A SURVEY OF NITRATE ISOTOPES TO DETECT ATMOSPHERIC NITRATE INPUTS TO STREAM AND SOIL WATERS OF FORESTED WATERSHEDS IN THE NORTHEASTERN USA

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- Our research shows that nitrate may be rapidly transported from rainfall and snowfall to streams without biological uptake in soils.
- Spatial data from many different forests help to quantify effects of an atmospheric pollutant on streams and ecosystems across the northern forest region.

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http://www.nsrcforest.org

PROJECT SUMMARY

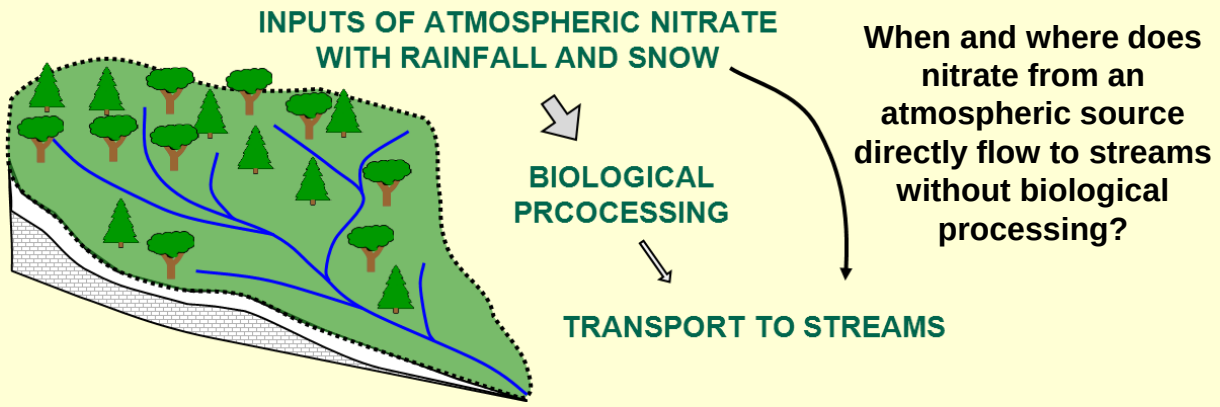
Nitrogen from atmospheric pollution affects forests and streams throughout the northeastern United States. The widespread effects include losses of vital ecosystem services that provide forest products, clean water, and aquatic habitat. The effects on streams may be indirect when nitrate from rainfall and snowmelt is retained by organisms and in soils before some nitrate is later remobilized to streams. In contrast, some nitrate from rain and snow may be directly transported during stormflow events to streams without biological processing. We measured stream water chemistry and environmental tracers at sites from New York to Maine that span the northern forest region to determine times when and places where atmospheric nitrate was transported to streams from precipitation. This research helps to define the geographic extent of pollutant effects on forest, soils, and stream waters .

Arbutus Lake at the Huntington Forest in the Adirondack Mountains, a site that was part of this study.

BACKGROUND AND JUSTIFICATION

Nitrogen pollution of ecosystems from atmospheric sources has widespread effects on forests and streams across the northeastern USA. The effects are pronounced in the northern forest region where nitrogen inputs from atmospheric sources are among the highest levels in the nation. Concentrations of nitrate, a form of nitrogen, in precipitation and stream waters have increased due to increased emissions of nitrogen to the atmosphere.

- Most of the inputs of nitrate from atmospheric sources to forests are retained in vegetation and soils until some is later remobilized to streams. However, another more direct routing to streams is possible when some nitrate from an atmospheric source is rapidly transported during rainfall and snowmelt events to streams without biological cycling within forests.
- Two isotopes of nitrate (^{15}N and ^{18}O) are environmental tracers that allow apportionment between atmospheric sources and nitrate that was derived from sources (i.e. nitrification) within a forest.
- Recent studies using these isotopic tracers show that some nitrate from atmospheric sources is transported to streams during particular stormflow and snowmelt events. These data are limited to a few sites. Consequently, little is known about the geographic extent and magnitude of inputs from atmospheric sources to soil and stream waters as well as the times of year when these inputs occur.



METHODS

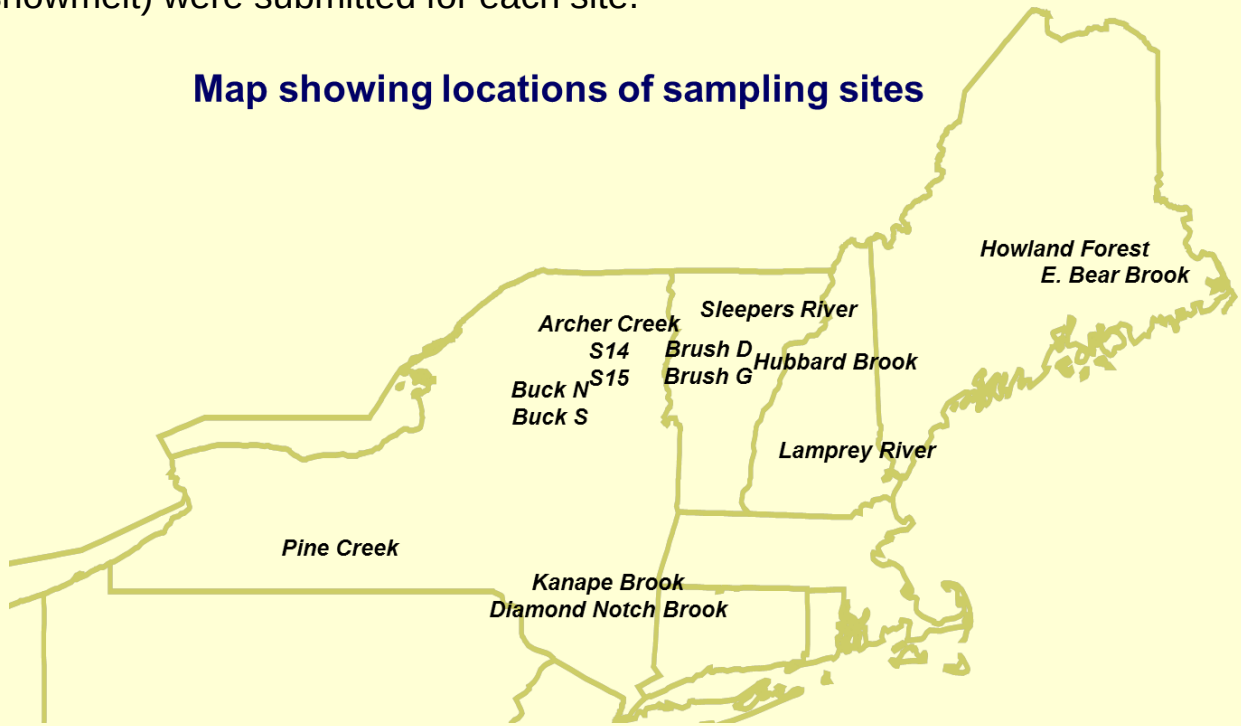
We used isotopic tracers of nitrate sources to quantify amounts of atmospheric nitrate in soil and stream waters from watersheds that are representative of the northern forest region.

- This study focused on sampling across a larger number of sites and broader geographic area than most previous studies while limited to a few samples from key events such as autumn storms and snowmelt events.
- Stream waters were submitted by cooperators for 15 streams from New York to Maine. Seven of the sites provided paired samples of soil water and stream water. Precipitation samples were submitted from several different sites.
- Samples were collected from October 2010 through August 2011. A minimum of two sample sets (autumn and spring snowmelt) were submitted for each site.

Cooperators providing samples

Jamie Shanley	USGS
Don Ross	Univ. of Vermont
Emily Elliott	Univ. of Pittsburgh
John Campbell	Forest Service
Bryan Dail	Univ. of ME
Michelle Daley	Univ. of NH
Ivan Fernandez	Univ. of ME
Christy Goodale	Cornell Univ.
Greg Lawrence	US Geological Survey
Gary Lovett	Cary Institute
Myron Mitchell	SUNY-ESF
Sarah Nelson	Univ. of ME

Map showing locations of sampling sites

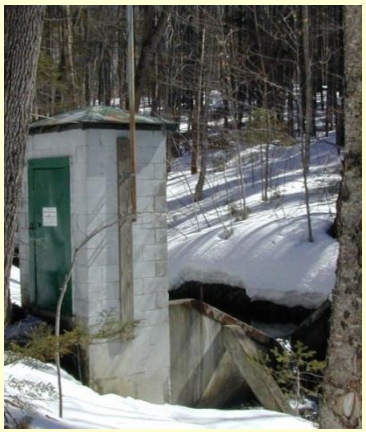


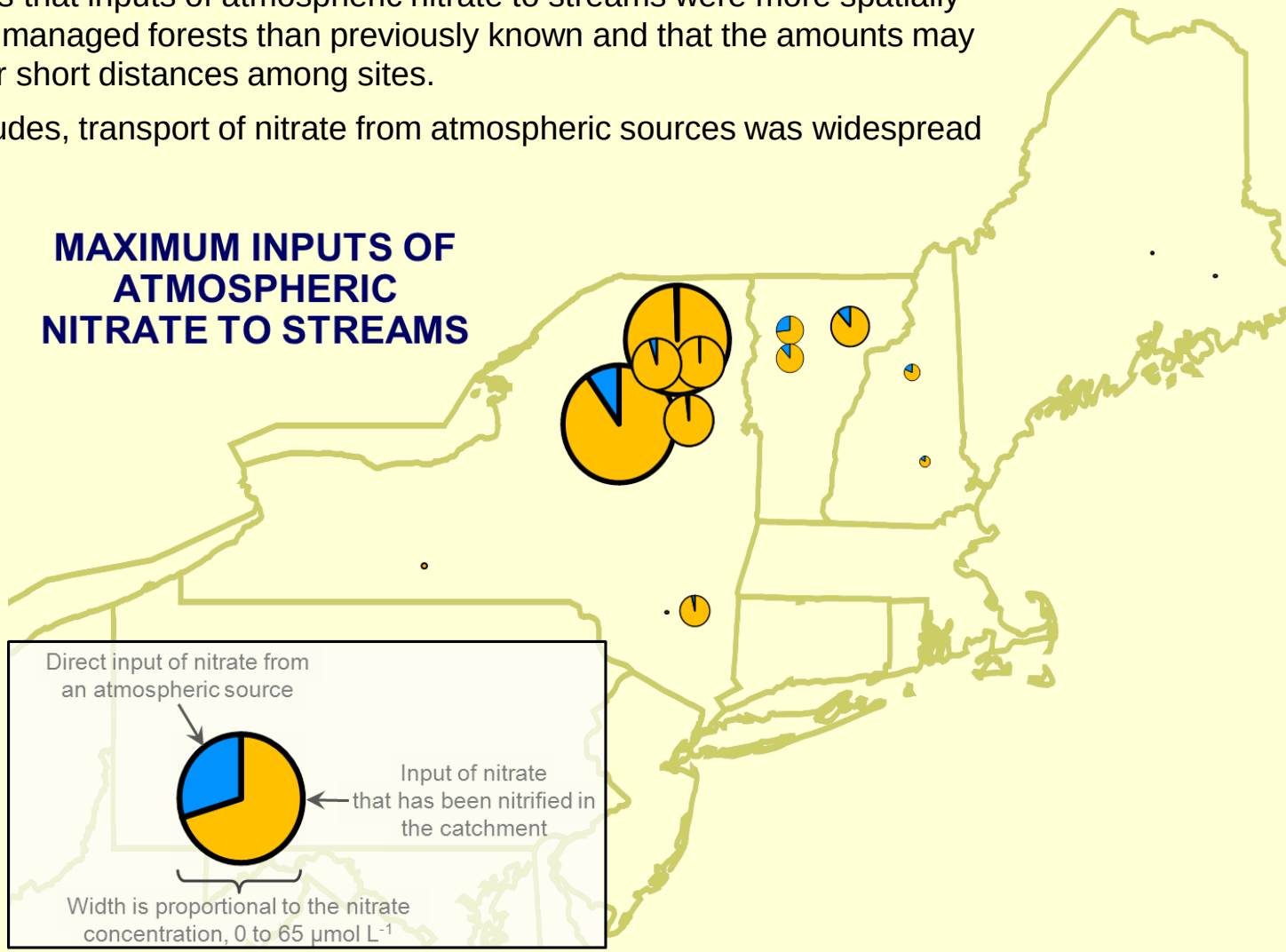
RESULTS / PROJECT OUTCOMES

Results show that substantial amounts of atmospheric nitrate were sometimes present in soil and stream waters during snowmelt.

- The range of nitrate concentrations in streams was large. Substantial (10 to 30%) amounts of nitrate from an atmospheric source were measured in some streams, with little to none at other streams.
- This information shows that inputs of atmospheric nitrate to streams were more spatially widespread among unmanaged forests than previously known and that the amounts may be highly variable over short distances among sites.
- Regardless of magnitudes, transport of nitrate from atmospheric sources was widespread and common.

The W-9 stream gage at the Sleepers River Research Watershed in Vermont.





IMPLICATIONS AND APPLICATIONS IN THE NORTHERN FOREST REGION

Nitrate from atmospheric deposition is highly retained in forests. However, higher concentrations of nitrate in stream waters occur during hydrological events, such as snowmelt, relative to baseflow. The occasional finding of large direct inputs from atmospheric sources during events affirmed a direct relationship of an atmospheric pollutant to the temporal and spatial variation of stream nitrate concentrations – an important finding that informs scientists, forest managers, and policy makers who are tasked with understanding and addressing the effects of nitrogen pollution.

- The nitrate isotope data from many different forests provided evidence of effects of an atmospheric pollutant on streams and ecosystems that were widespread. These inputs occurred across a variety of forests and watersheds within the northern forest region.
- Source apportionment and knowledge of hydrological processes provided information needed to discern why stream nitrate concentrations varied over time and space.

The Kittredge Hills near Danville Vermont where the Pope Brook drains W-9 in the Sleepers River Research Watershed in Vermont.

FUTURE DIRECTIONS

- We are interested in expanding this research to better define times other than snowmelt when nontrivial inputs of atmospheric nitrate occur.
- We are compiling data to provide more context for the findings of our study relative to other available data that document variation among years and research sites.
- We are also considering new studies to determine how water and nitrate are routed through forests in managed as well as unmanaged forests.

LIST OF PRODUCTS

Presentations:

- Sebestyen SD. Identifying when, where, and why atmospheric nitrate is directly transported to streams in nitrogen polluted forests. Dept. of Land Resources & Environmental Sciences, Rocky Mountain Research Station, USDA Forest Service, Ft. Collins, CO, Oct 2012.
- Sebestyen SD. Identifying when, where, and why atmospheric nitrate is directly transported to streams in nitrogen polluted forests. Dept. of Land Resources & Environmental Sciences, Montana State University, Bozeman, MT, Sep 2012.
- Sebestyen SD, Shanley JB, Ross DS, Elliott EM, Kendall C, Boyer EW. Identifying when, where, and why atmospheric nitrate is directly transported to streams in nitrogen polluted forests. Biogeomon, Lincolnville, ME, Jul 2012.
- Sebestyen SD, Shanley JB, Ross DS, Elliott EM, Kendall C, Boyer EW. Identifying when, where, and why atmospheric nitrate is directly transported to streams in nitrogen polluted forests. 2012 Annual Meeting, Society for Freshwater Sciences, May 2012.
- Sebestyen SD. Identifying when, where, and why atmospheric nitrate is directly transported from atmospheric deposition to streams in forests. School of Forest Resources and Environmental Sciences, Michigan Tech University, Houghton, MI, Mar 2012.
- Sebestyen SD. Identifying when, where, and why atmospheric nitrate is directly transported to streams in nitrogen polluted forests of the northeastern and midwestern USA. Plant and Soil Sciences, University of Delaware, Newark, DE, Mar 2012.
- Sebestyen SD. Identifying when, where, and why atmospheric nitrate is directly transported through catchments to streams. American Geophysical Union Fall Meeting, San Francisco, CA, Dec 2011 [published abstract B12D-07, EOS Trans. AGU].

Manuscript to be submitted for peer-reviewed journal publication.

- We continue to analyze these data for the preparation of at least one co-authored publication. Writing will be led by the principle investigator with input from collaborators and cooperators on the project.