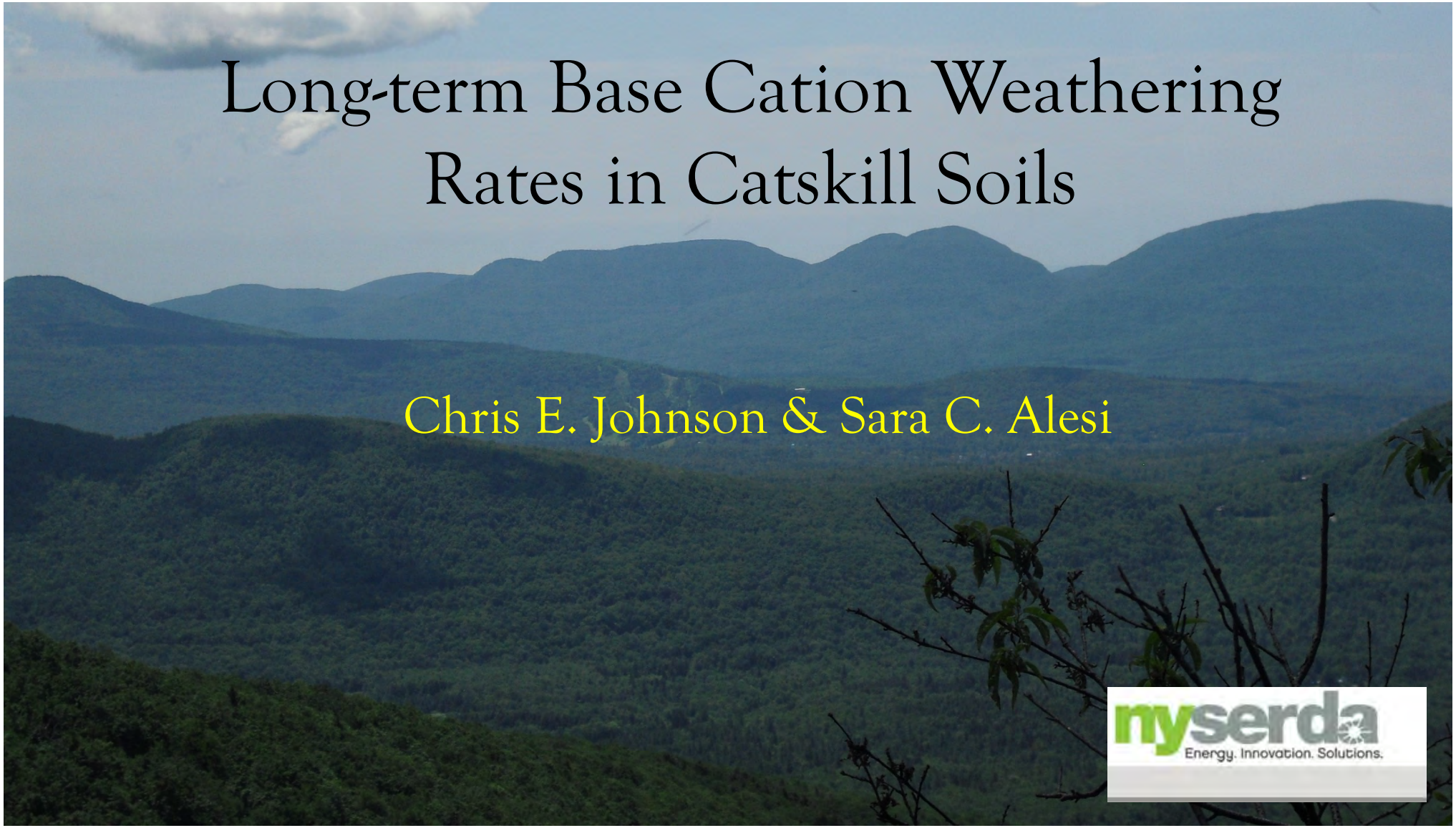
Syracuse University



Long-term Base Cation Weathering Rates in Catskill Soils

Chris E. Johnson & Sara C. Alesi

nyserda
Energy. Innovation. Solutions.

Chemical Weathering

- Dissolution of minerals in soils and parent material.

  Plagioclase Feldspar:

  $Na_{0.79}Ca_{0.20}Al_{1.19}Si_{2.81}O_8$ (s)

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  Plagioclase Feldspar:

  $Na_{0.79}Ca_{0.20}Al_{1.19}Si_{2.81}O_8\ (s) + 6.81H_2O + 1.19H^+\ (aq) \rightarrow$

  $0.79Na^+\ (aq) + 0.20Ca^{2+}\ (aq) + 1.19\ Al(OH)_3\ (s) + 2.81H_4SiO_4\ (aq)$

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  Releases base cations to soil water

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- Dissolution of minerals in soils and parent material.

Plagioclase Feldspar:

Neutralizes acidity

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Releases base cations to soil water

Chemical Weathering

- Dissolution of minerals in soils and parent material.

Plagioclase Feldspar:

Neutralizes acidity → Critical Loads

$$Na_{0.79}Ca_{0.20}Al_{1.19}Si_{2.81}O_8\ (s) + 6.81H_2O + 1.19H^+\ (aq) \rightarrow$$

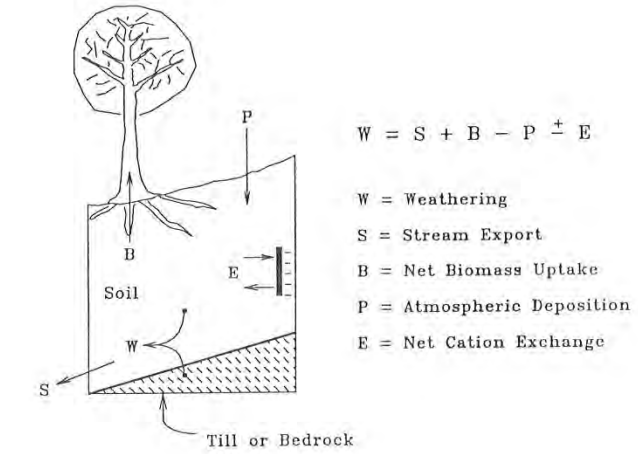
$$0.79Na^+\ (aq) + 0.20Ca^{2+}\ (aq) + 1.19\ Al(OH)_3\ (s) + 2.81H_4SiO_4\ (aq)$$

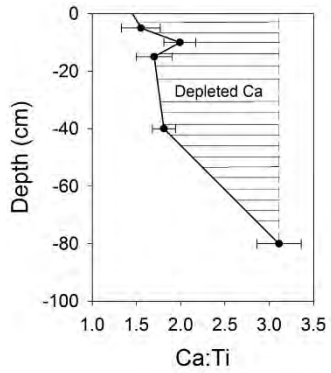
Releases base cations to soil water

Sustainable Water Quality

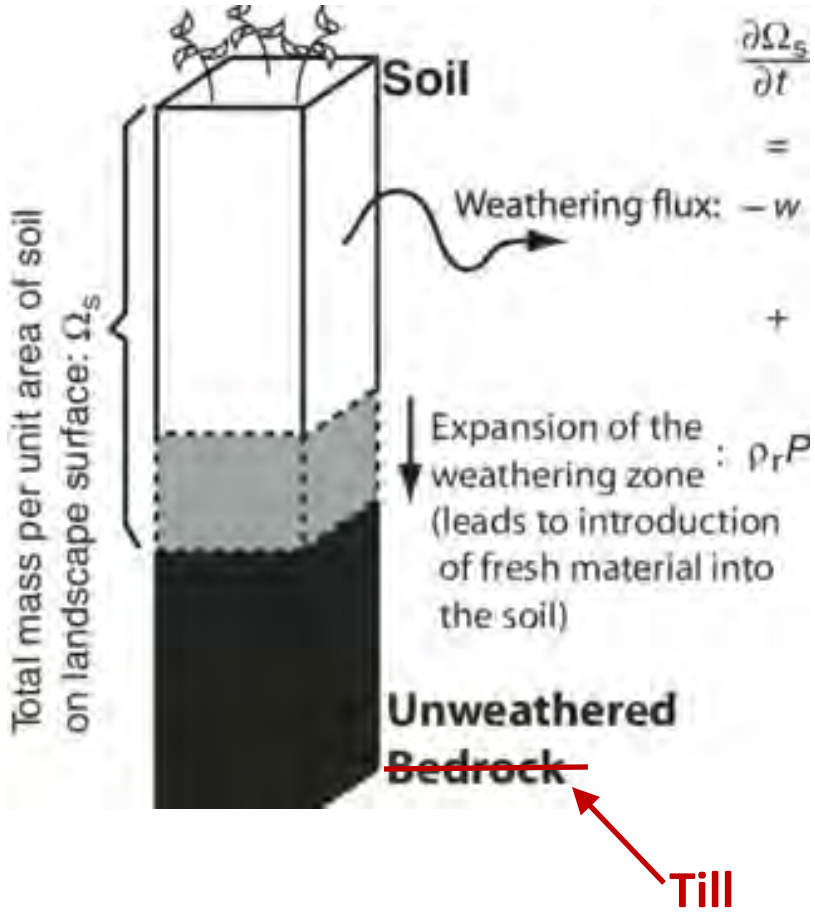
Chemical Weathering

- Watershed mass balances
  - Estimate release of ions via weathering using inputs to and outputs from watersheds.
- Element Depletion
  - Estimate loss of weathering products relative to an immobile element (e.g., Zr, Ti)
- Modeling
  - PROFILE (and its offspring)
    - Requires bulk soil/parent material chemistry, climate data, precipitation chemistry.
    - Successfully applied in Europe, Canada, USA
    - Used for setting critical loads targets in Europe

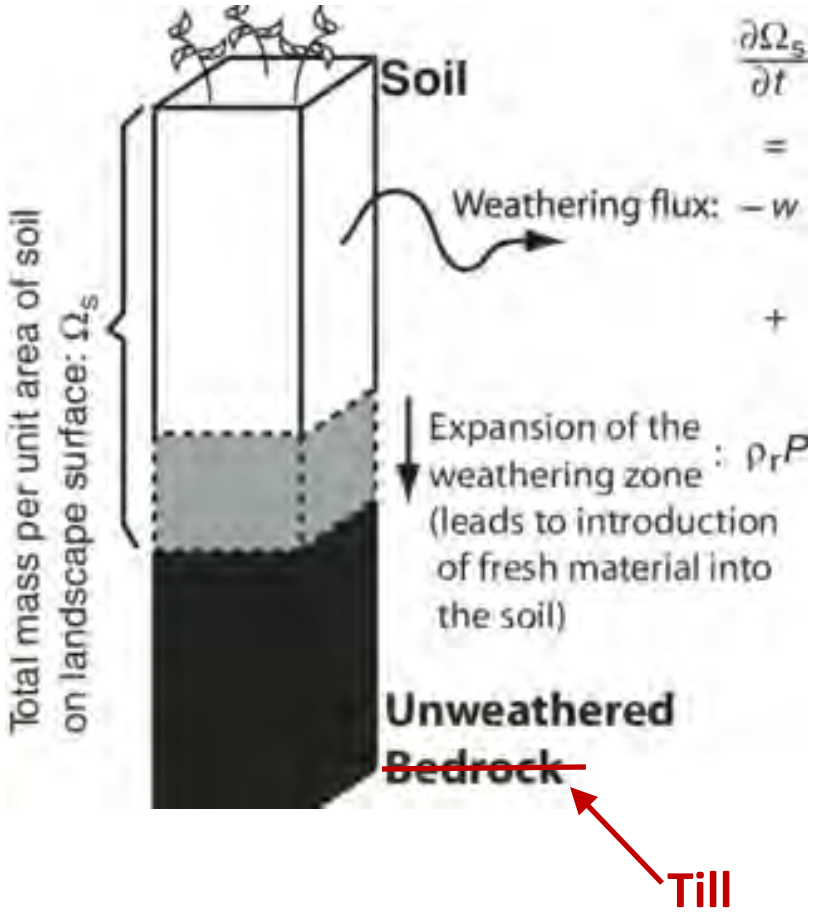




Element Depletion in Weathering Soil Profiles



Element Depletion in Weathering Soil Profiles



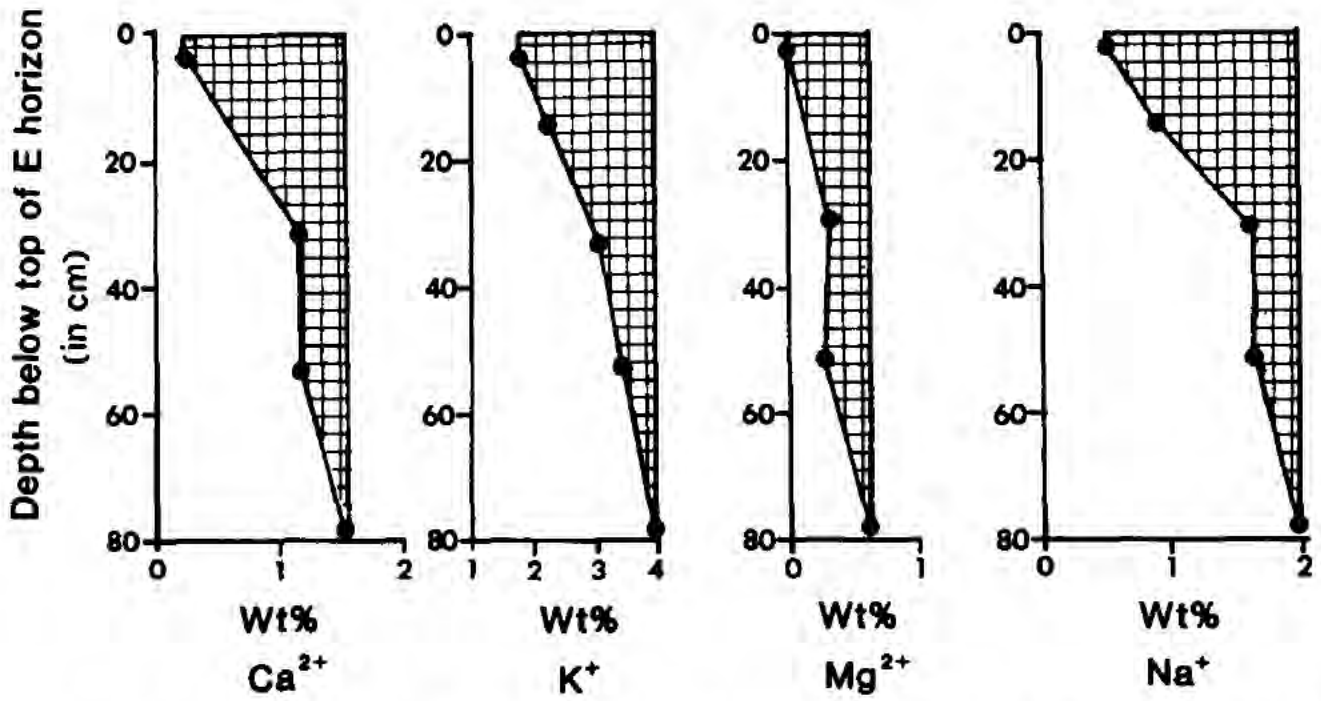
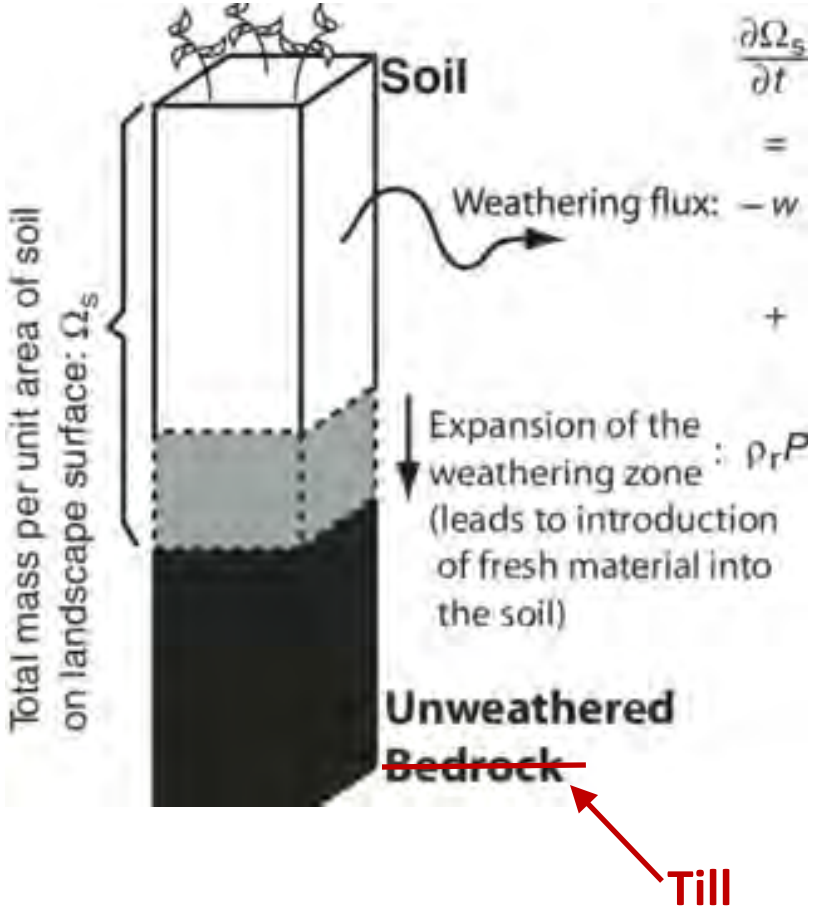


Figure 4. Example of cation-depletion curves constructed for soils in Panther Lake watershed.

April et al. (1986)

Element Depletion in Weathering Soil Profiles



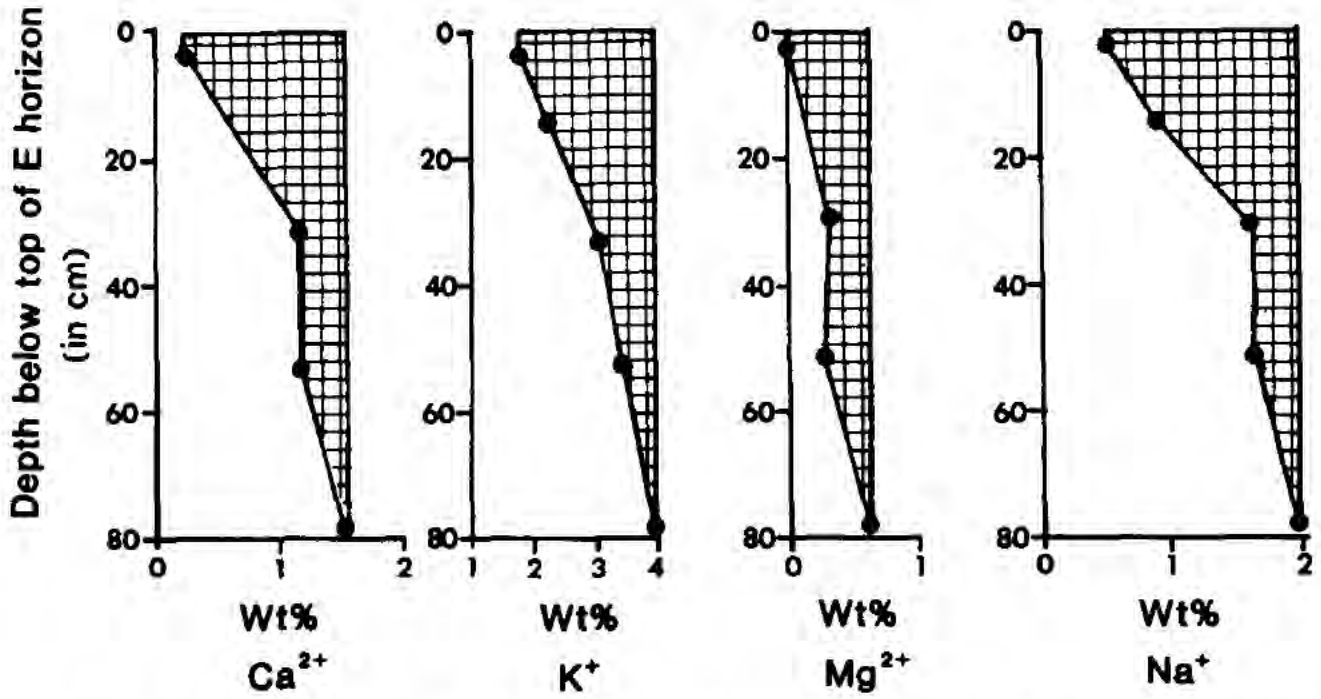
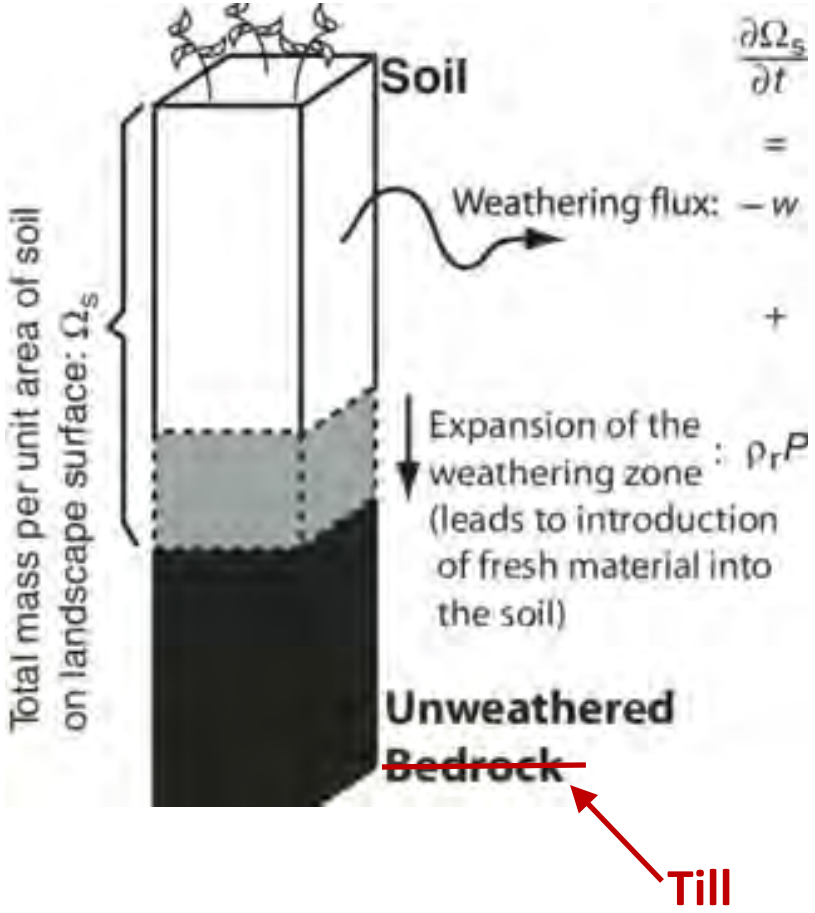


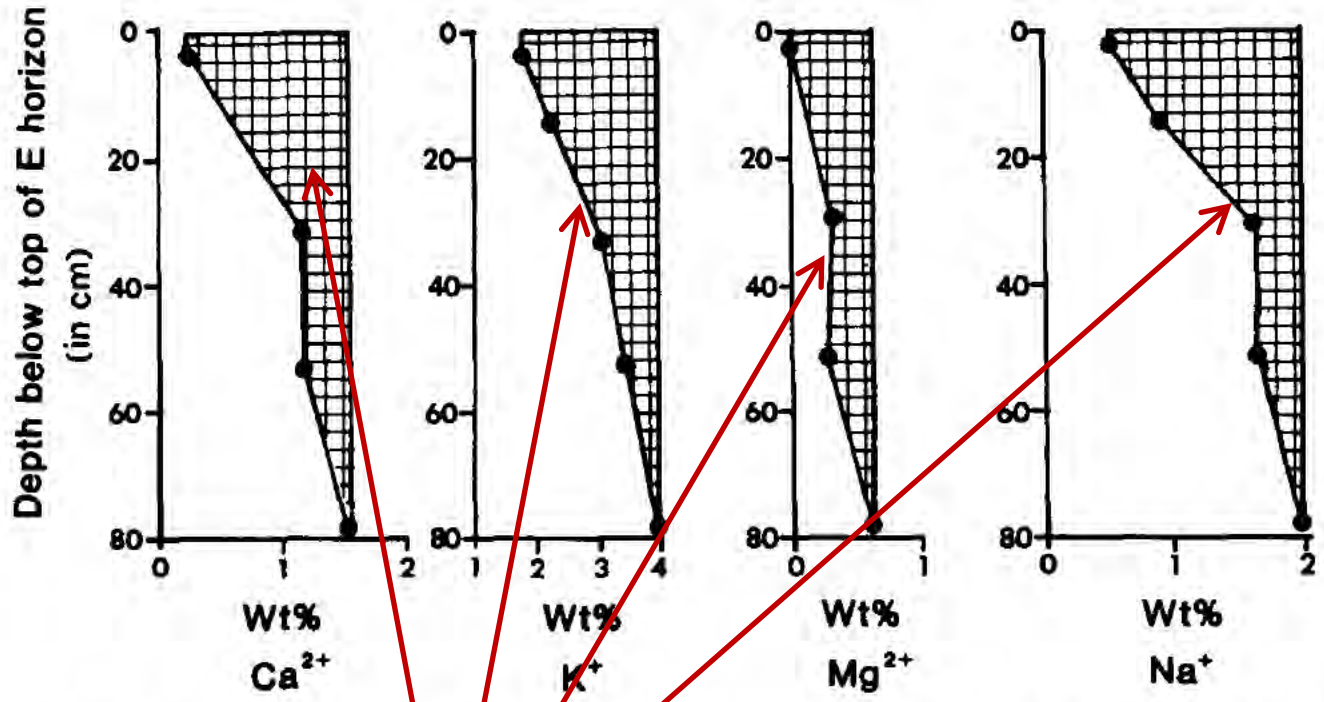
Figure 4. Example of cation-depletion curves constructed for soils in Panther Lake watershed.

April et al. (1986)

$$M_j = \frac{C_{j,p}}{C_{i,p}} \int_0^{L_w} \rho_w(z) C_{i,w}(z) \tau_j(z) dz$$

Element Depletion in Weathering Soil Profiles





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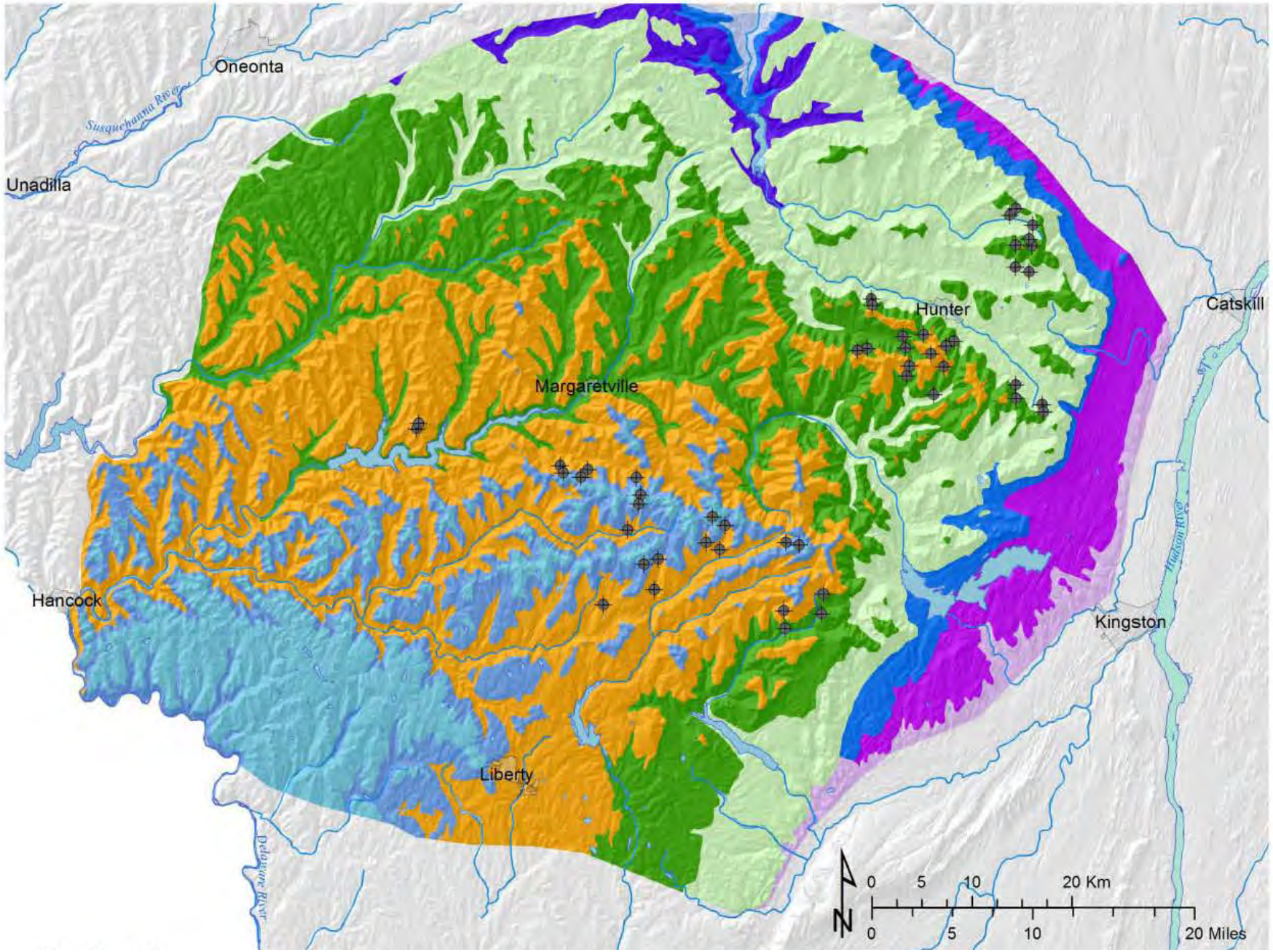
$$M_j = \frac{C_{j,p}}{C_{i,p}} \int_0^{L_w} \rho_w(z) C_{i,w}(z) \tau_j(z) dz$$

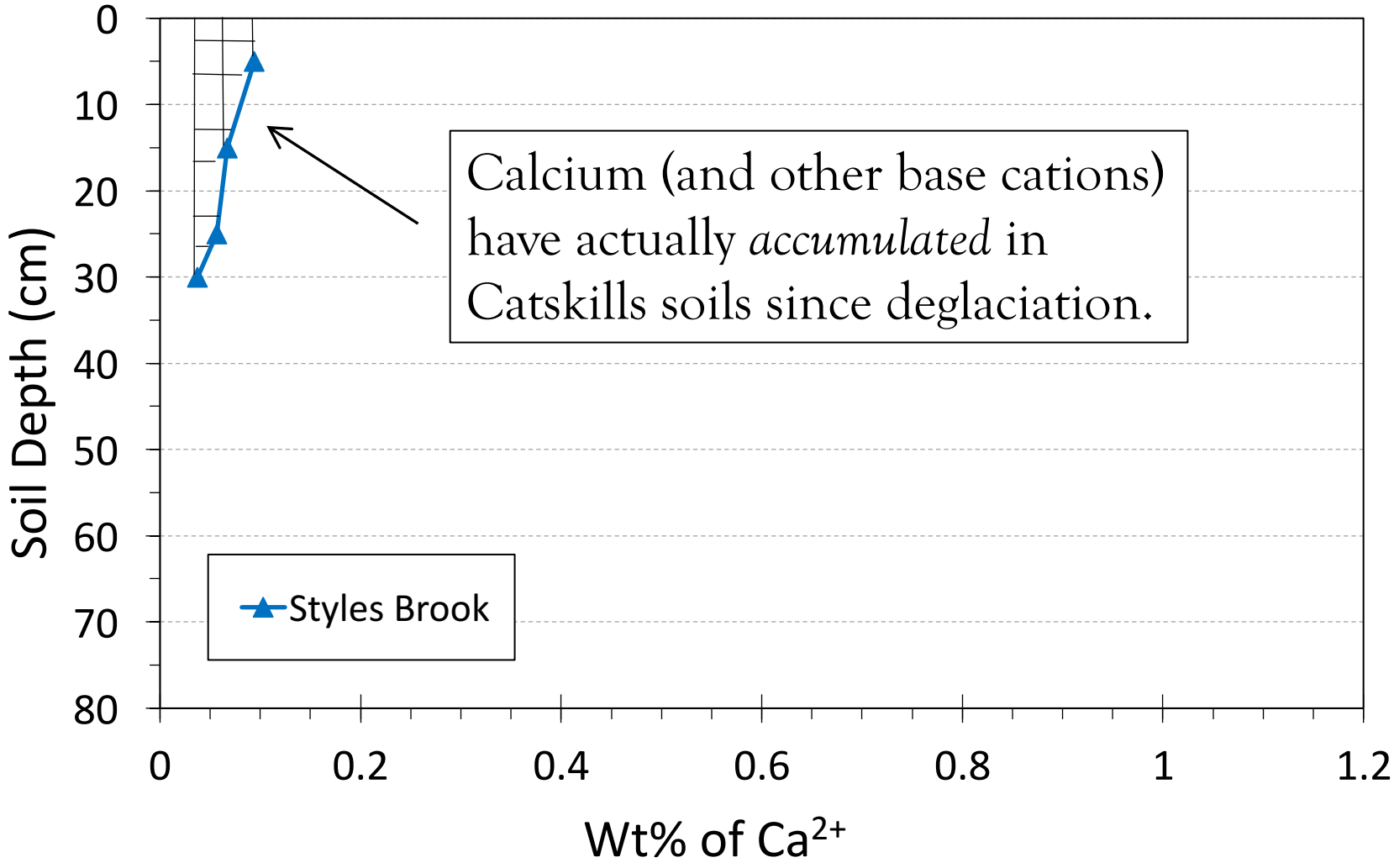
Study Sites


Oneonta
Susquehanna River
Unadilla
Hunter
Catskill
Margaretville
Hancock
Kingston
Liberty
Delaware River
Hudson River
N
0 5 10 20 Km
0 5 10 20 Miles

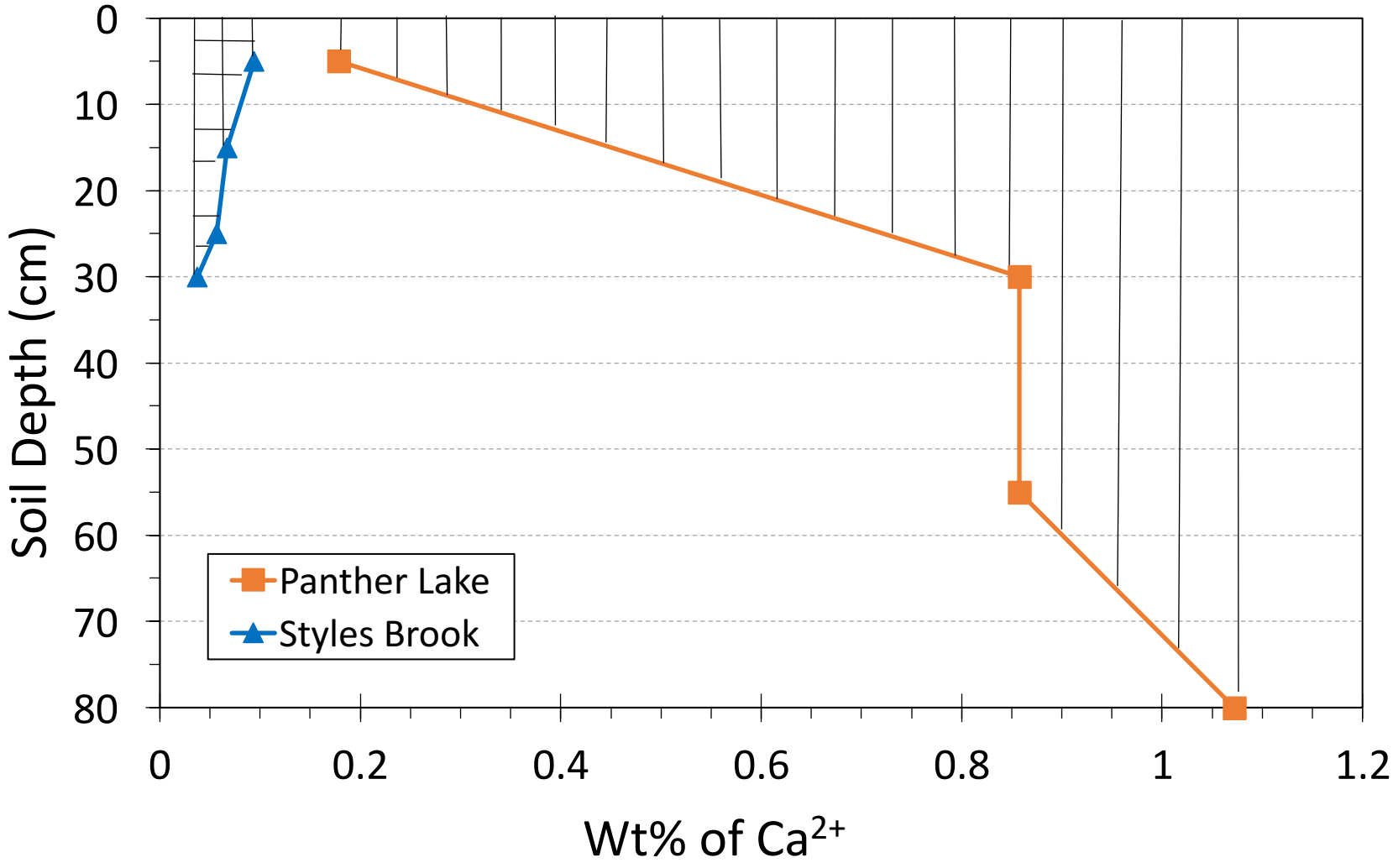
Methods

- "Quantitative" Soil Pits
  - Sampled by 10-cm depth increments.
- X-Ray Fluorescence Spectrometry
  - Total concentrations of 29 elements.
- Data Analysis
  - Zirconium (Zr) determined to be the most immobile reference element.

Results


Soil Depth (cm)
0
10
20
30
40
50
60
70
80
0
0.2
0.4
0.6
0.8
1
1.2
Wt% of Ca2+
Styles Brook
Calcium (and other base cations) have actually *accumulated* in Catskills soils since deglaciation.

Results


Soil Depth (cm)
0
10
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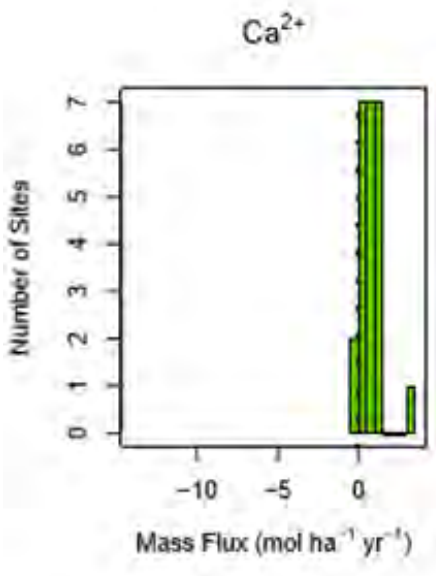
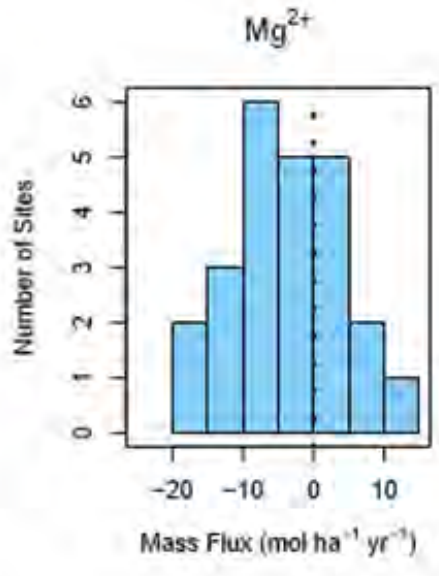
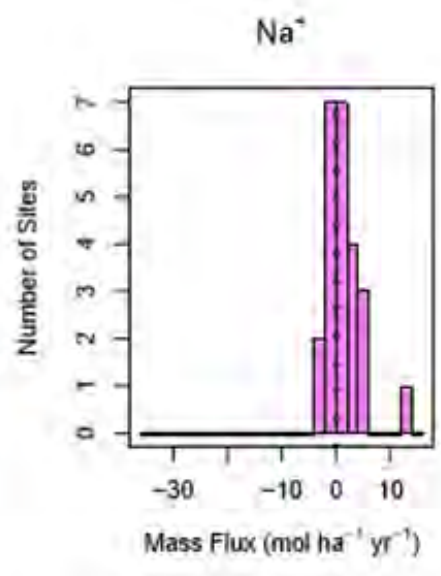
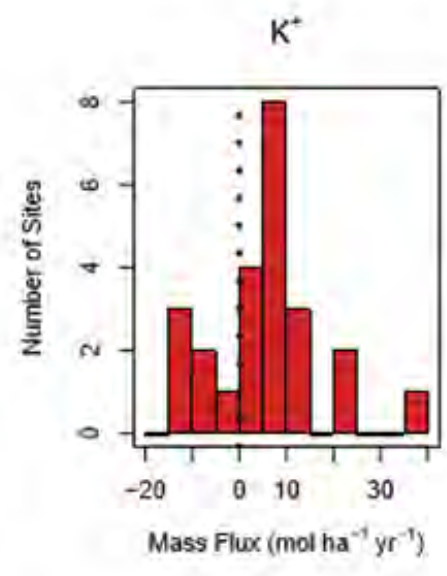
0.4
0.6
0.8
1
1.2
Wt% of Ca2+
Panther Lake
Styles Brook

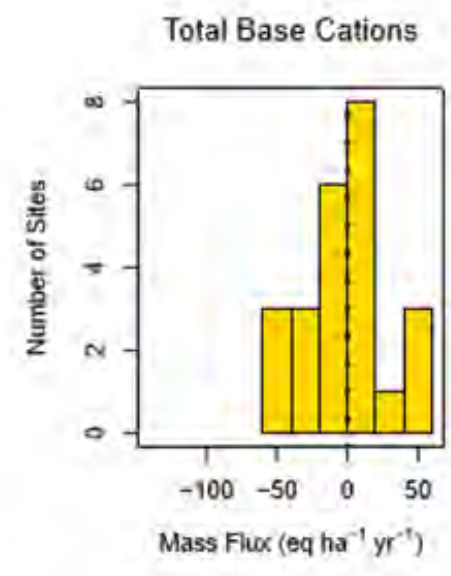
Results


Ca^{2+}
Number of Sites
0 1 2 3 4 5 6 7
−10 −5 0
Mass Flux (mol ha^{-1} yr^{-1})

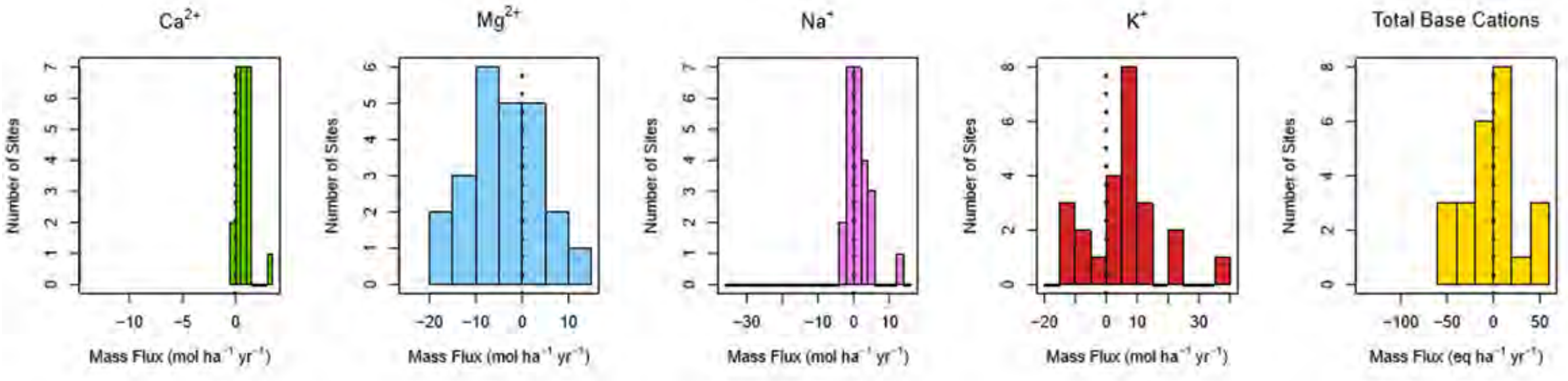

Mg^{2+}
Number of Sites
0 1 2 3 4 5 6
−20 −10 0 10
Mass Flux (mol ha^{-1} yr^{-1})


Na^{+}
Number of Sites
0 1 2 3 4 5 6 7
−30 −10 0 10
Mass Flux (mol ha^{-1} yr^{-1})


K^{+}
Number of Sites
0 2 4 6 8
−20 0 10 30
Mass Flux (mol ha^{-1} yr^{-1})

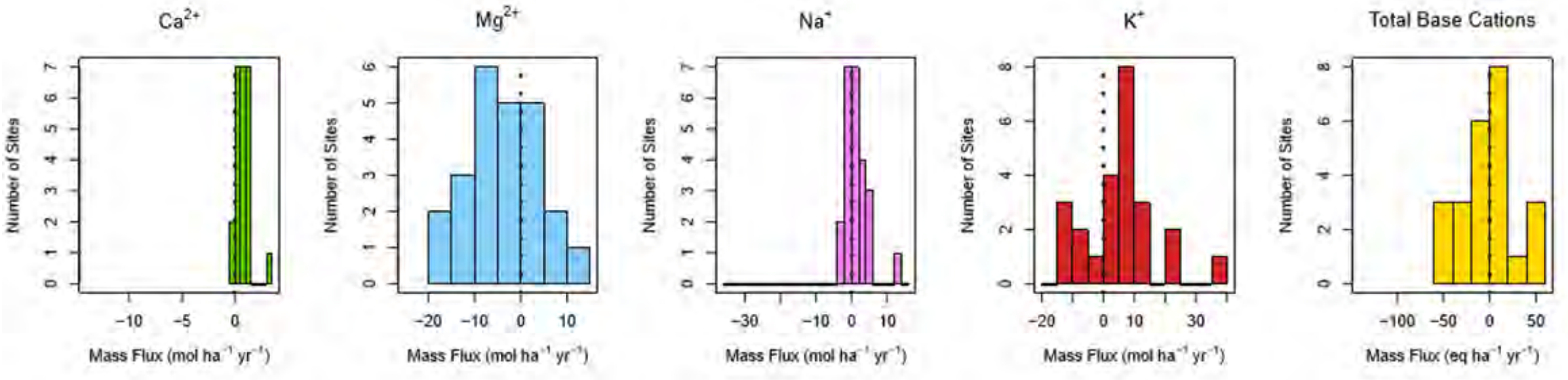

Total Base Cations
Number of Sites
0 2 4 6 8
−100 −50 0 50
Mass Flux (eq ha^{-1} yr^{-1})

Results



What could explain the apparent accumulation of base cations in Catskills soils?

Results



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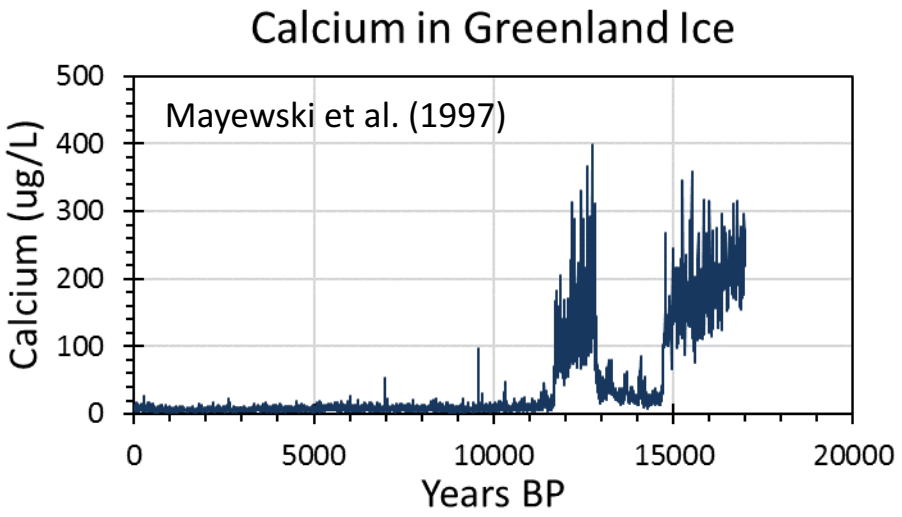
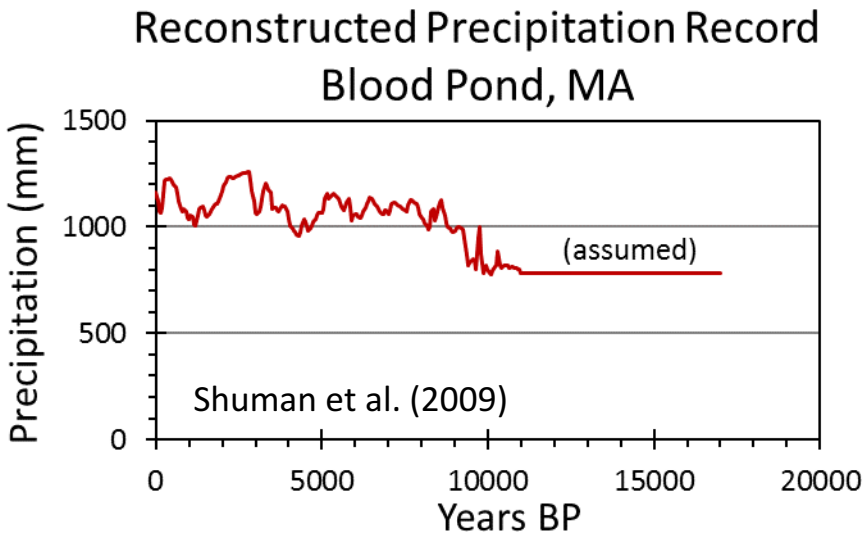
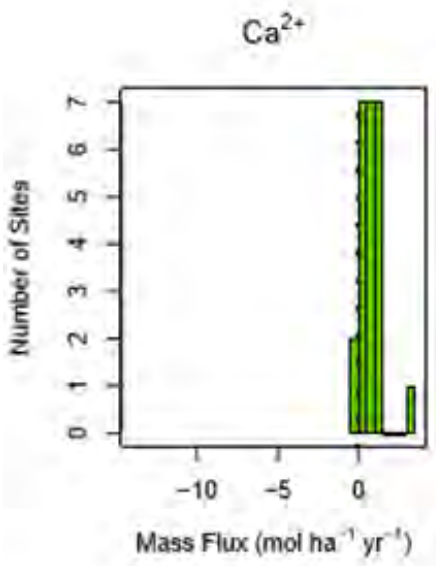
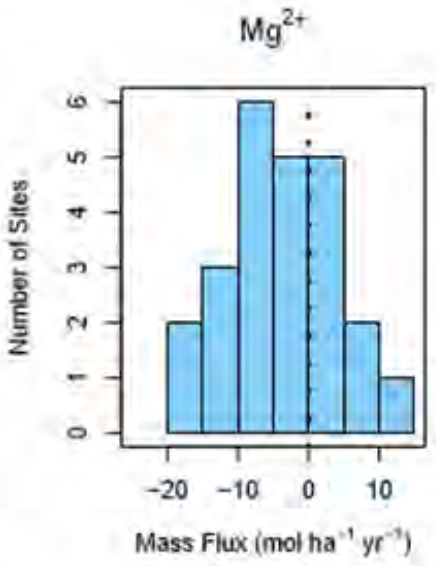
Atmospheric Inputs?

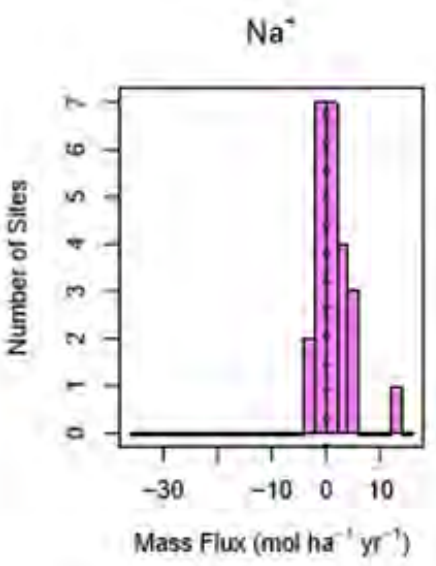


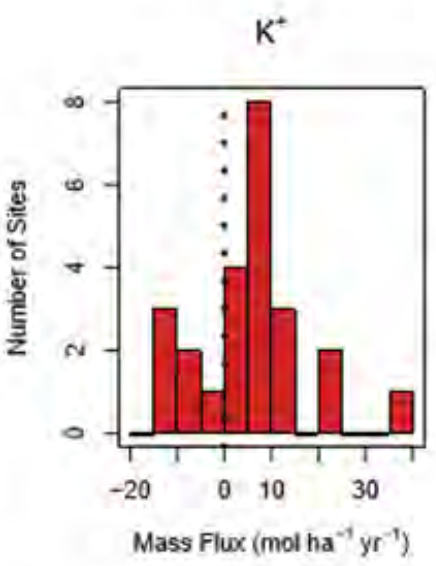


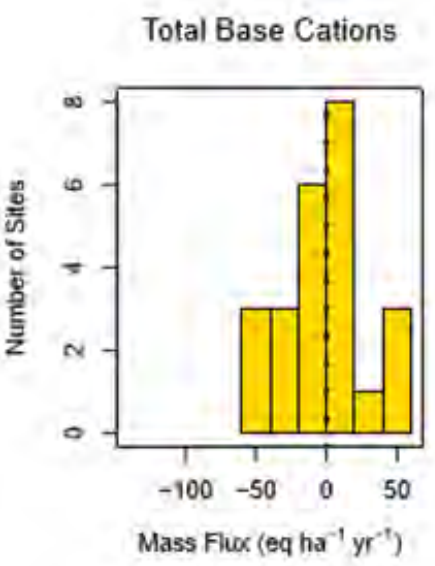
Results (using Greenland ice core data)

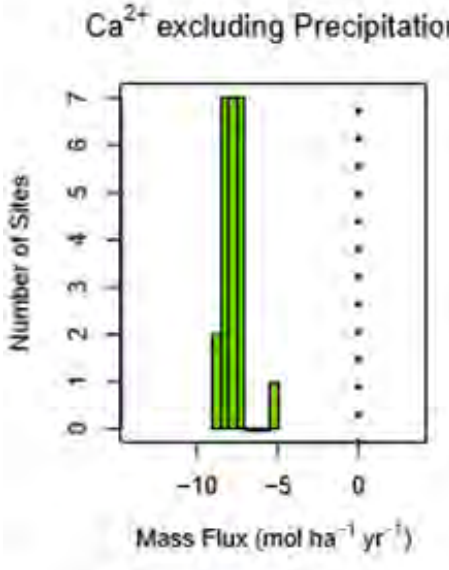


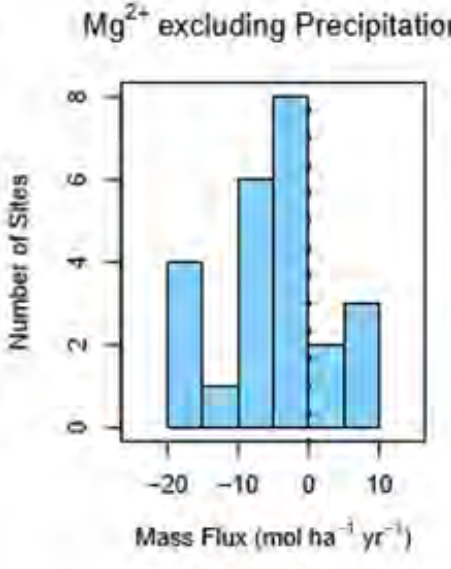


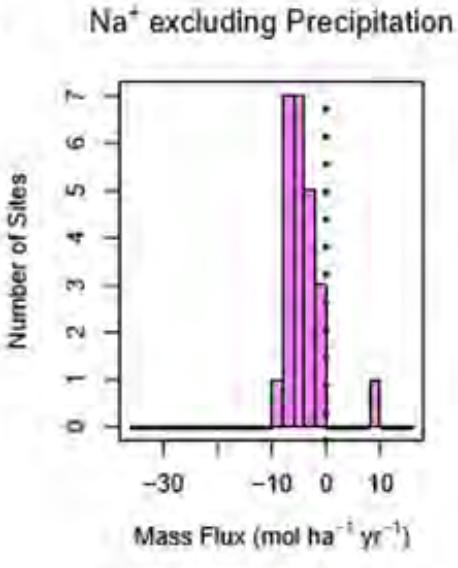


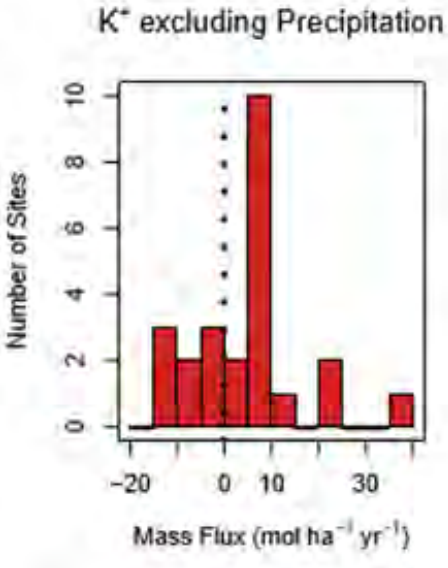


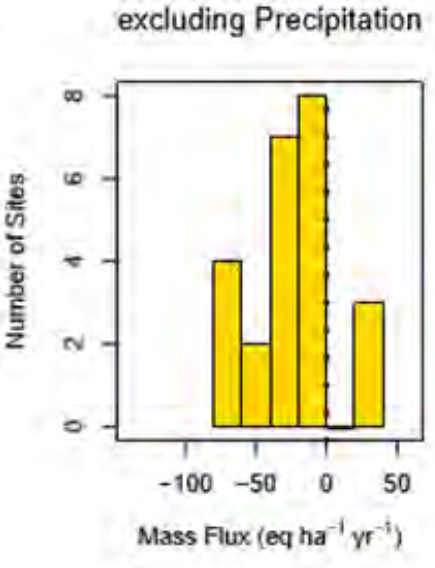




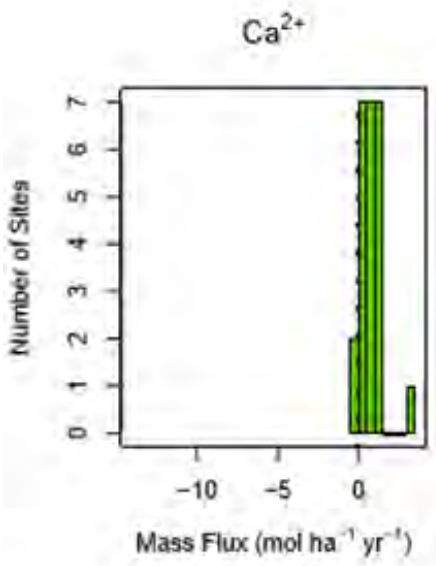


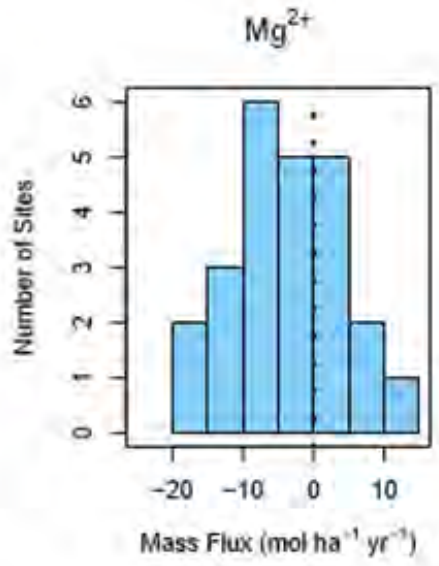


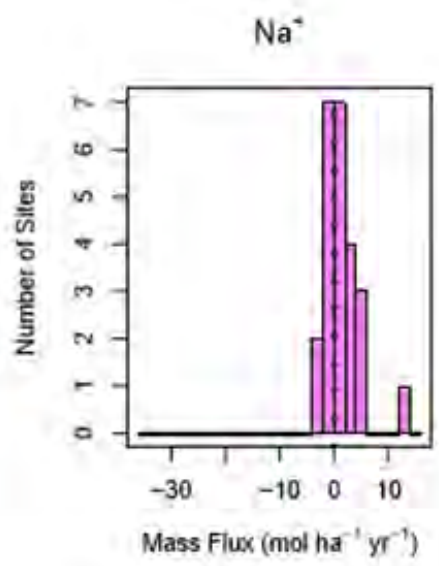


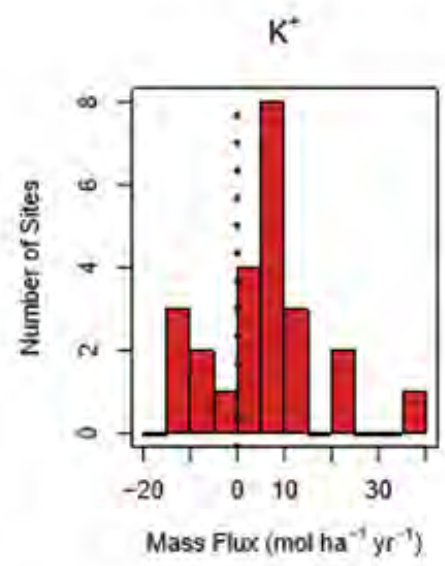


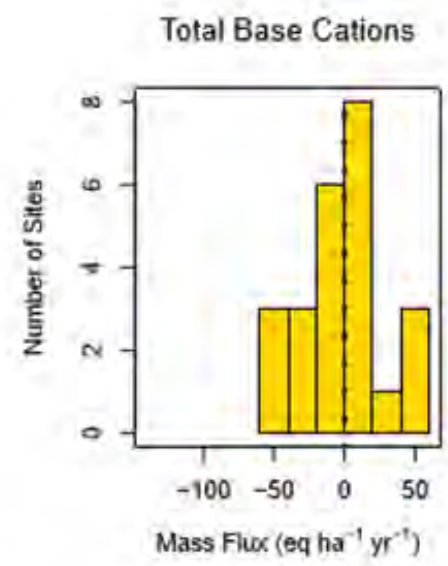
Results (using Denali, AK precipitation chemistry data)

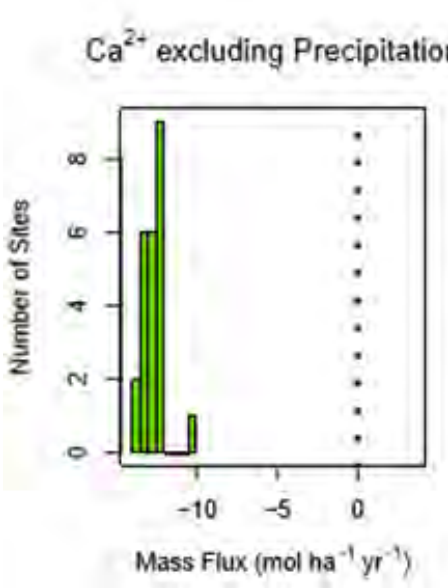


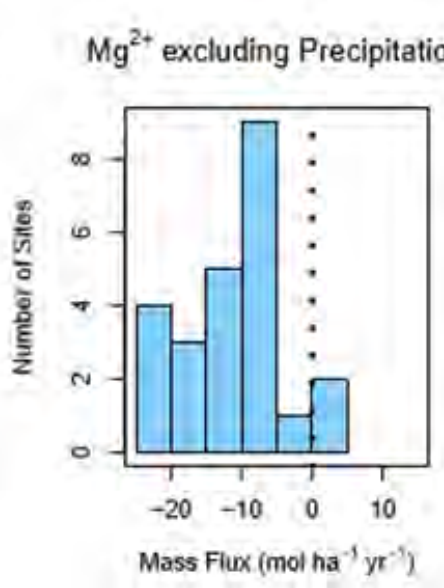


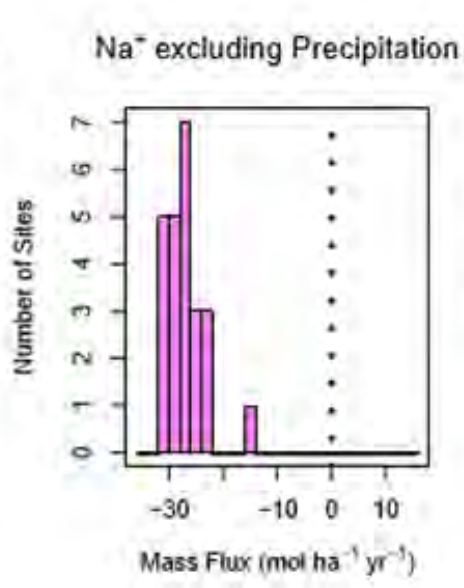


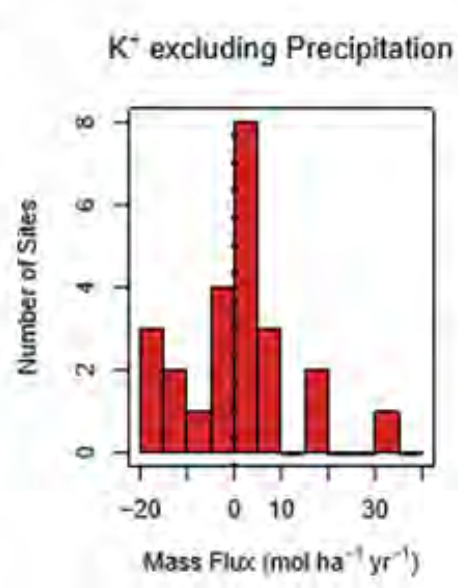


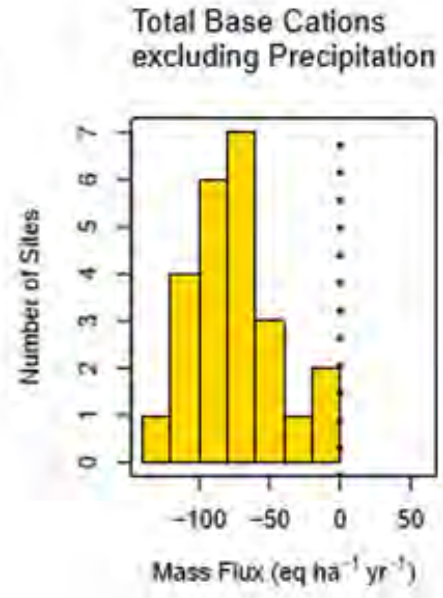




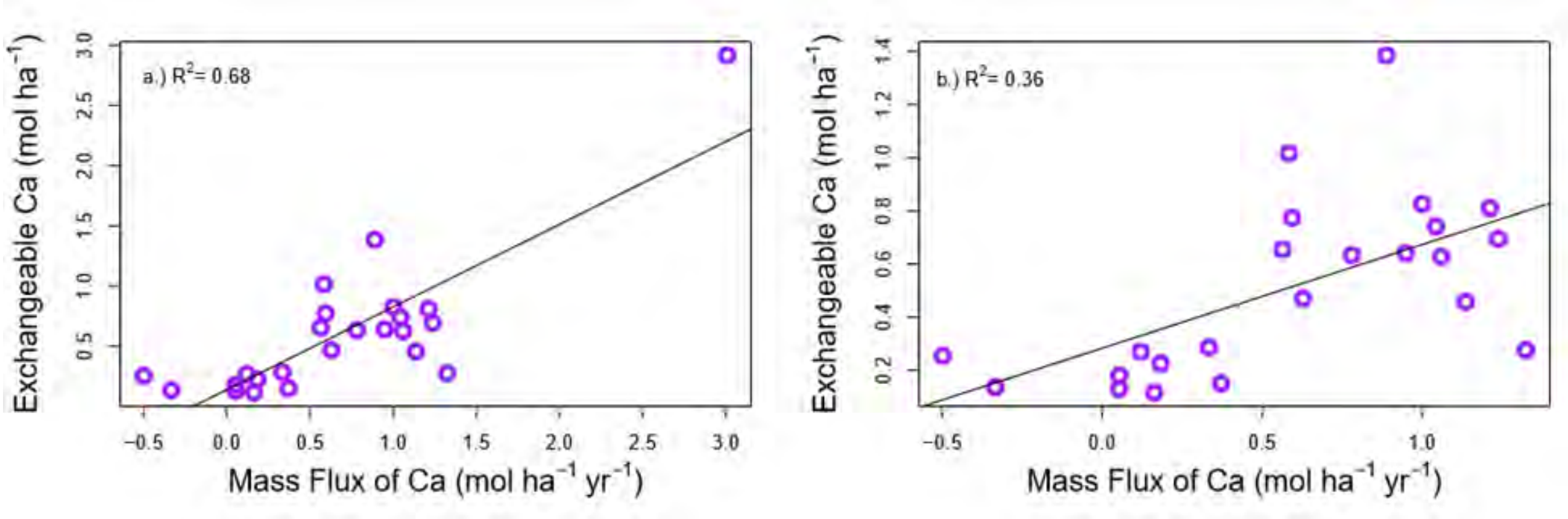








Results


a.) R^2= 0.68
Exchangeable Ca (mol ha^{-1})
Mass Flux of Ca (mol ha^{-1} yr^{-1})
b.) R^2= 0.36
Exchangeable Ca (mol ha^{-1})
Mass Flux of Ca (mol ha^{-1} yr^{-1})

Net BC Export is High Relative to Soil Pools

	2010-2013			2011	
Watershed	Ca Input	Ca Export	Net Export	Total Soil Ca	Years to Depletion
	mol ha^{-1} yr^{-1}			mol ha^{-1}	
Styles Brook	23	505	482	25,200	52
Biscuit Brook	25	286	261	12,260	47
Batavia Kill	18	308	290	35,300	122
Hollow Tree	24	868	844	56,600	67

Conclusions

1. Calcium and other base cations have accumulated in soil profiles of the Catskills in the period since deglaciation.
2. The amount of base cations accumulated can be explained by inputs in precipitation in the post-glacial period.
3. "You can't draw blood from a stone"
   - Catskills soils have extraordinarily low base cation concentrations → Naturally low weathering rates.
   - Even "pristine" precipitation inputs exceed long-term base cation release rates. (Useful case study for critical zone science)
   - Current base cation export from Catskills streams is large relative to long-term weathering rates in the region.