25 Years of Whole-Watershed Experimental N Additions in a Forested Maine Watershed

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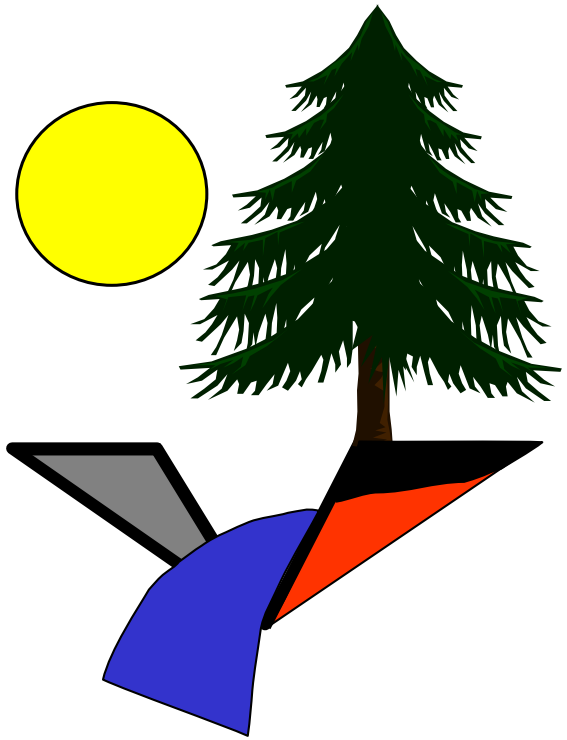
National Atmospheric Deposition Program

Why is there a Bear Brook Watershed in Maine (BBWM)?



1. US EPA interest in **testing models** of surface water acidification (i.e., MAGIC, ILWAS, Trickle-Down) in the 1980s.

2. Short-term goals of providing input to the reauthorization of the **CAA in 1990**.

3. Initial constraints from EPA were to do **S only, no biology, no N**.

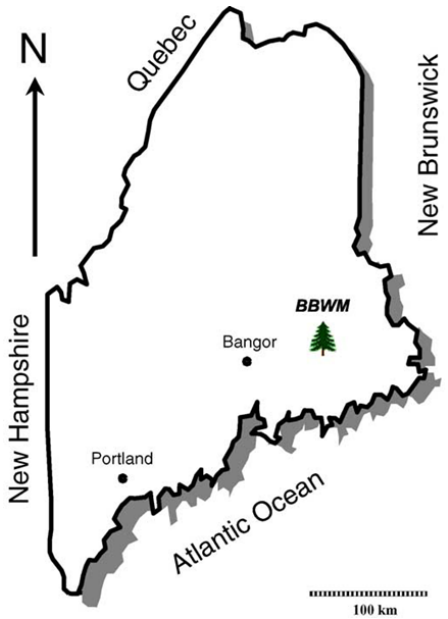
4. Funding began in 1986 for **site selection.** ~70 paired catchment candidates in Maine were assessed, approximately 50 intensively.

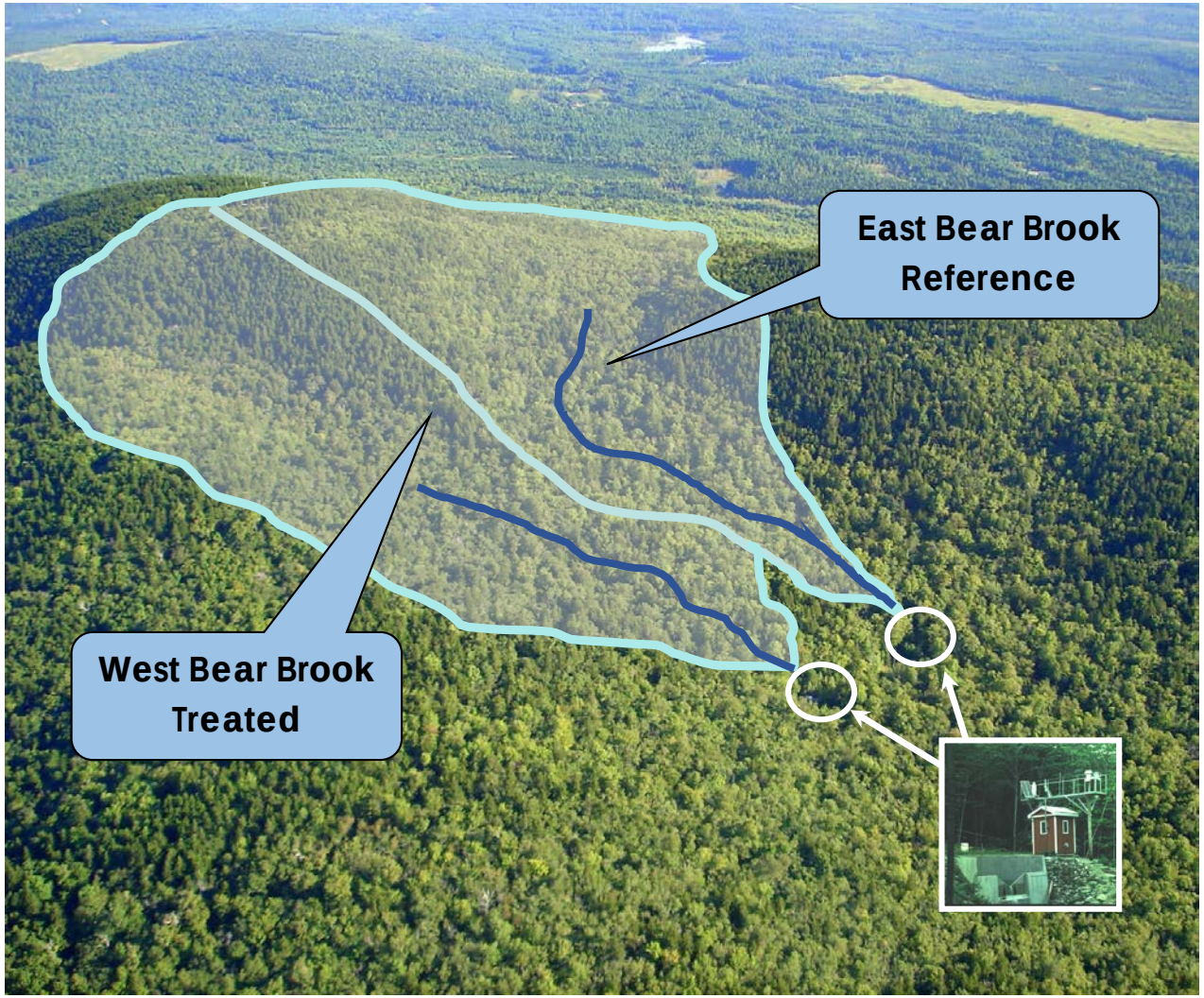
5. The **Bear Brook Watershed in Maine** site was located and research initiated in 1987 and continues to today.

The Bear Brook Watershed in Maine

Whole watershed manipulation

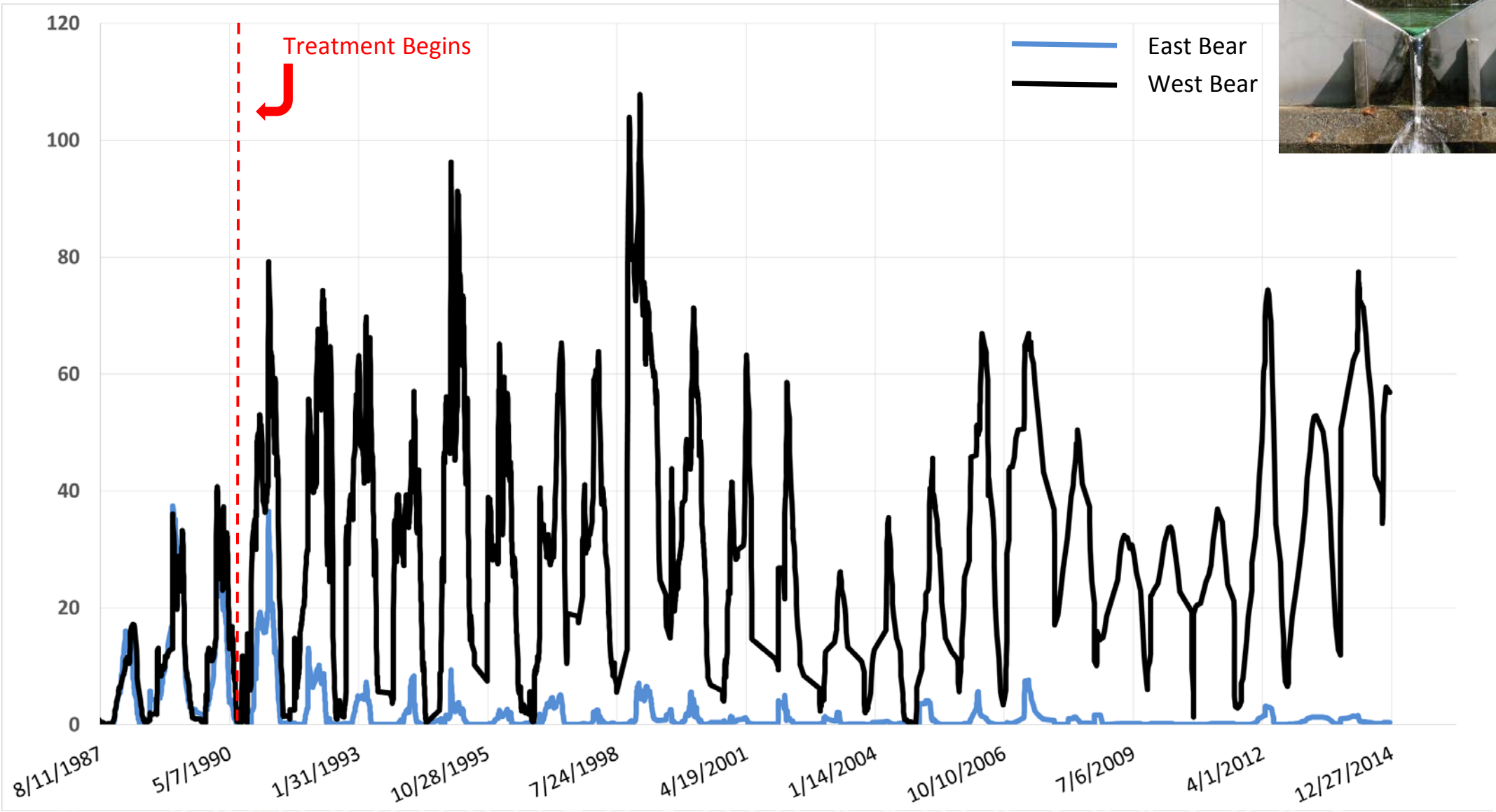
- $(NH_4)_2SO_4$ bimonthly (25.2 kg N $ha^{-1}yr^{-1}$)
- Treatments started in 1989



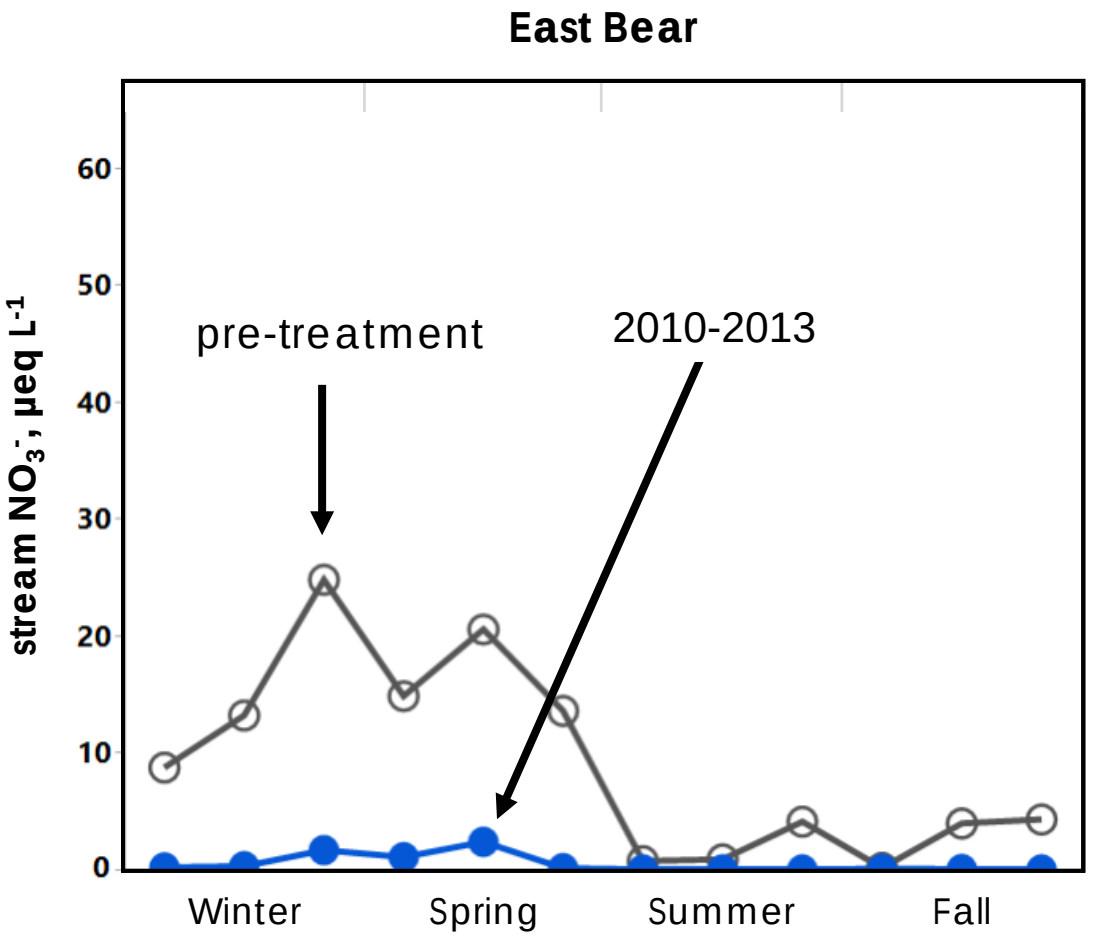


What has happened to N at BBWM?

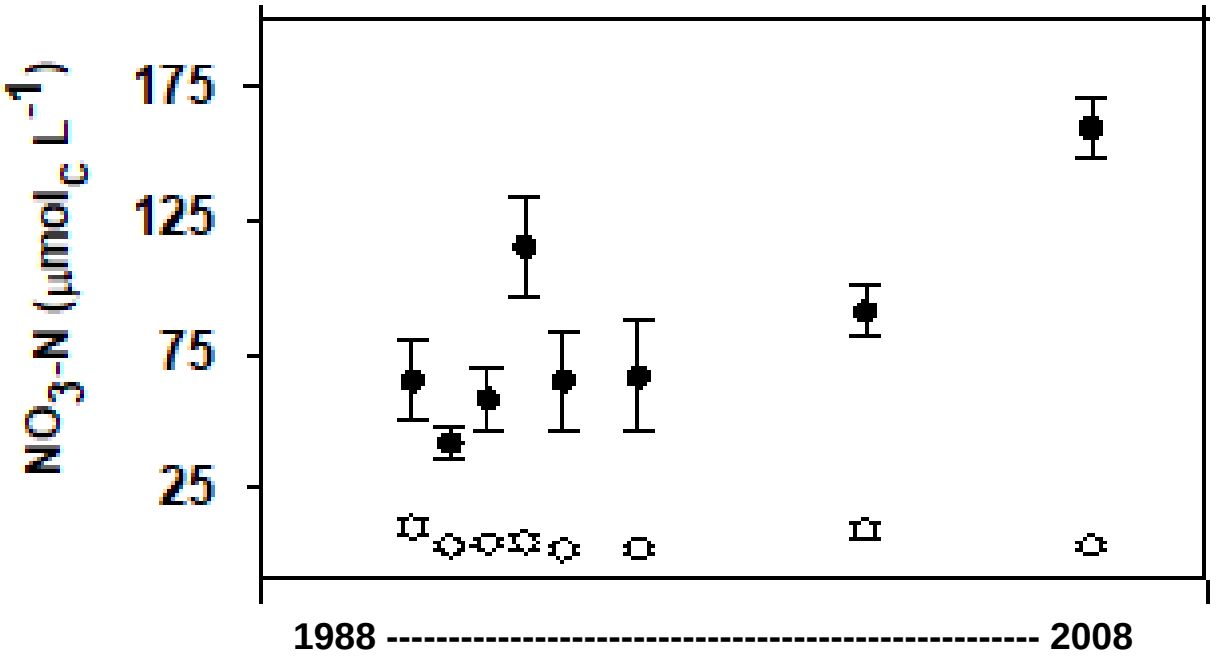
Stream NO_3 ($\mu eq\ L^{-1}$)



Stream N Seasonality

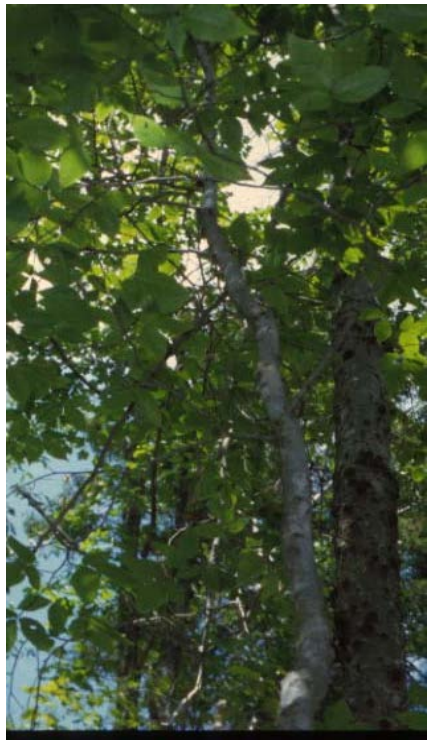


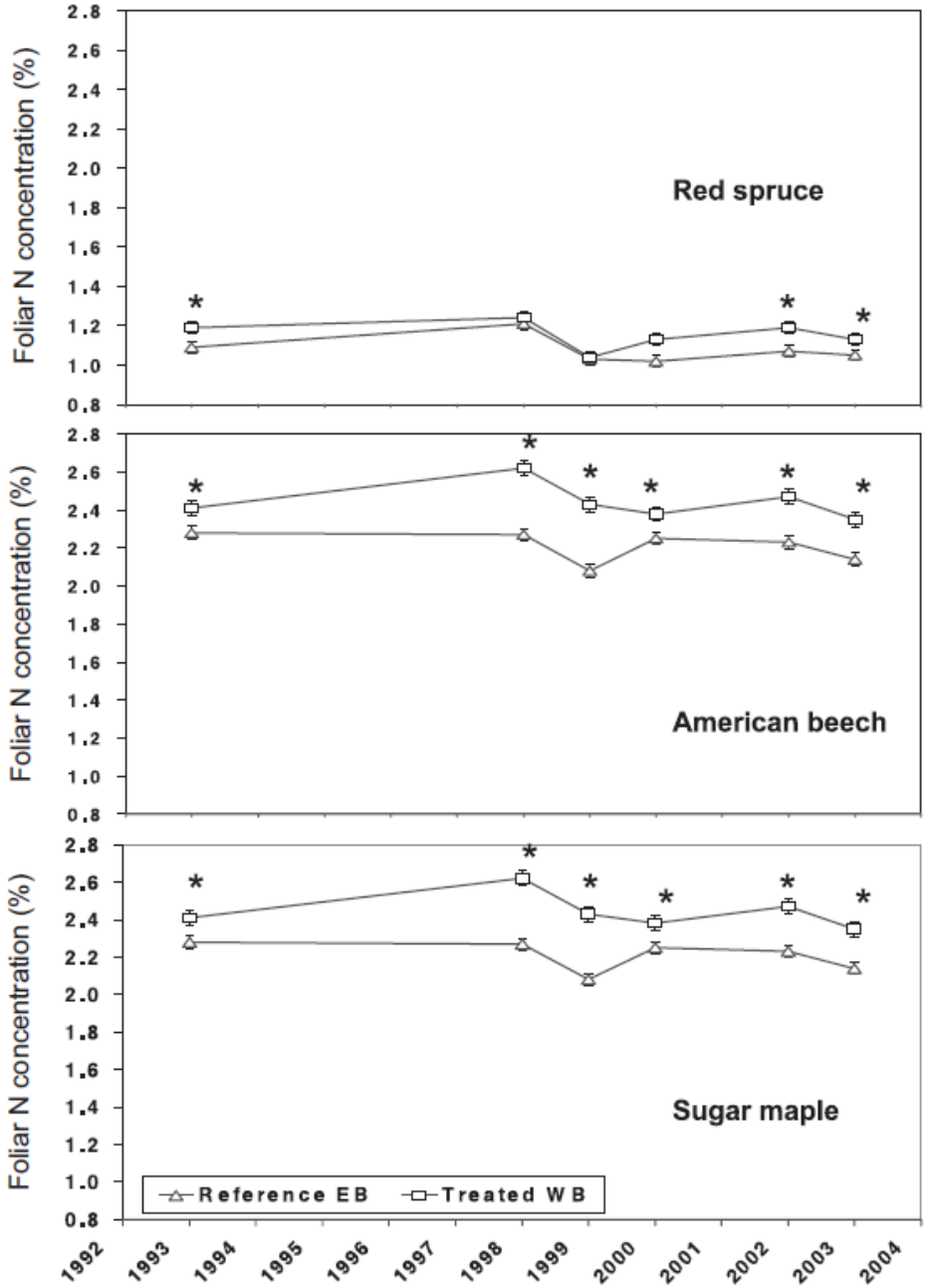
Soil Solutions

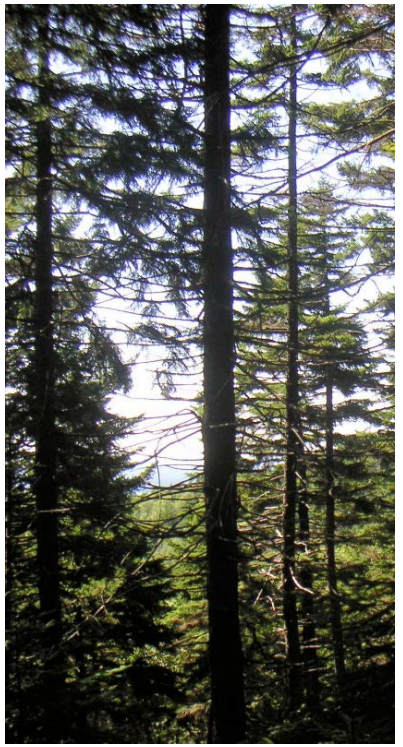


Fatemi et al. 2012

Foliar N

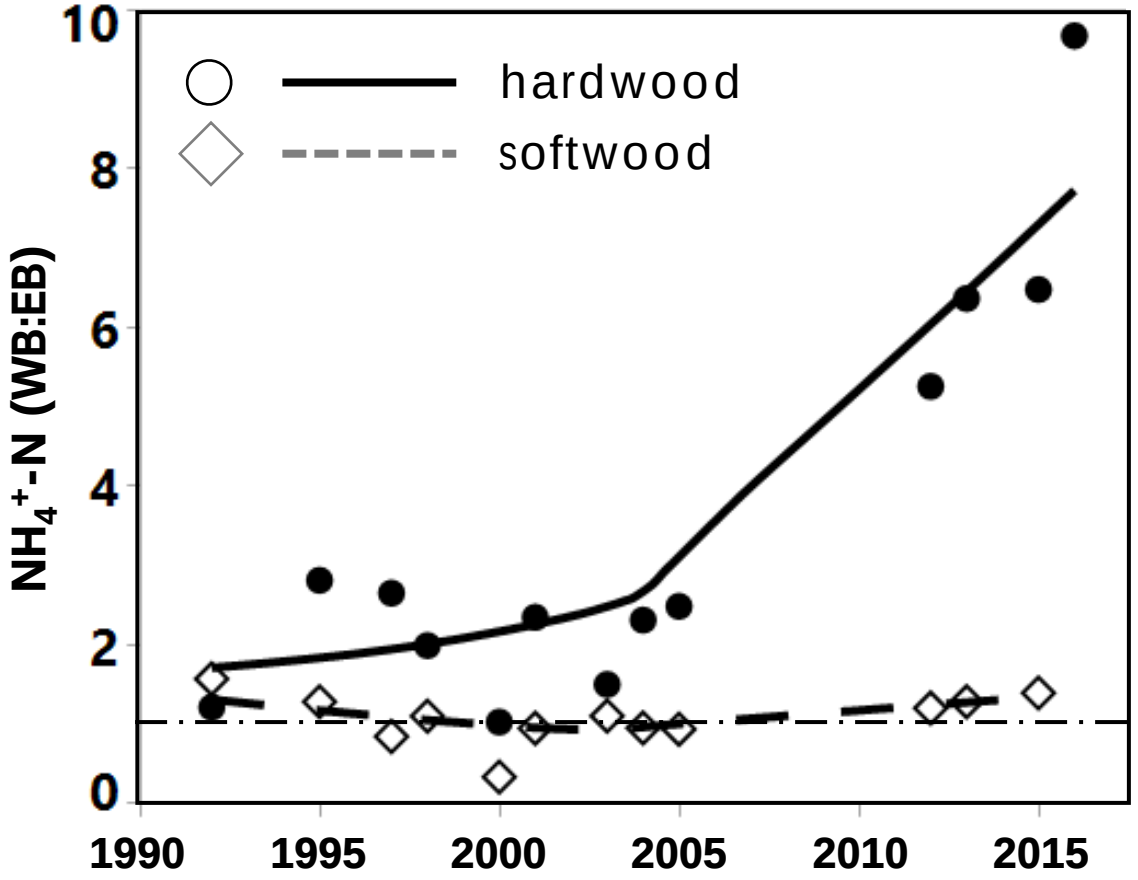


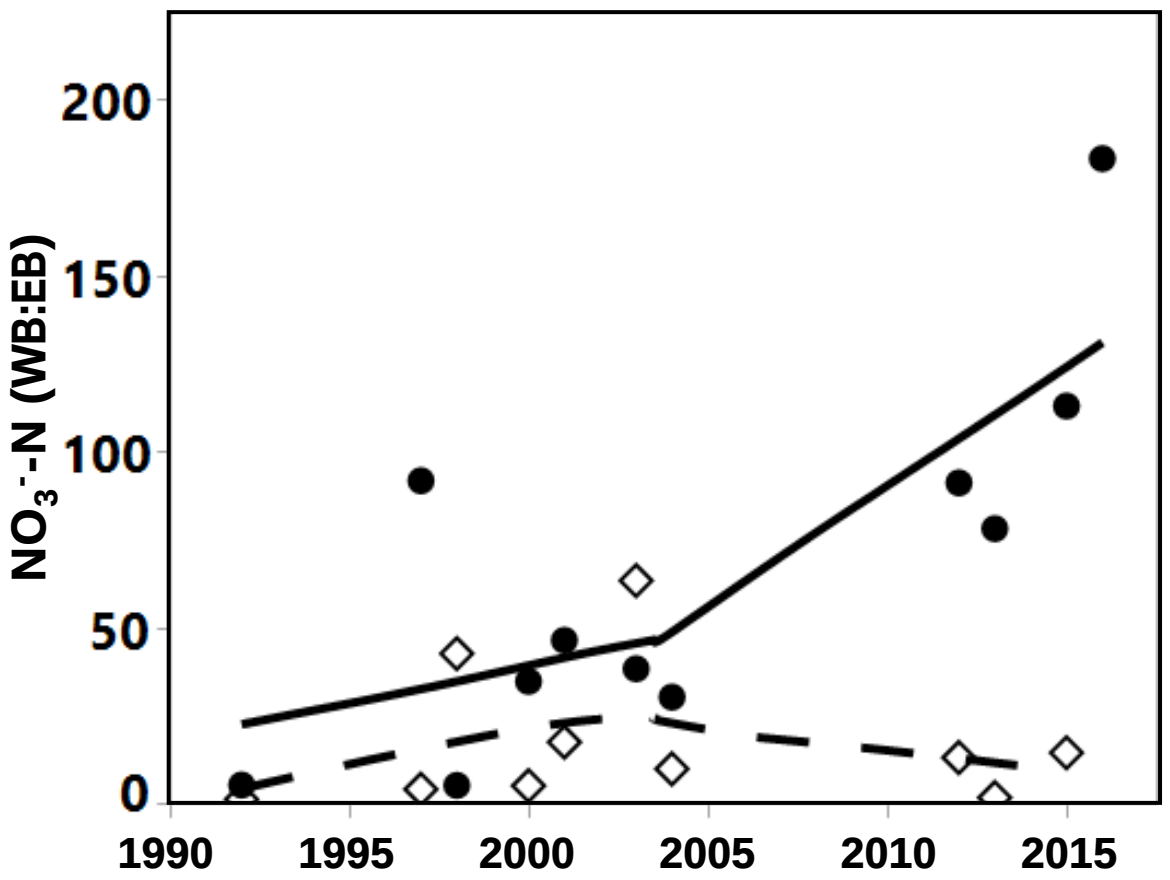




Elvir et al. 2005

Soil Extractable N





Patel & Fernandez 2018. Environ. Monit. Assess.

N Mass Balance

East Bear (reference)

West Bear (treated)

- ambient N inputs declined ~50%
- dry now <5% of total N deposition

Input, kg N ha^{-1} yr^{-1}

Output, kg N ha^{-1} yr^{-1}

30 20 10 0 10 20 30

Inputs

Dry NH_4^+

Wet NH_4^+

Dry NO_3^-

Wet NO_3^-

Treated NH_4^+

Outputs

NH_4^+

NO_3^-

1990 1995 2000 2005 2010

1990 1995 2000 2005 2010

Patel et al. 2018

Cumulative N mass balance after 25 years

90 kg ha^{-1}

East Bear (reference)
81 kg ha^{-1} retained

Retention: 90%

9 kg ha^{-1}

Excess N retained in WB by mass balance = 502 kg ha^{-1}

724 kg ha^{-1}

West Bear (treated)
583 kg ha^{-1} retained

Retention: 81%

141 kg ha^{-1}

Patel et al. 2018

Ecosystem N pools today

kg N ha^{-1}

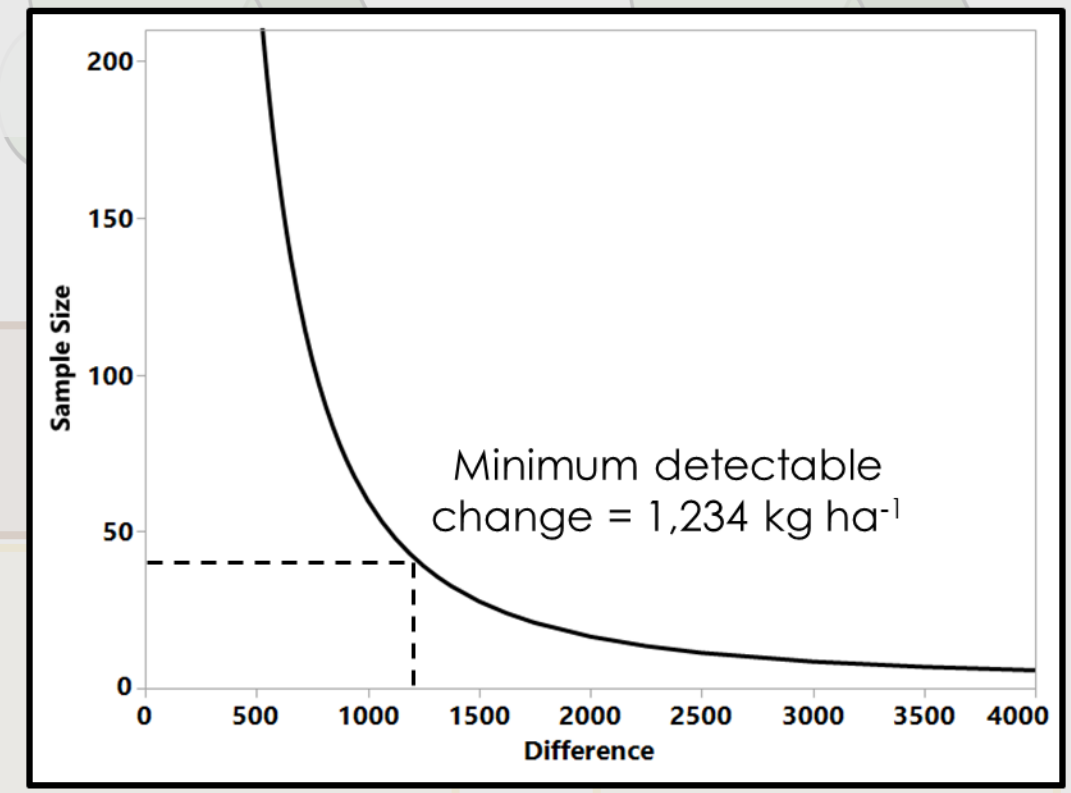
Excess in WB = 764 kg ha^{-1}

East Bear (reference)

West Bear (treated)

Vegetation N pools:
WB > EB

greater biomass
higher N concentrations



Total soil N pools:
WB ≈ EB

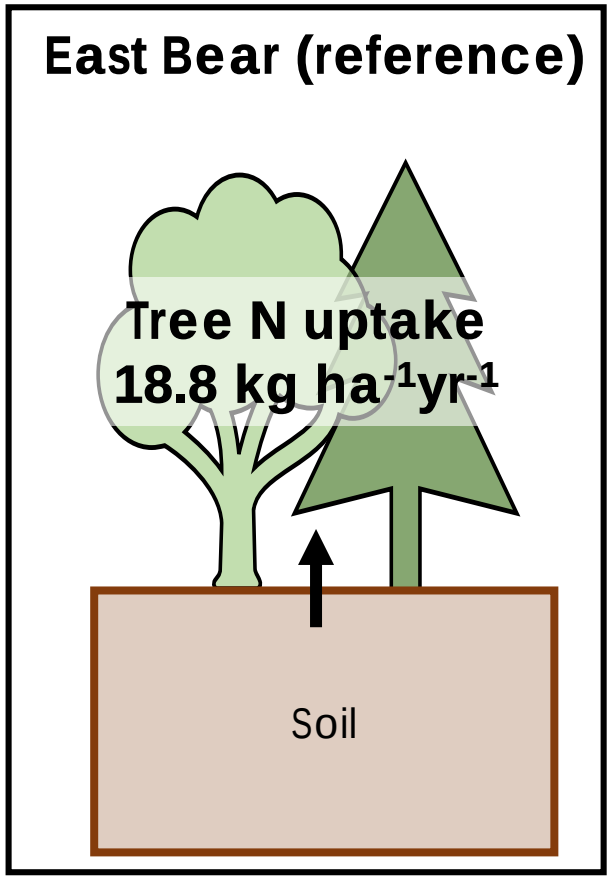
soil N pool >>> inputs
spatial variability

Organic soil N:
WB > EB

thicker soils in WB
suppressed decomposition
increased litterfall

Patel et al. 2018

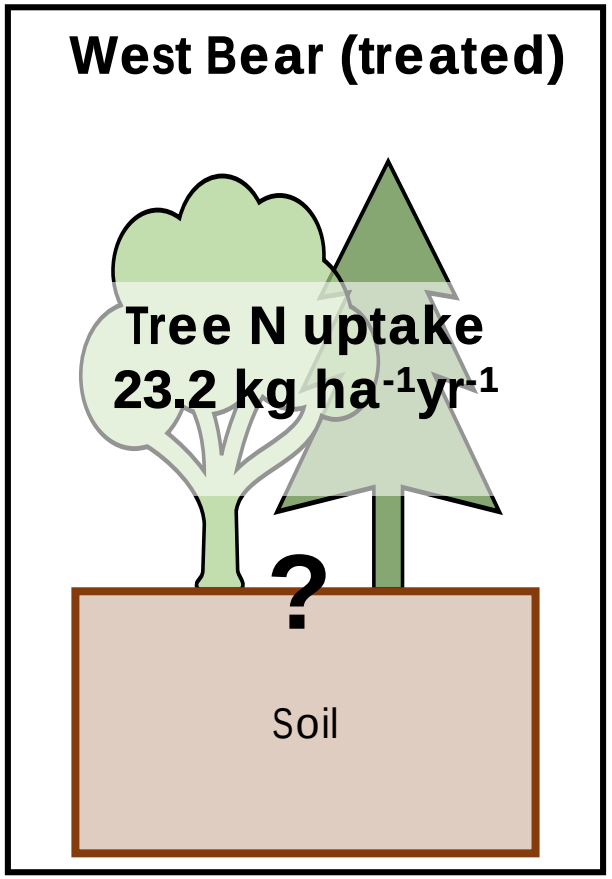
Current annual aboveground biomass accumulation



1.8 kg ha^{-1} yr^{-1} annual watershed retention

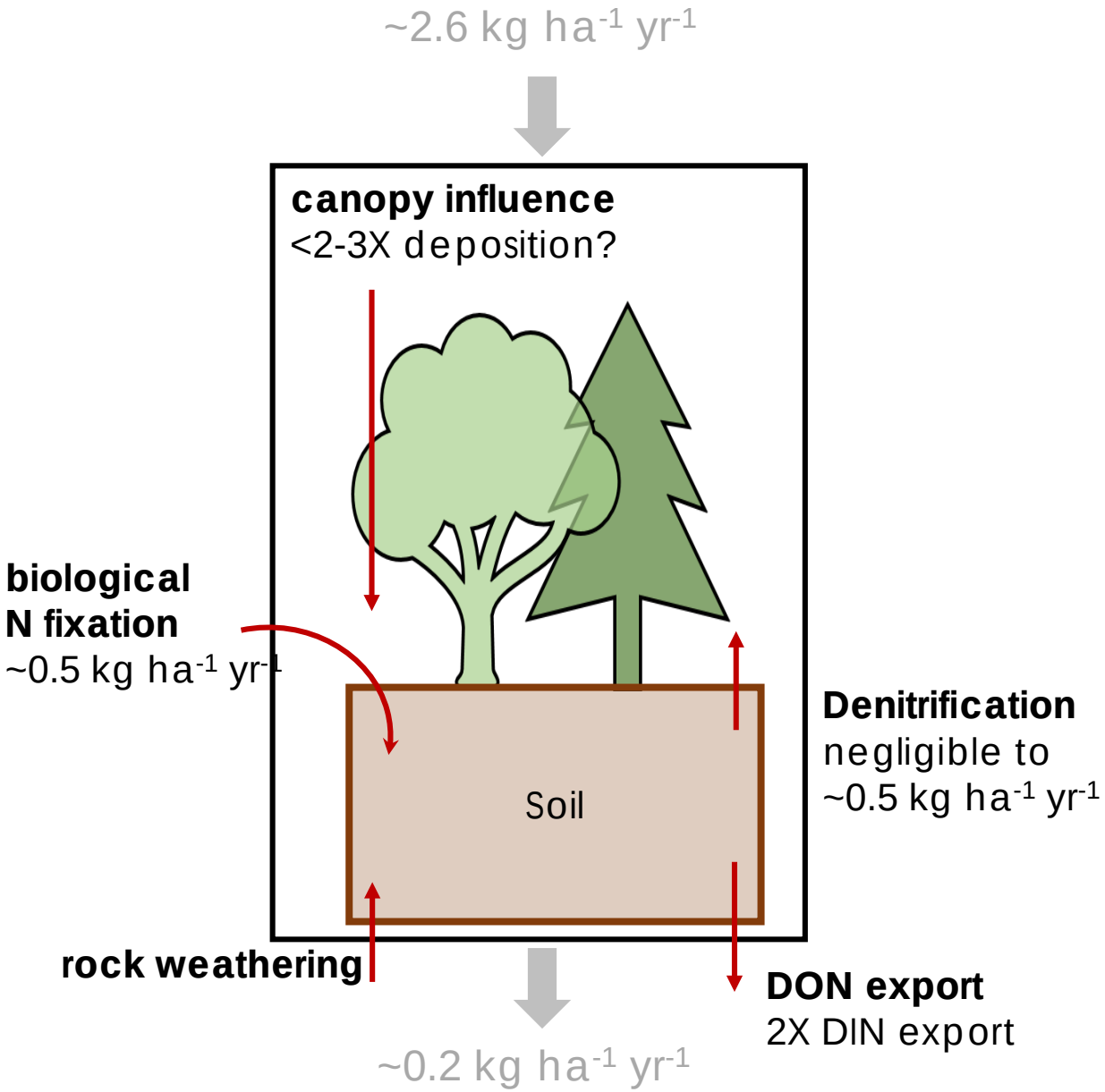
Tree growth
WB > EB

Are trees 'mining' soil N at BBWM?



20 kg ha^{-1} yr^{-1} annual watershed retention

Patel et al. 2018



Missing fluxes?

Likely total N inputs exceed exports in West Bear today, and meet tree uptake demand.

Patel et al. 2018

What we learned at 25 yr about N?

- Response varied by decade, with hardwoods dominating the positive vegetation response to N
- N saturation (Aber et al. 1989; Stoddard 1994)
- Critical Loads (Pardo et al. 2011)
- Oligotrophication (Craine et al. 2018; Gilliam et al. 2018; Goffman et al. 2018)
- Ecological surprises and the value of long-term research

- The “Recovery Experiment” is underway

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