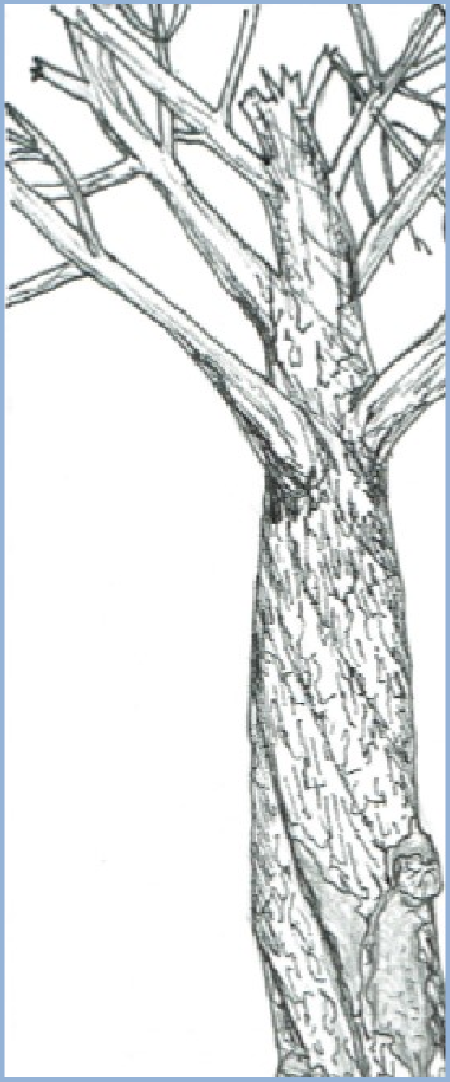
Legacy of acid rain: A tale of two species



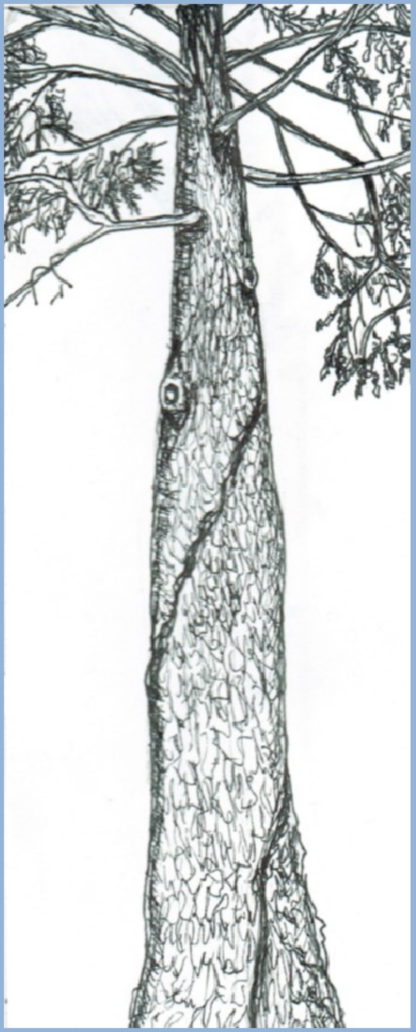
Background

Changes in emissions, deposition and streamwater

Soil calcium depletion and effects on red spruce and sugar maple

Watershed calcium addition experiment

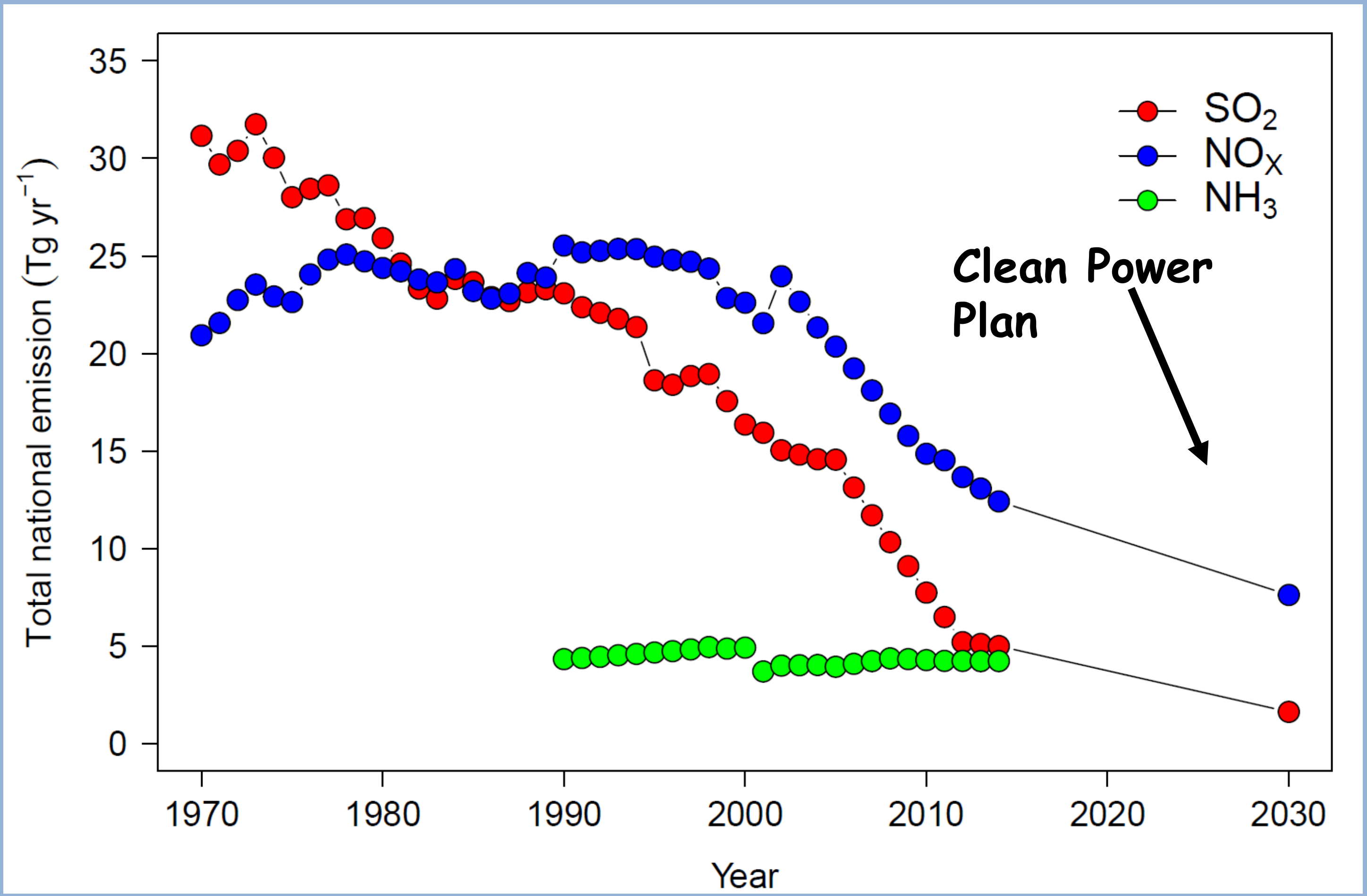
Legacies of acid rain



Help from: H. Fakhraei, G.Lovett
J. Battles, C. Johnson, G. Likens

NSF LTER Mini-symposium, March 21, 2017

Temporal trends in total U.S emissions

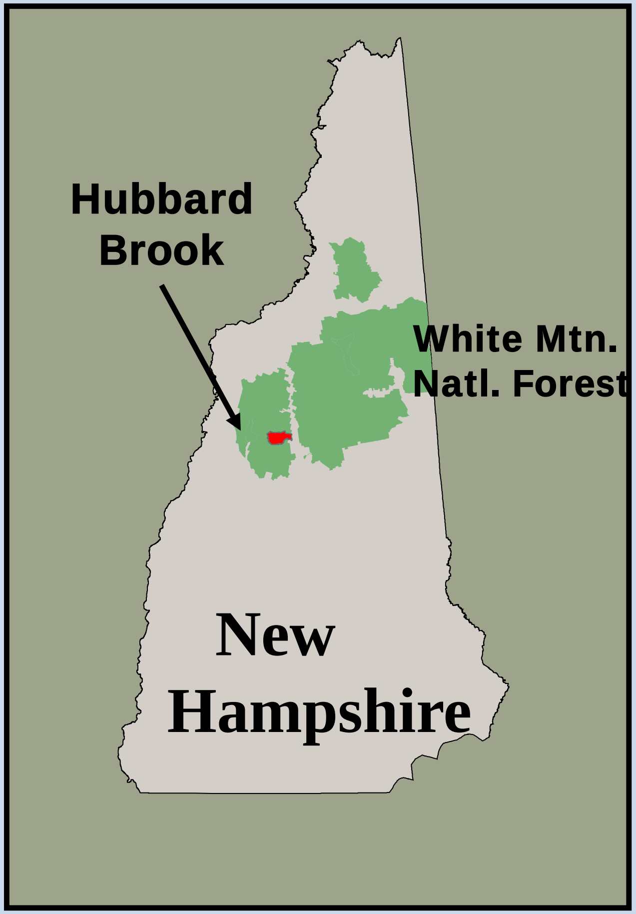


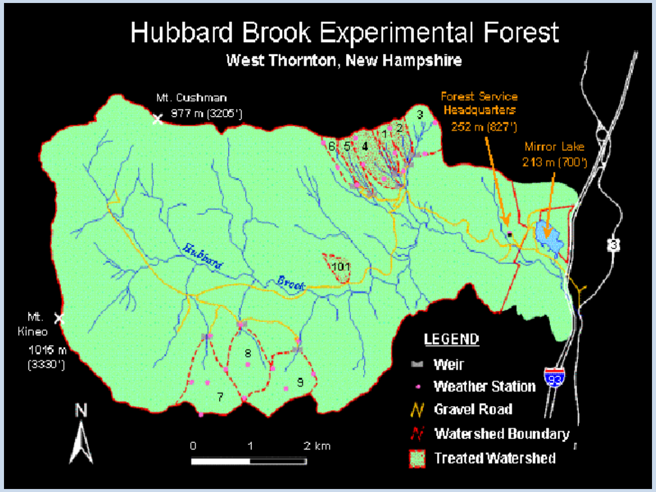
Power Plant Contribution

SO_2: 69$\pm$4%
NO_x: 21$\pm$4%
NH_3: < 1%

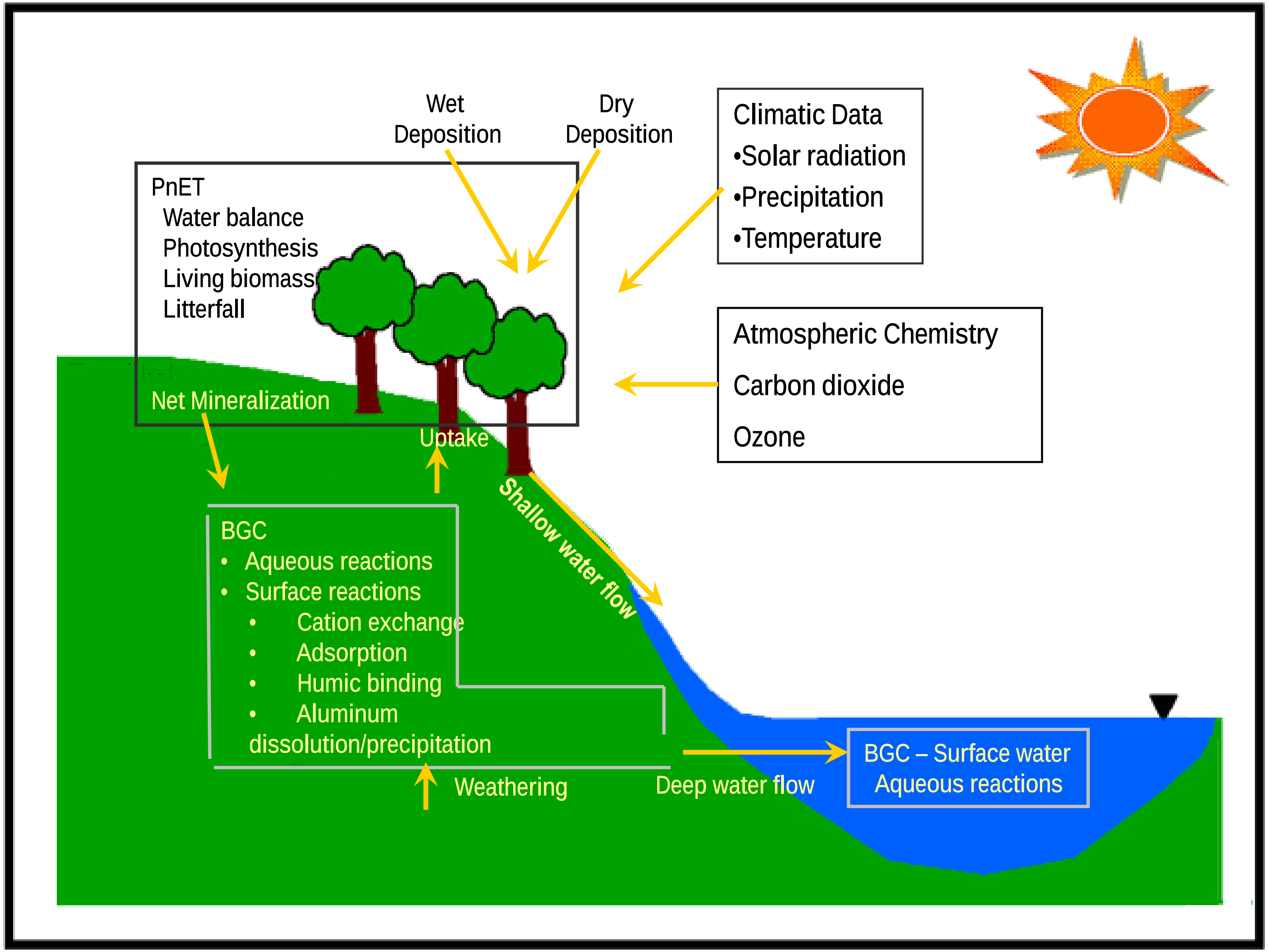
USEPA 2015

Hubbard Brook Experimental Forest
White Mountain National Forest, NH

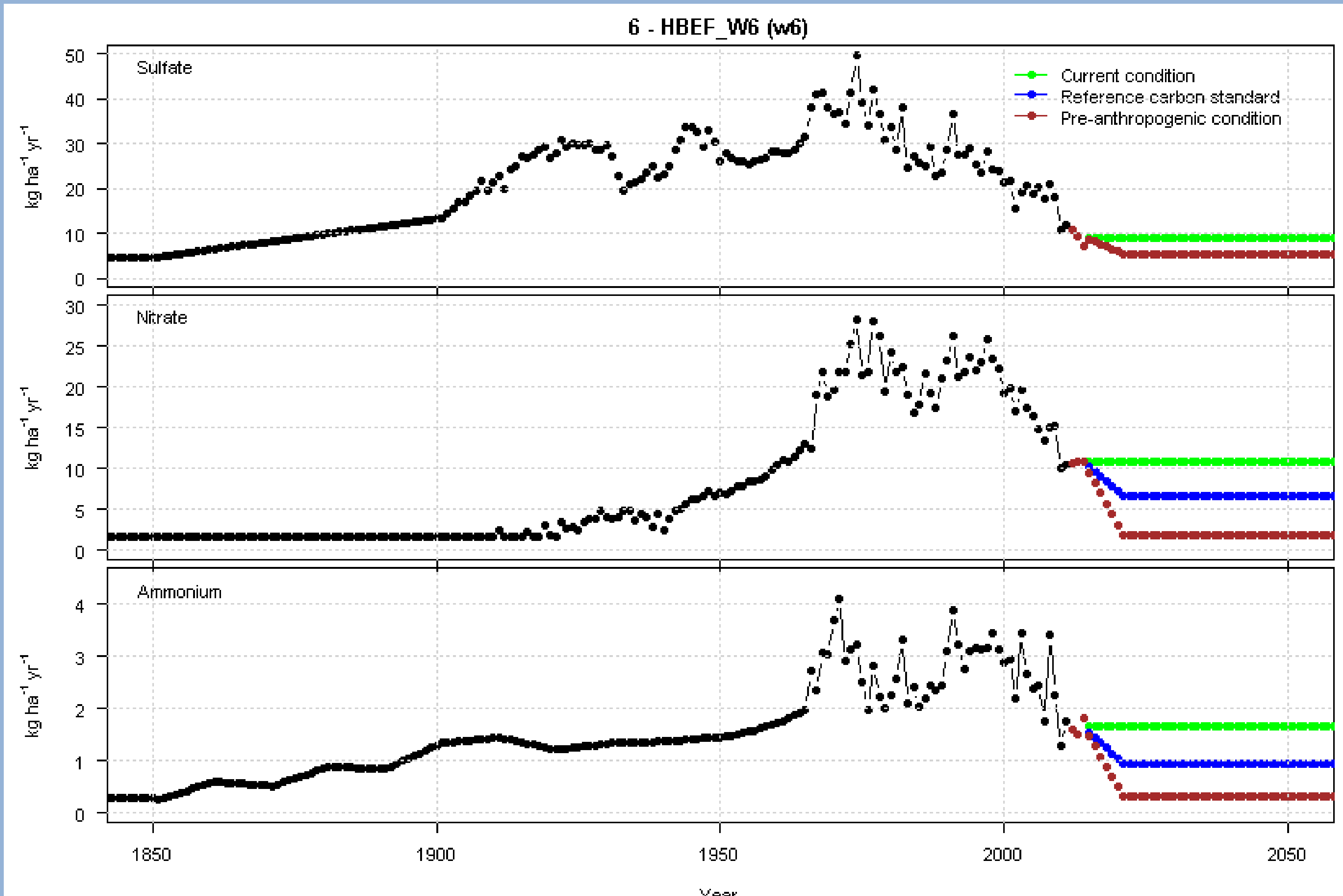


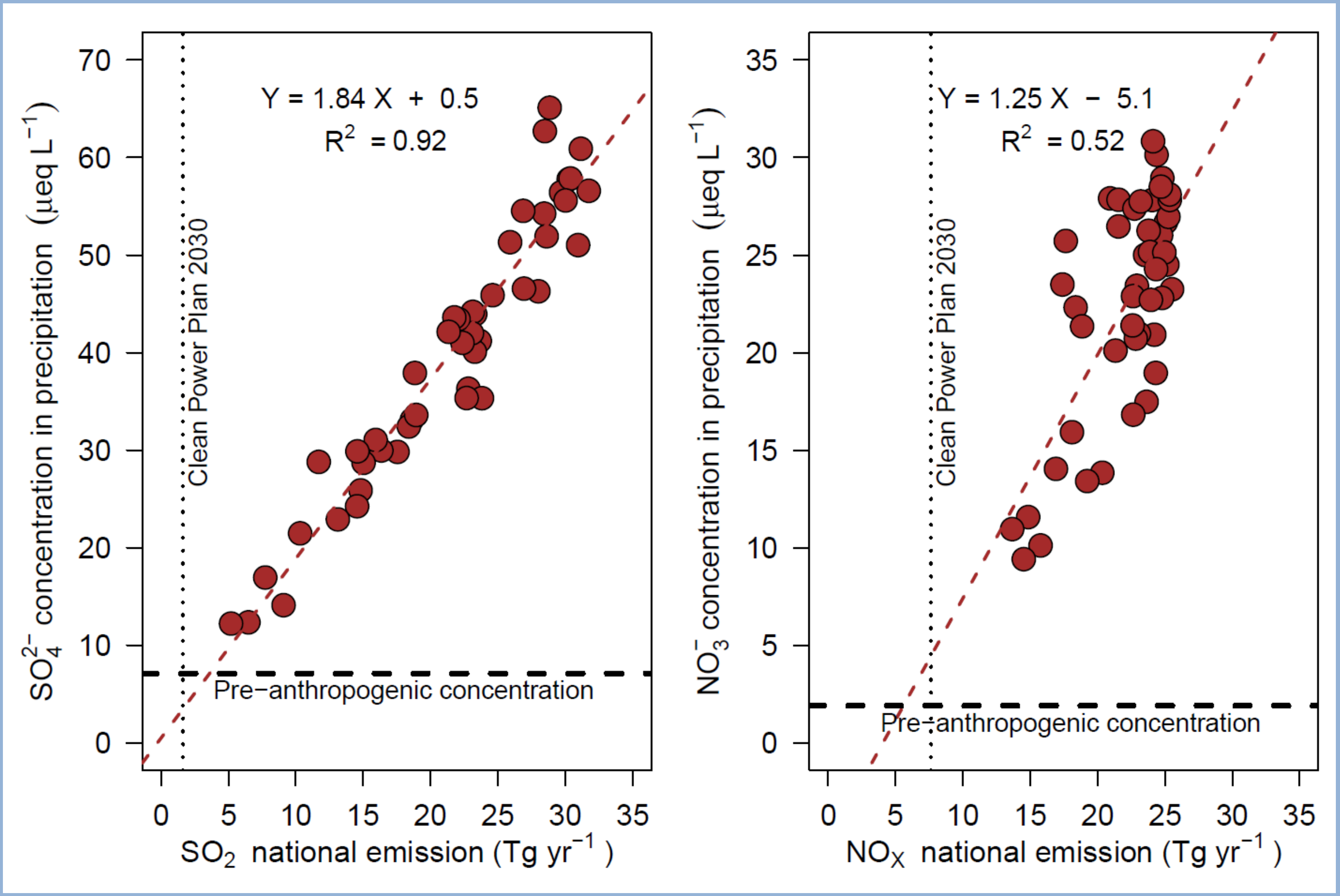


PnET-BGC - Forest biogeochemical model

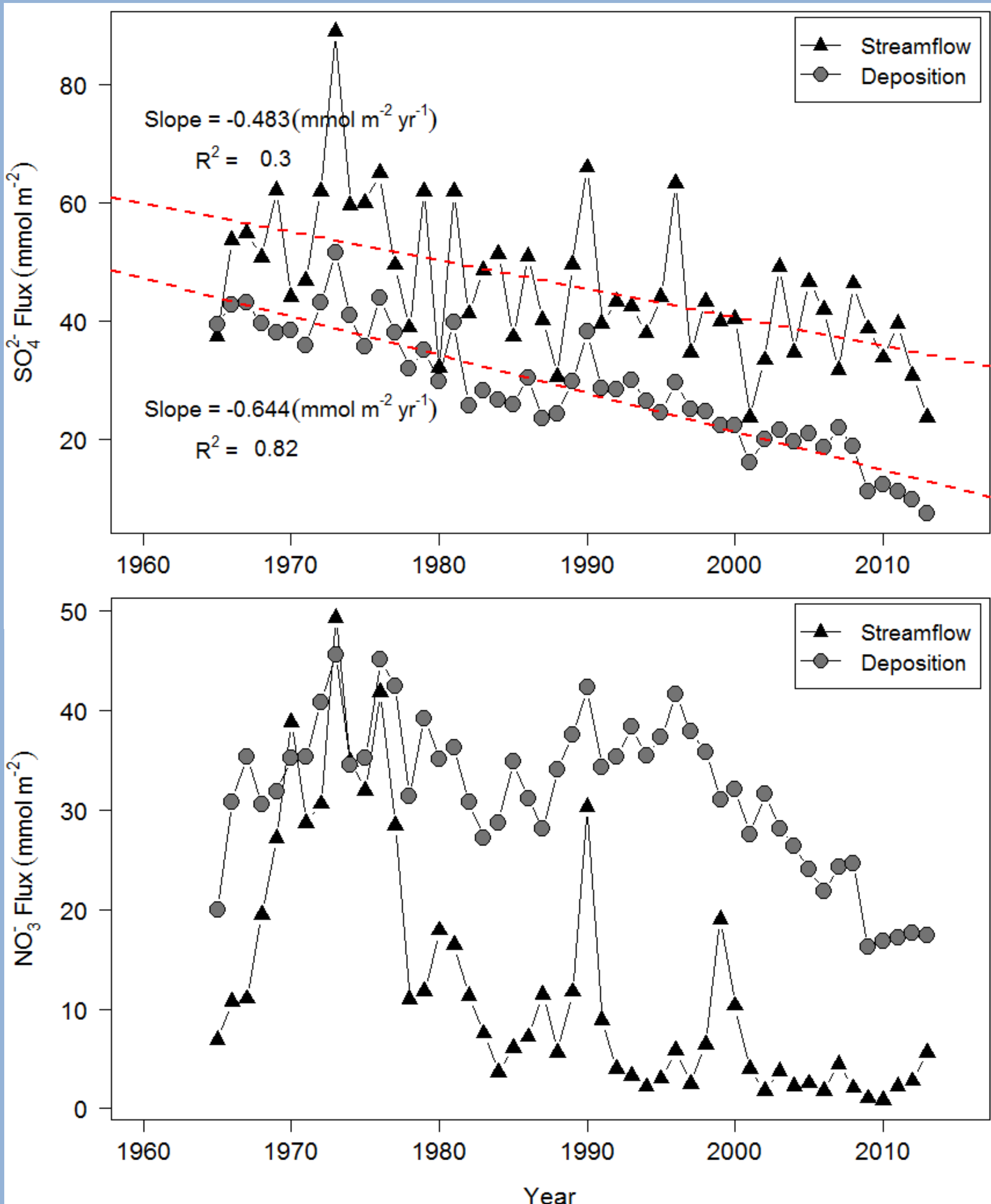


Past and future deposition



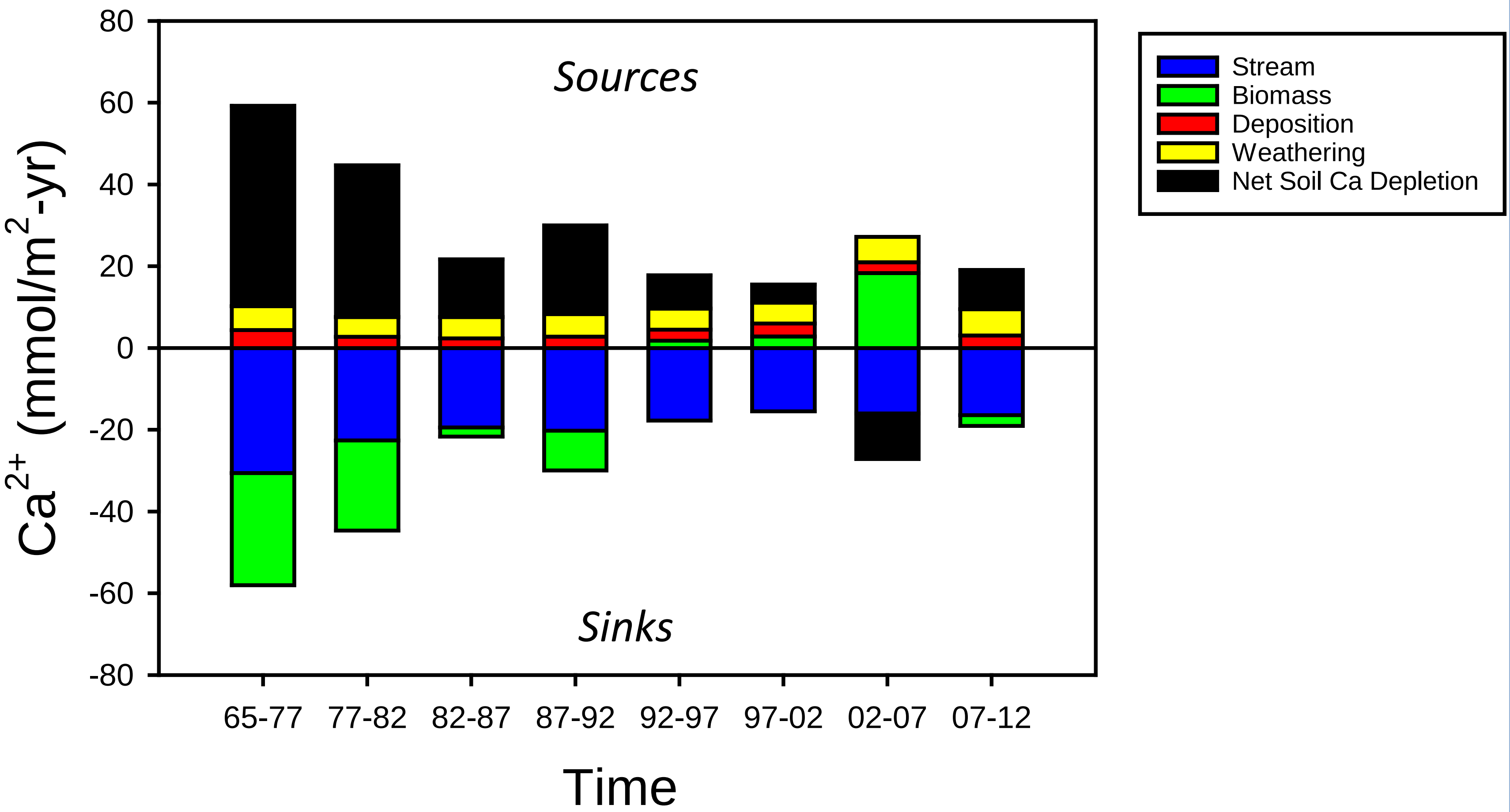


Y = 1.84 X + 0.5
R^2 = 0.92
Clean Power Plan 2030
Pre−anthropogenic concentration
SO_4^{2-} concentration in precipitation (µeq L^{-1})
SO_2 national emission (Tg yr^{-1})
0
10
20
30
40
50
60
70
0
5
10
15
20
25
30
35
Y = 1.25 X − 5.1
R^2 = 0.52
Clean Power Plan 2030
Pre−anthropogenic concentration
NO_3^- concentration in precipitation (µeq L^{-1})
NO_X national emission (Tg yr^{-1})
0
5
10
15
20
25
30
35
0
5
10
15
20
25
30
35

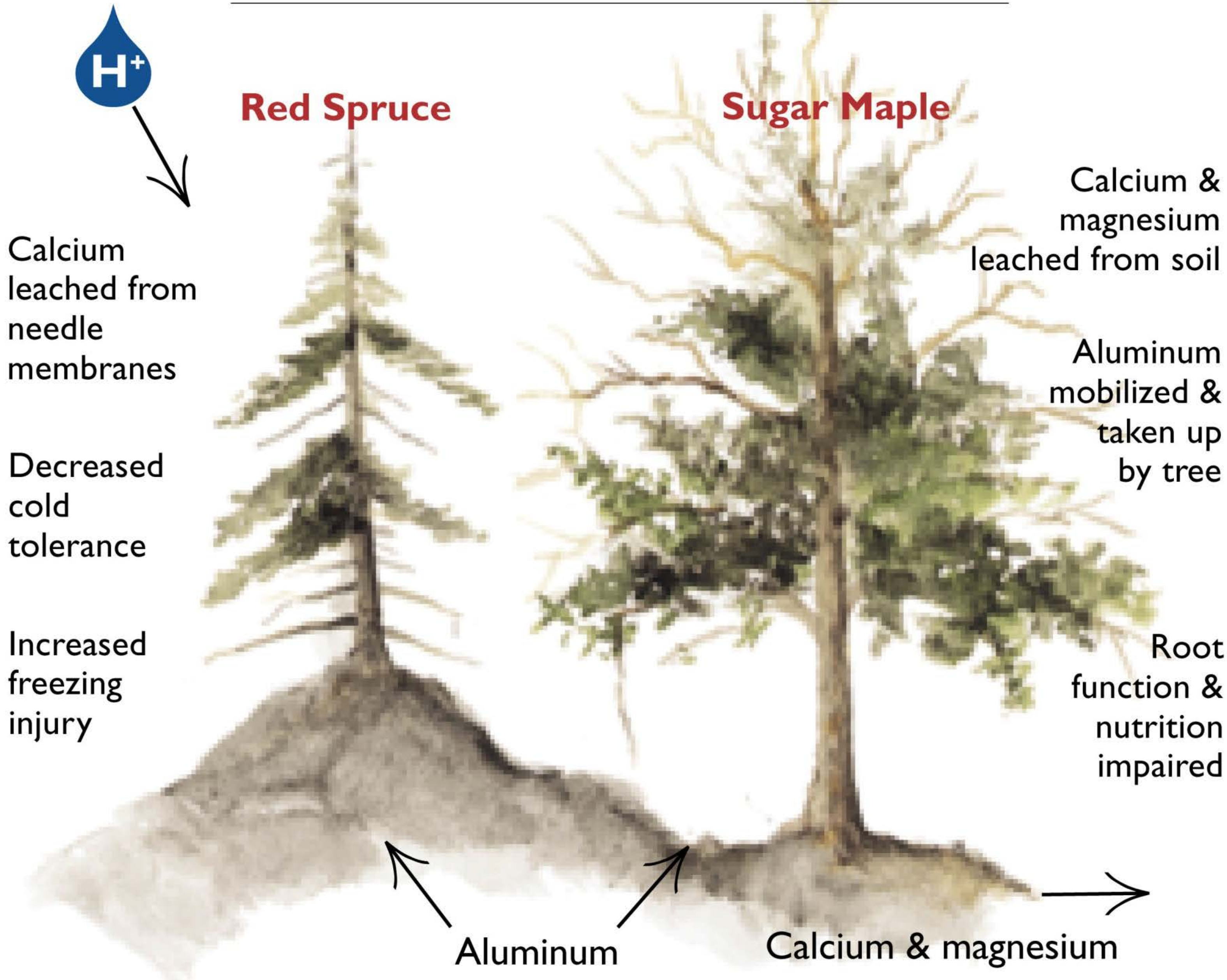


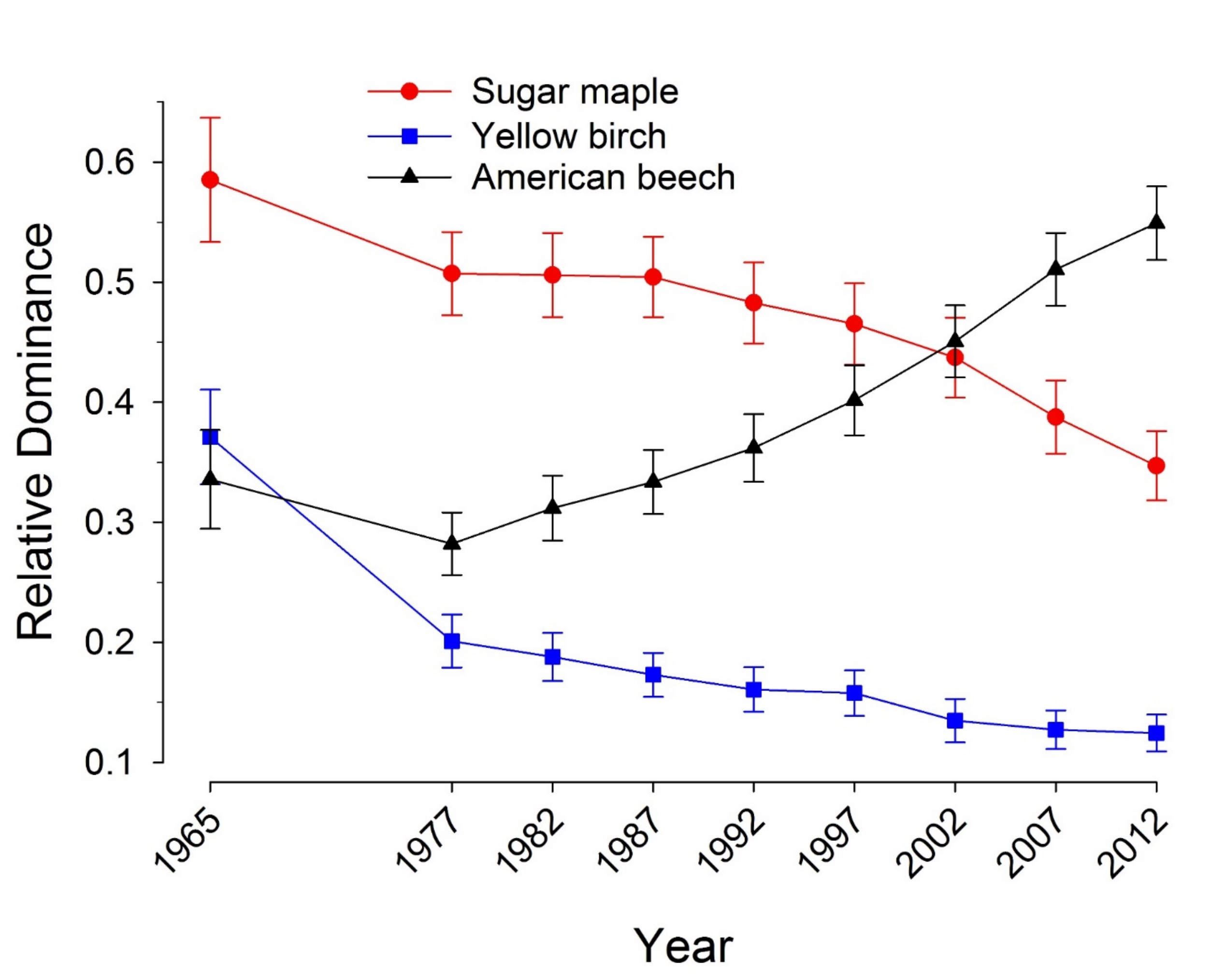
With decreases in emissions there have been decreases in wet deposition and stream concentrations

Time-series of calcium mass balance



Acid Deposition Effects on Trees



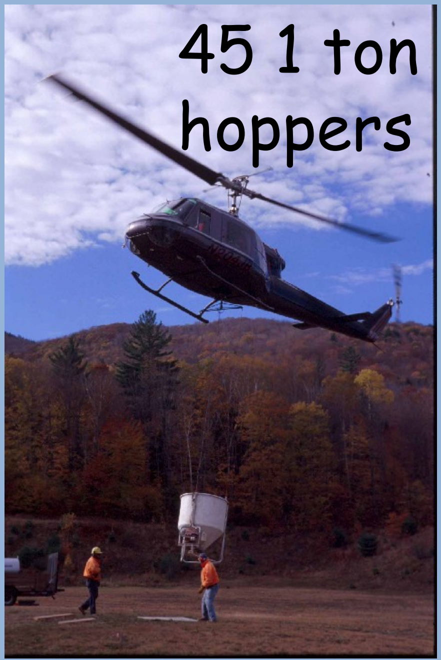


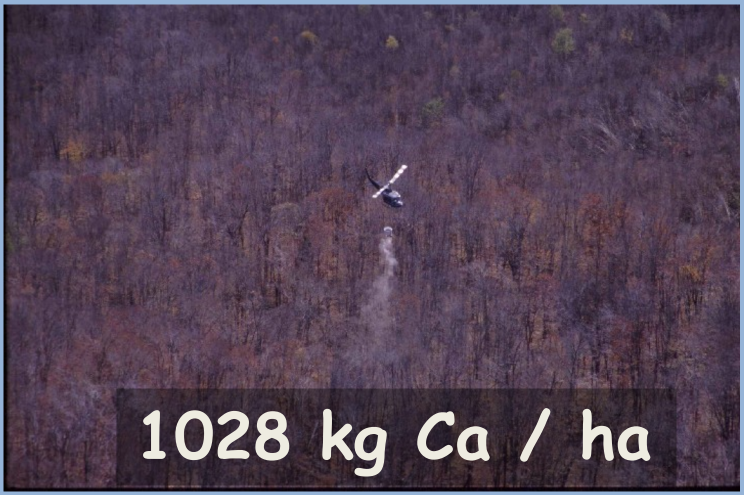
Biomass of sugar maple has declined substantially

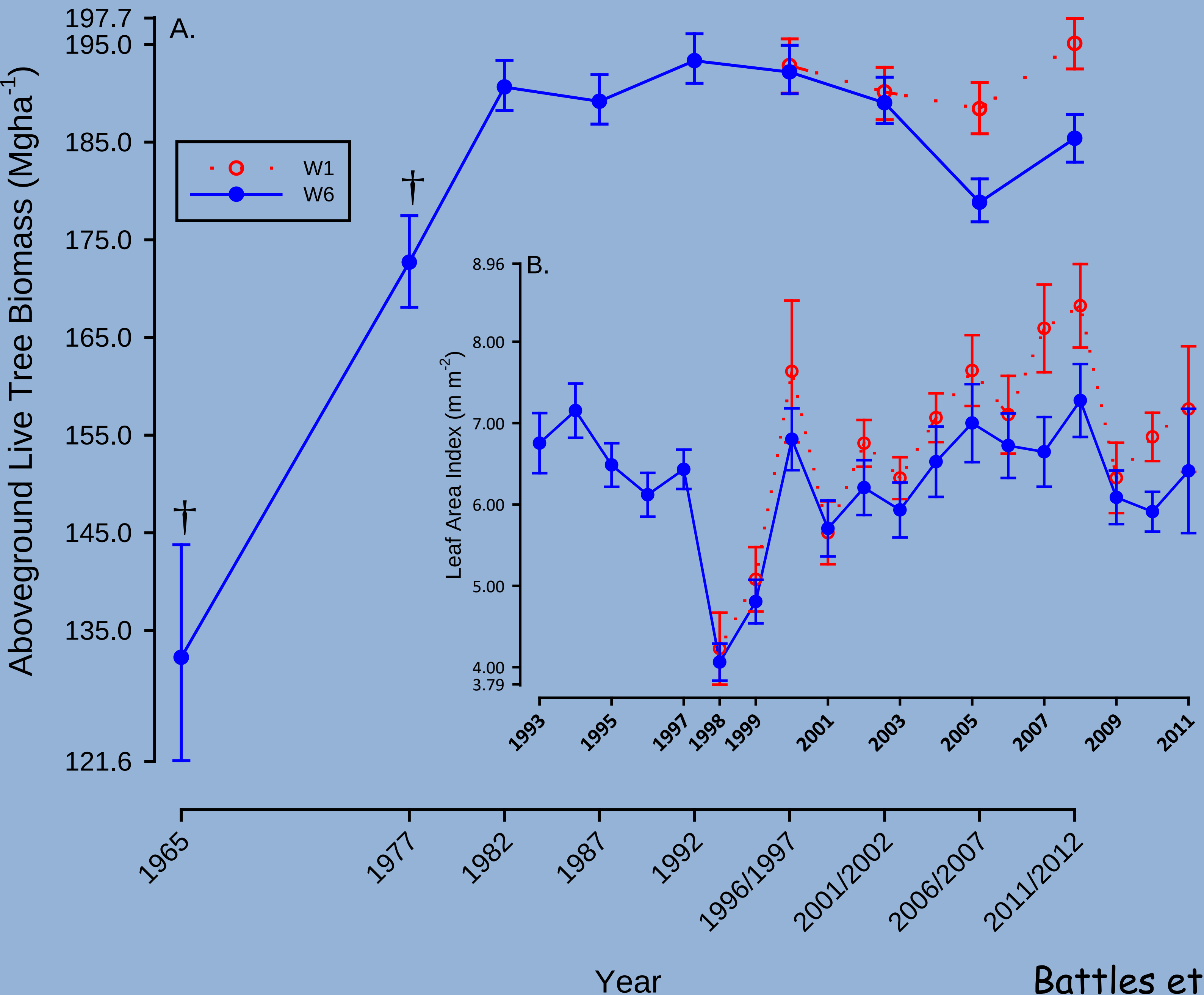
Winter injury of red spruce

Hawley et al., UVM

Wollastonite Addition: Hubbard Brook W1 1999

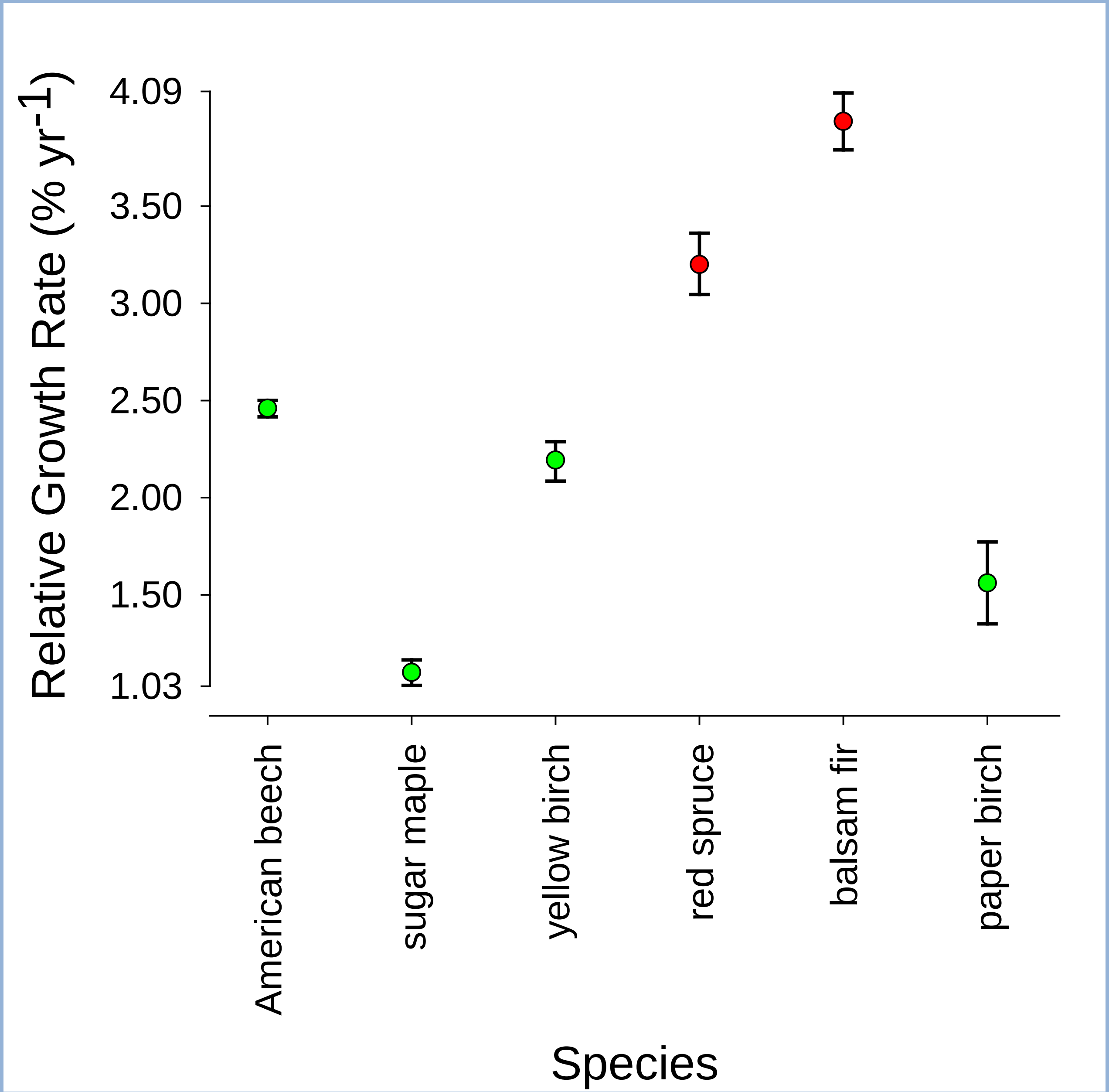






Battles et al 2014

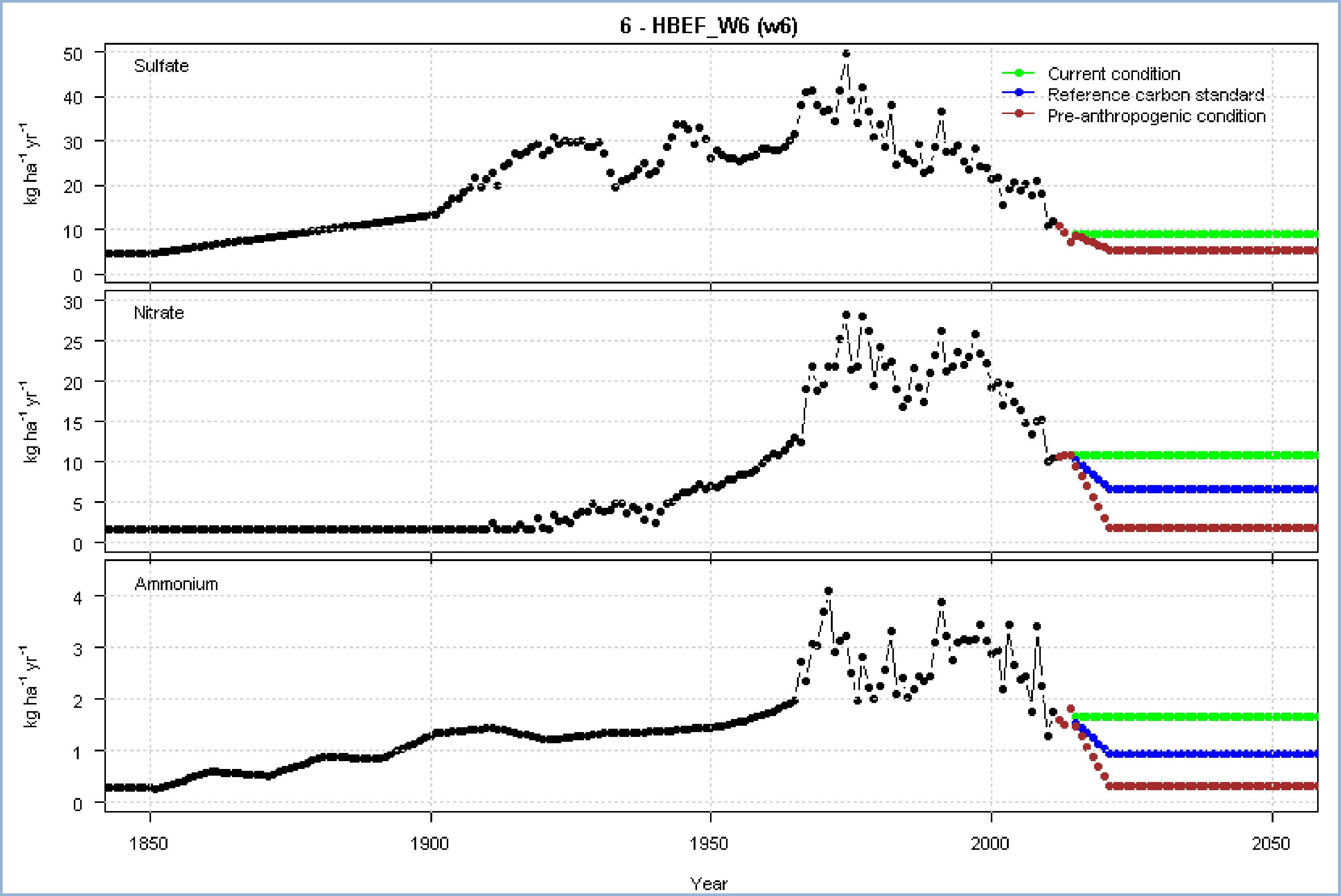
Relative growth rate of major tree species in W6 (2007-2012)



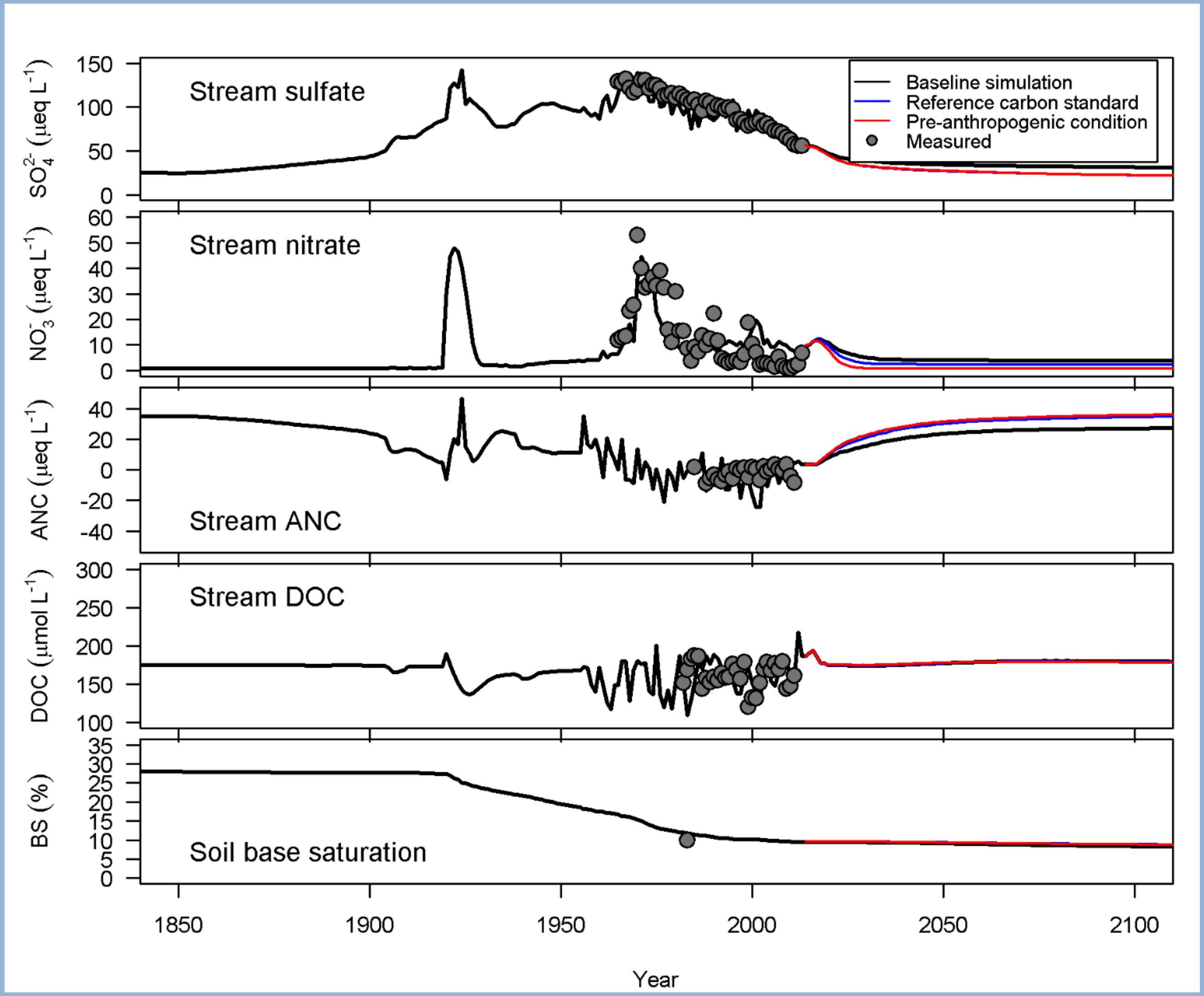
Red spruce is doing well because winter injury is diminished due to warmer winters and decreases in acid deposition

Growth of sugar maple remains poor because soil calcium is slow to recover, due to inherently slow mineral weathering

Past and future deposition



Simulated stream and soil chemistry for watershed 6



Forest Ecosystem Response to Increases and Decreases in Acid Deposition

- Reversible (is any disturbance reversible?)
  - Leaching of sulfate and nitrate
  - Changes in pH, acid neutralizing capacity, and increases in dissolved inorganic aluminum
  - Aquatic effects: decreases in diversity, loss of sensitive species and recovery (?)
  - Terrestrial effects: red spruce due to deposition effects on foliage

- Irreversible (legacies)
  - Depletion of available nutrient cations
  - Loss of sugar maple
  - Leaching of dissolved organic matter (browning)

- *The HBR-LTER is supported by the NSF. Any opinions, findings, conclusions, or recommendations expressed in the material are those of the author(s) and do not necessarily reflect the views of the NSF.*