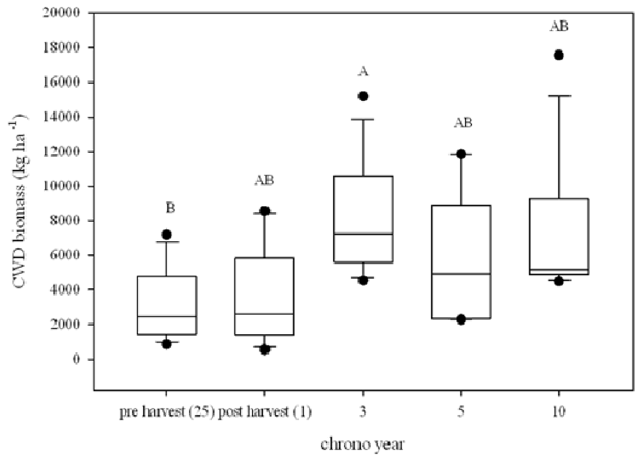
bark and wood calcium

	Ca (mg/kg)	
Species	Bark	Wood
Red Oak	23104	4839
White Ash	19877	3729
Ironwood	27441	2175
Striped Maple	21883	2084
Sugar Maple	21291	2021
Eastern Hemlock	5280	1940
Red Maple	14764	1810
Balsam Fir	8165	1533
Black Cherry	9752	1333
Yellow Birch	2949	1128
American Beech	15880	641

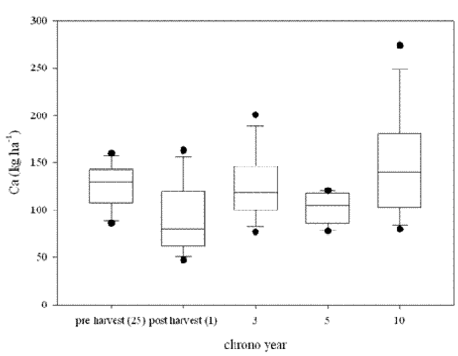
Calcium in Above Ground Biomass



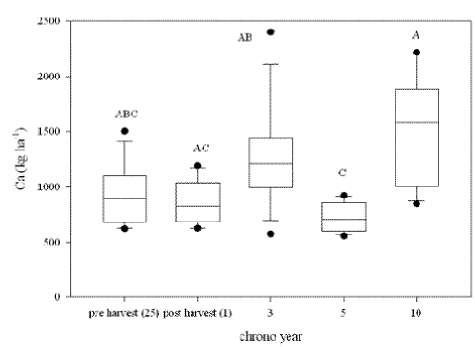
Calcium in Coarse Woody Debris



Impact on soil Calcium pool

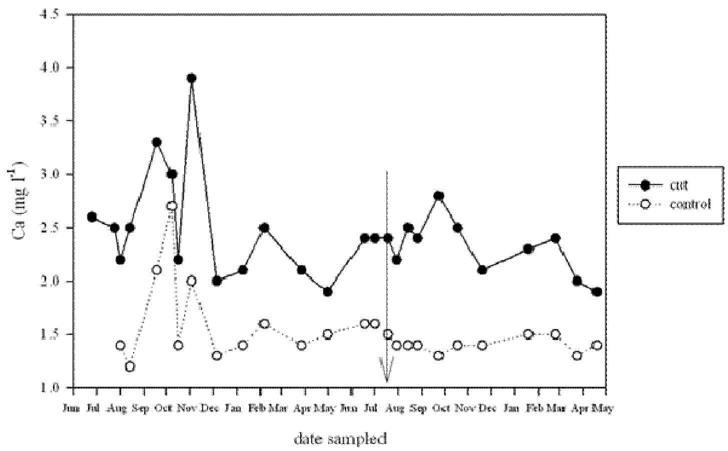


Forest Floor



Soil Rooting Zone

Impact on Stream Chemistry



Mineral Weathering

Oxide	(% weight ± SD)	minerology	(%wt)	weathering rate (kg/ha/yr)
SiO2	58 ± 2.8	K-Feldspar	5.4	Ca 4.9
TiO2	0.76 ± 0.06	Plagioclase	24.9	Mg 1.7
Al2O3	13.8 ± 0.53	Albite	21.6	K 1.9
Fe2O3	5.7 ± 0.43	Hornblende	5.5	Na 4.0
MnO	0.08 ± 0.01	Biotite	4.7	
MgO	1.3 ± 0.19	Muscovite	6.9	
CaO	2.4 ± 0.27	Fe-Chlorite	2.5	
K2O	2.3 ± 0.20	Mg-Vermiculite	3.9	
Na2O	2.6 ± 0.12	Kaolinite	4.2	
P2O5	0.18 ± 0.05	Calcite	0.5	

Bulk Deposition (2000-2006): 2.2 kg/ha/yr

Mass Balance (assuming 15 year rotation)

	kg ha^{-1}		
nutrient	worst	measured	best
Ca	-21.5	-14.9	-10.6
K	-4.9	-2.8	-1.4
Mg	-2.9	-0.32	0.88
Na	1.2	4.1	6.2
Mn	-0.39	-	-
Al	0.15	-	-
Fe	-0.14	-	-
P	-0.03	-0.005	0.01
C			
N	0.42	0.95	1.21
S	8.64	11.3	12.7

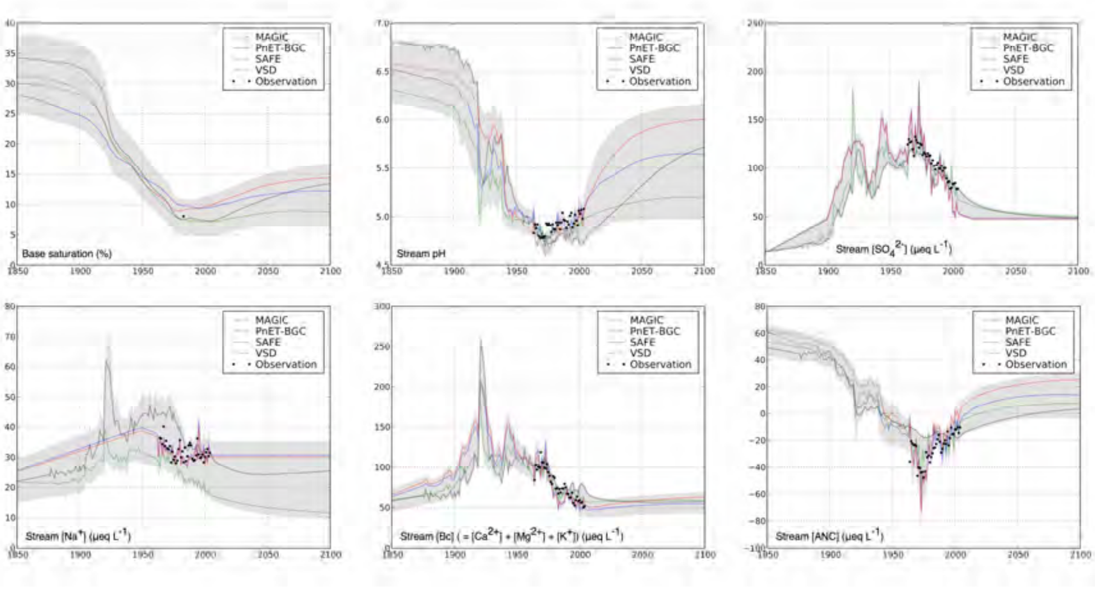
The Use of Dynamic Models

- Response of soils to acid deposition is slow.
- <u>When</u> can we expect to see changes?
- MAGIC model applied to central Ontario forest catchments.

	Hindcast and calibration period			Harvesting scenario	
	1875	1975	2000	2050	2100
Chub-1	34.9	15.7	11.5	7.3	5.1
Harp-4	23.9	12.9	9.9	6.2	3.9

Estimated exchangeable Ca (%) in soil of 2 forested catchments obtained using MAGIC and including estimates of nutrient uptake and timber harvesting scenarios (see Watmough and Aherne 2008 CJFAS, for more details)..

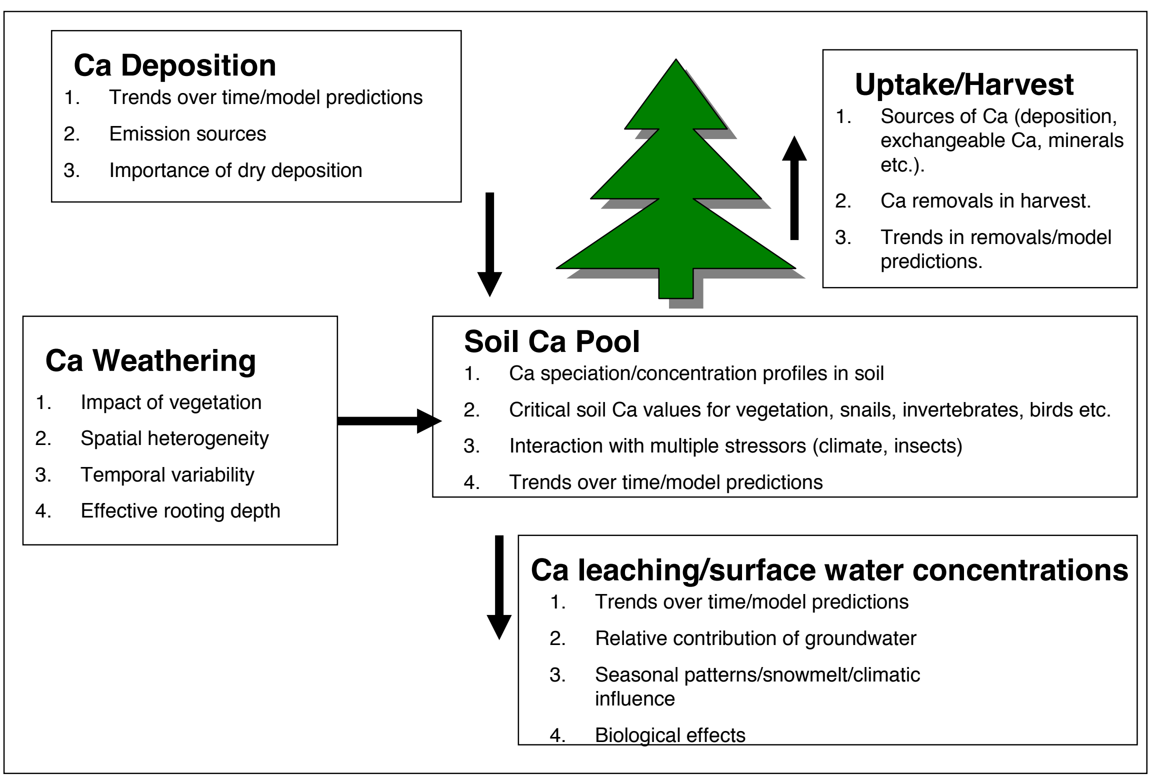
Assessing uncertainty (data and models)



Prediction is that:

'If our current understanding of Ca biogoechemistry is correct, Ca levels will be much lower than are currently observed with potential biological ramifications'

However, several unanswered questions remain:



Acknowledgements

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