Assessing the Role of Tree Species and Nitrogen Deposition in Stabilizing Carbon in Northern Hardwood Forest Soils

Principal Investigator: Gary M. Lovett

Cary Institute of Ecosystem Studies

Email:Lovettg@caryinstitute.org

Mailing address: Cary Institute of Ecosystem Studies, Box AB, Millbrook, NY 12545

Co-Principal Investigator: Alexandra Rodriguez

Cary Institute of Ecosystem Studies

Email:xandrouva@gmail.com

Completion date: July 10, 2013

Key results:

- Long-term nitrogen addition reduced decomposition and carbon mineralization in the forest floor
- This effect varied across tree species, with forest floors under American beech and red oak stands having the greatest reductions among the five species we studied

Funding support for this project was provided by the Northeastern States Research Cooperative (NSRC), a partnership of Northern Forest states (New Hampshire, Vermont, Maine, and New York), in coordination with the USDA Forest Service.
http://www.nsrcforest.org

Project Summary

Forests have an important role in sequestering atmospheric carbon dioxide, and understanding how atmospheric nitrogen (N) deposition affects carbon (C) stabilization in forest soils has become an important focus as humans continue to alter global C and N cycles. While some recent studies have reported that increased N inputs tend to increase C stabilization in soils of temperate forest ecosystems, other studies have shown no effect. Some of this variation in response may be due to differences among tree species. We evaluated the response of soil C lability (i.e., the susceptibility of the organic matter to microbial decomposition) to experimental N additions across plots with different dominant tree species: sugar maple (*Acer saccharum)*, American beech (*Fagus grandifolia)*, yellow birch (*Betula alleghaniensis)*, eastern hemlock (*Tsuga canadensis)* and northern red oak (*Quercus rubra*). We used a 14-year N addition experiment with a single-species, paired-plot design, and several measurements to estimate C lability, including soil laboratory incubations and density fractionation. There was no significant effect overall of N treatment on the mass of the light fraction, one index of C lability. For the other index of lability (potentially mineralizable C from the laboratory incubation), N fertilization and tree species had interactive effects: soils from beech stands showed the greatest N effect (a 23% decrease). Decreases in soil decomposition and respiration rates in organic and mineral horizons in response to N addition across all five species suggest a significant suppression of C mineralization, particularly in the first few weeks of the incubation, with the strongest responses in beech and oak stands. Our results confirm that increased N additions significantly reduce soil organic matter decomposition rates and the lability of soil C for some tree species. Further, our research illustrates the need to consider varying responses among different tree species when predicting future consequences of N inputs on soil C storage. In the Northern Forest, years of excess N deposition from air pollution have probably led to increased soil C storage, particularly in beech and oak stands.

Background and Justification

- Atmospheric deposition of nitrogen (N) from air pollution is a serious environmental problem in most developed areas of the world, eastern U.S included.
- Because soils contain the largest near-surface reservoir of terrestrial carbon (C) and represent the primary sink for added N in most forest ecosystems, an improved understanding of the controls on C storage in soils and its response to changing N availability is crucial for accurate modeling and predicting of future atmospheric CO_2 concentrations.
- Unfortunately, considerable uncertainty remains concerning the magnitude of the effect of chronic N input on forest soil C pools. Some recent studies have shown that N fertilization increases soil C storage, while other studies have shown no effect.
- The role of N deposition in C sequestration depends on whether the deposited N ends up in “stable” or “labile” fractions of soil organic matter. Stable organic matter is expected to be resistant to further decomposition and represents a long-term sink for C and N, whereas labile soil organic matter is more easily decomposed and represents more transient storage.
- We used two different techniques to examine the lability of C and N in soils under five different tree species that have been part of a long-term N fertilization experiment. By measuring soil C lability, we are able to learn how much of the soil C is available to microbes for decomposition, as opposed to being sequestered in soils for decades or centuries.

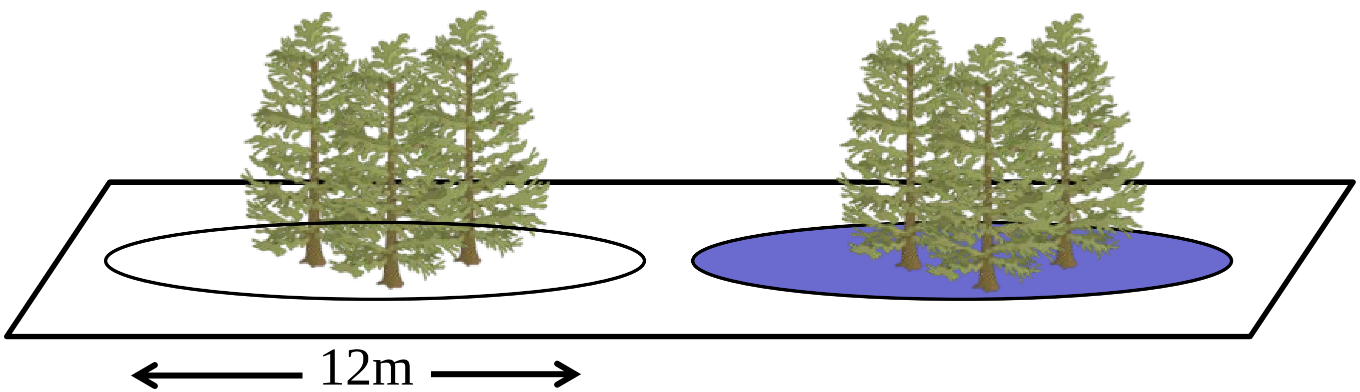
Methods

- We took advantage of a long-term (14-year) nitrogen fertilization experiment on replicate stands of five different tree species (sugar maple, American beech, yellow birch, eastern hemlock, and red oak) in the Catskill Mountains, NY.
- We took samples of organic and mineral (top 10 cm) horizons from control and fertilized plots. The fertilized plots had ammonium nitrate fertilizer (pelletized) added 4 times per year since 1997, for a total of 50 kg N/hectare/year.
- Overall, we measured 116 samples. There were 60 samples of organic horizons (5 species x 6 replicates x 2 N treatments (control and fertilized)) and 56 samples of mineral horizons, because 4 of the plots did not have any mineral soil.
- In the laboratory, we separated the mineral soil samples by density fractionation. The heavy fraction is stabilized by the association of the organic matter with mineral soil grains. The light fraction is considered more labile.
- For a second measure of C lability, we incubated the soils (both mineral and organic horizons) in the lab for a year, measuring the amount of carbon dioxide released from them over time (soil respiration). We call this “microbial fractionation,” because the microbial activity in the soil determines what fraction of the soil C is labile.

Long-Term N fertilization Study (1997 – 2010)

- Single-species plots of 5 different tree species: sugar maple, American beech, red oak, yellow birch, and eastern hemlock
- 6 replicate plot pairs (control + fertilized) for each species, for a total of 60 plots

Control	**N Fertilized**
Ambient N	Ambient N
~9 kg N ha^{-1} y^{-1}	+ 50 kg N ha^{-1} y^{-1} NH_4NO_3

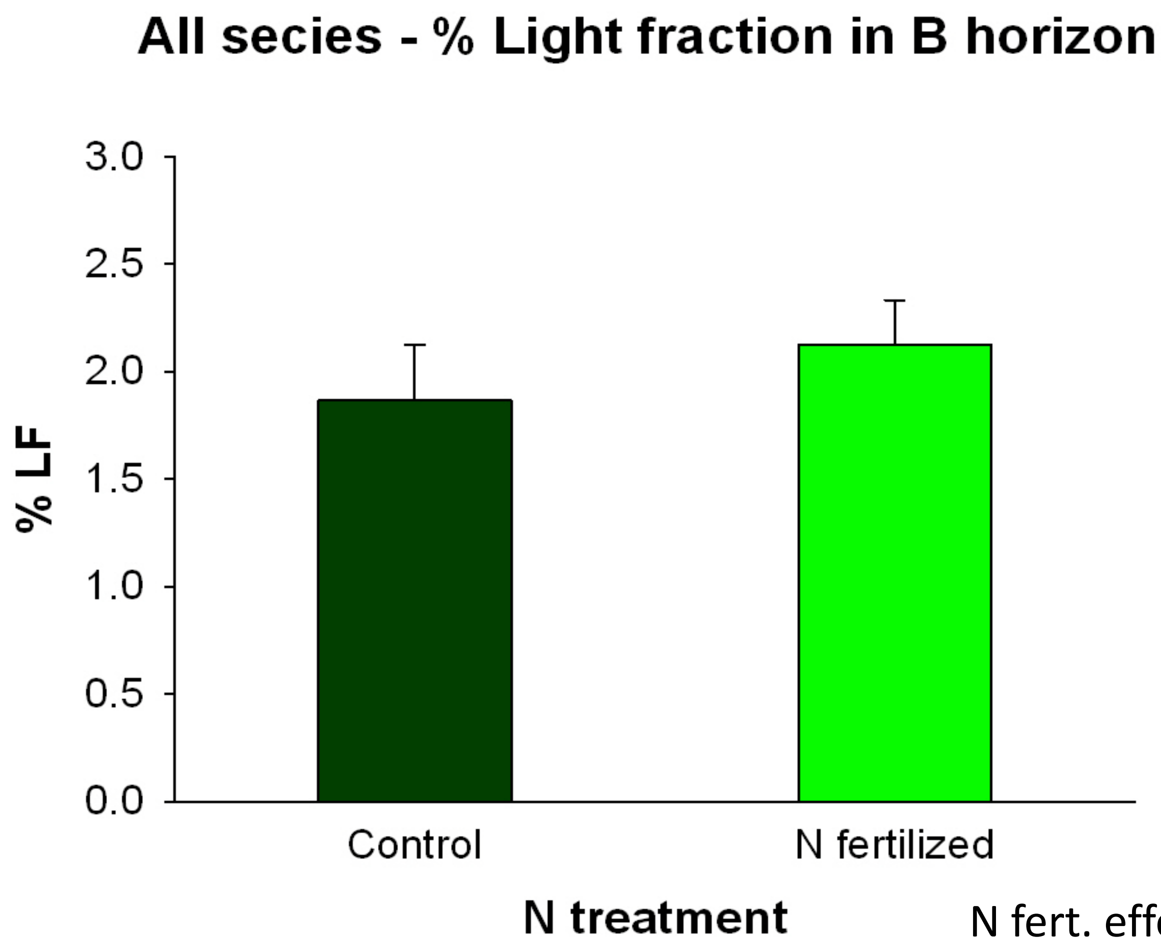


Dr. Alexandra Rodriguez sampling soil in a hemlock stand.

Soil samples sealed in jars for measuring release of carbon dioxide in the laboratory.

RESULTS 1: Density Fractionation

No significant differences were observed in % light fraction across species or N treatments .



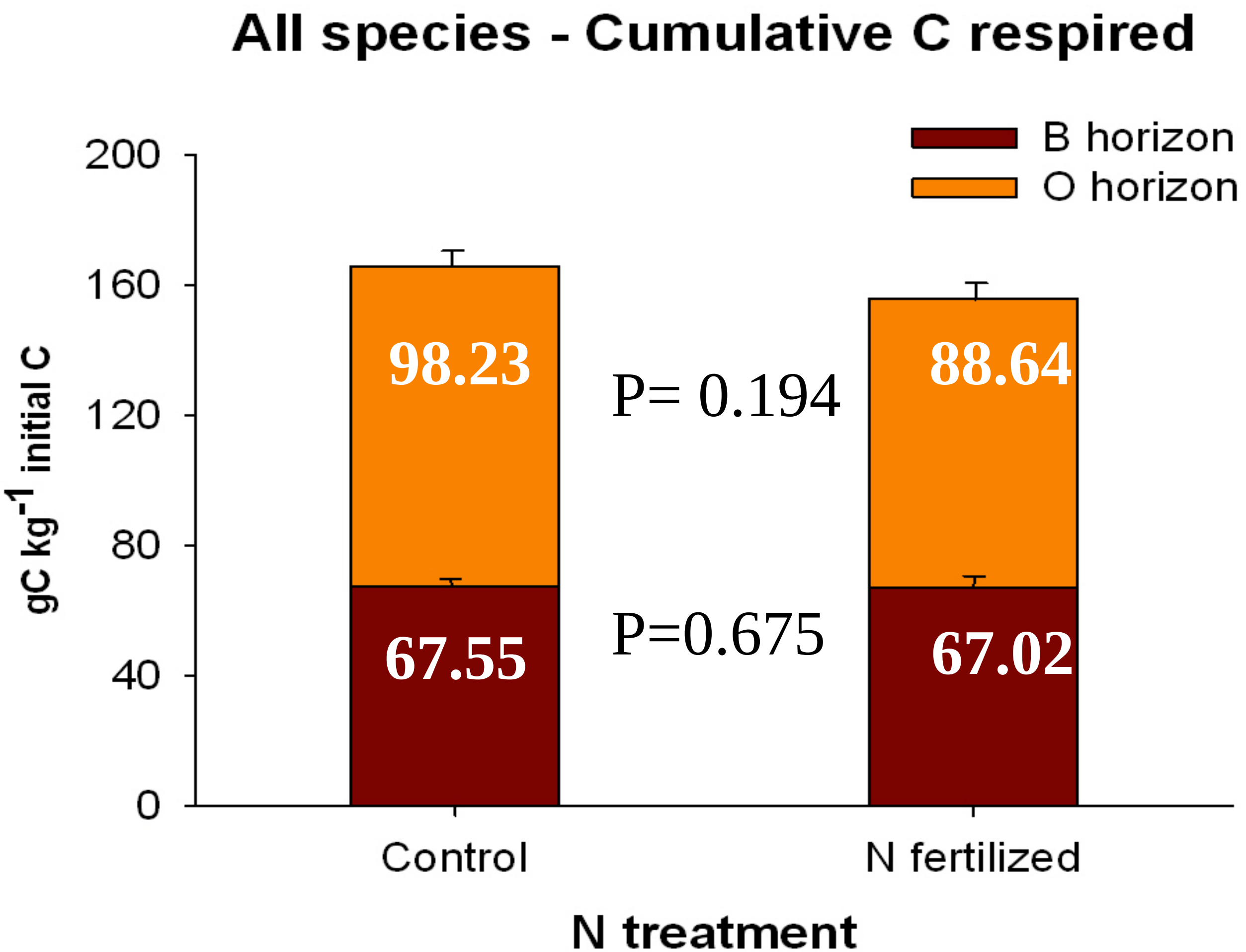
N fert. effect: P= 0.256

Spp effect: P= 0.374

N treat*spp: P= 0.261

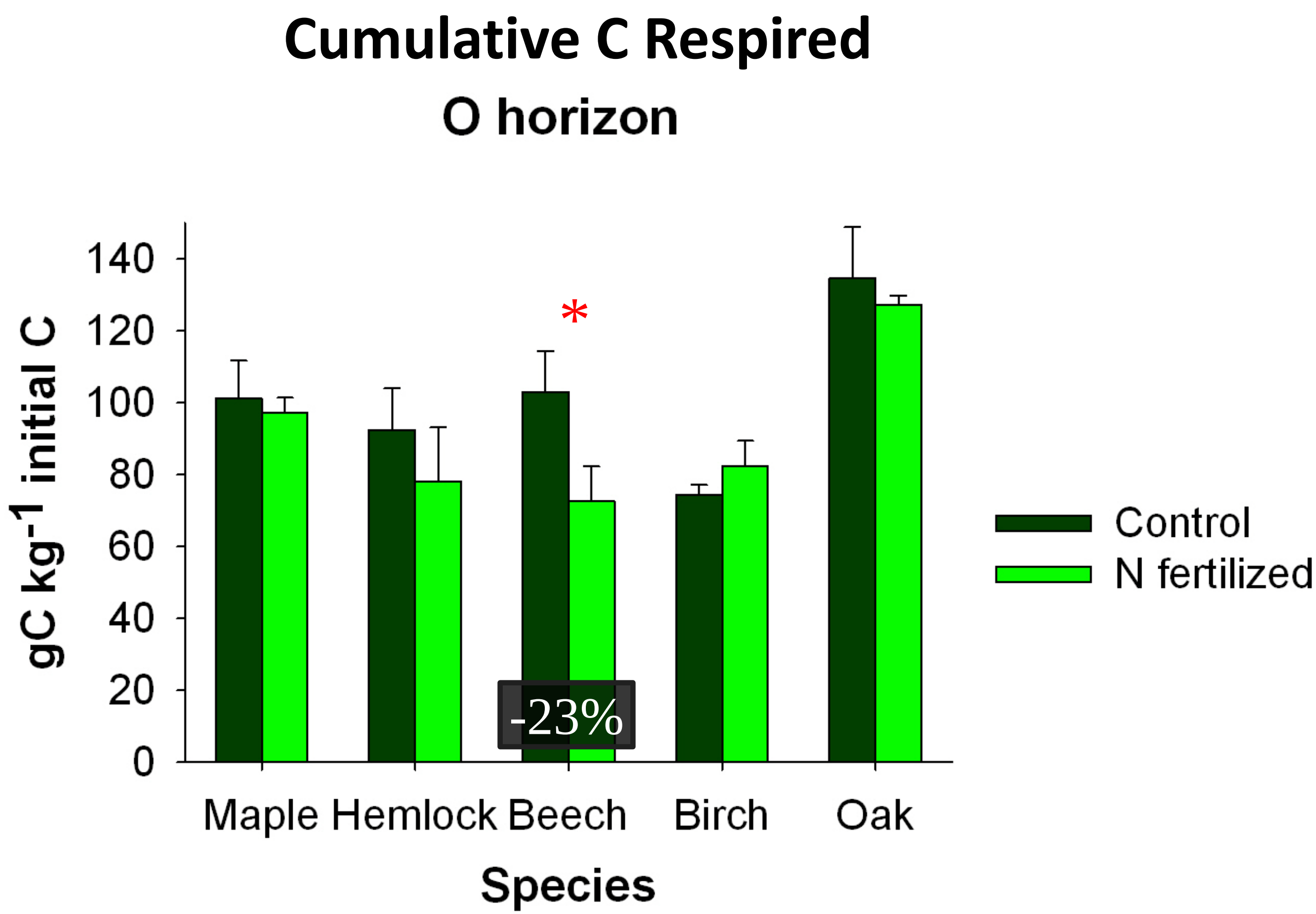
RESULTS 2: Microbial Fractionation

Considering all species together, there was about a 6% decline in cumulative C respired over the entire 1-year incubation in the organic horizons of the N treated plots compared to the controls, but this was not statistically significant. No differences were observed for the B horizons.



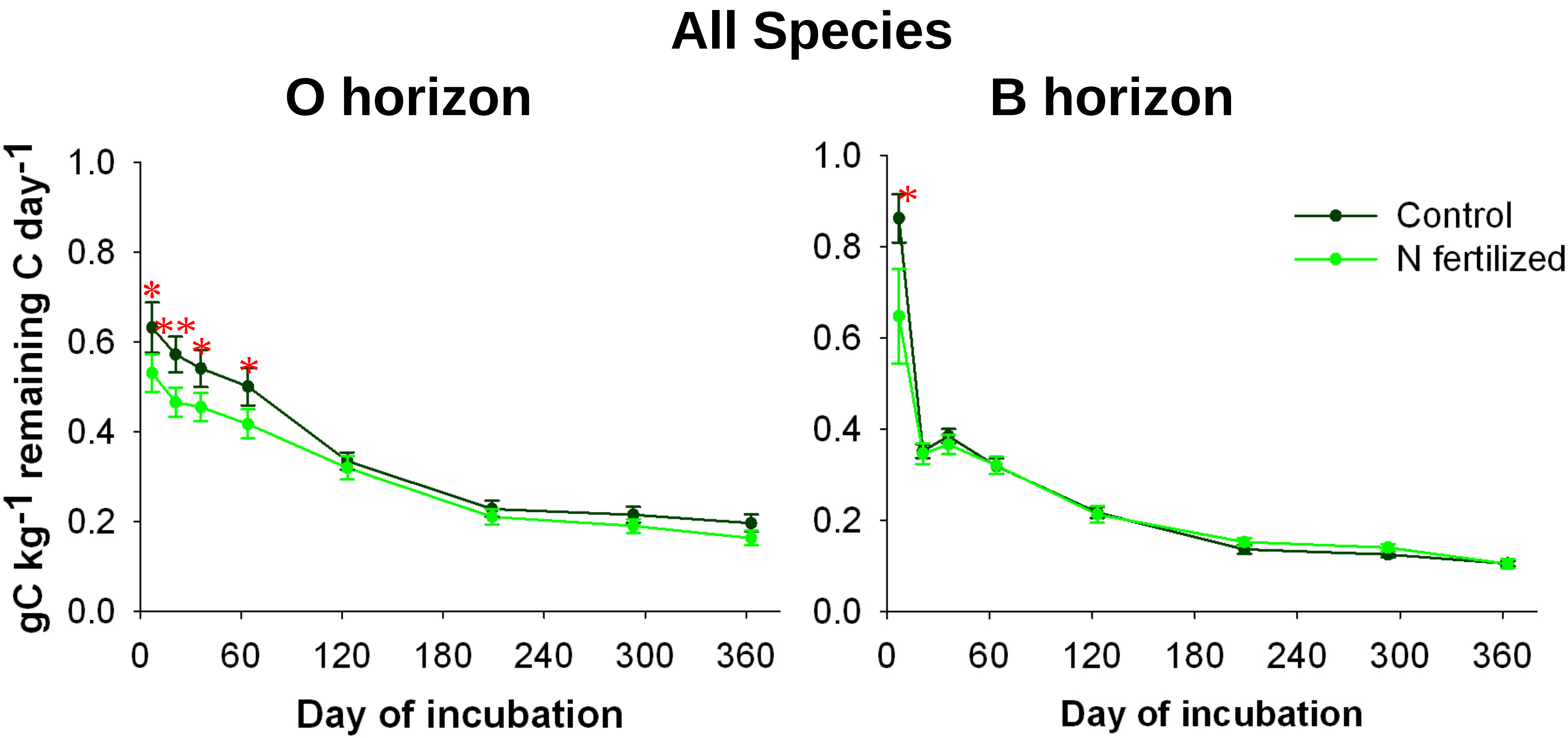
RESULTS 3: Microbial Fractionation

When broken out by species, there was a trend toward decreased respiration in the N treated plots for all species except yellow birch, and this effect was significant for beech, which showed a 23% decrease.



RESULTS 4: Microbial Fractionation

The time course of respiration during the 1-year incubation showed that the greatest effects of the N treatment on the suppression of microbial activity occurred during the beginning of the incubation. This may be the period that best represents field conditions because of fewer artifacts of long-term incubation in the lab. The largest effects were observed in soils from beech and oak stands.



Conclusions and Implications for the Northern Forest

1) Physical (density) fractionation did not show an effect of N addition on C stabilization.

2) However, microbial fractionation showed decreased microbial respiration (thus decreased lability) in N-treated soils in the first few weeks of the long-term incubation. The effect was strongest for soils in beech stands.

3) This result is consistent with some field studies showing buildup of soil carbon in N-fertilized plots.

4) The results indicate that excess N deposition, as can occur from air pollution, can result in increased stability of soil carbon, but the effect will differ by tree species. In the Northern Forest, years of excess N deposition from air pollution have probably led to increased soil C storage, particularly in beech and oak stands.

5) Our research illustrates the need to consider varying responses among different tree species when predicting future consequences of N inputs on soil C storage.

Outreach

- The results were presented at the 2013 annual meeting of the Ecological Society of America.
- The results are being used to parameterize a computer model of the effects of tree species change and N deposition on Northern Forest ecosystems. This will permit use of these experimental results to predict broader-scale responses of the Northern Forest to environmental changes.

Products

Abstract from Conference Presentation: Rodriguez, A., Lovett, G., Weathers, K., Arthur, M., Templer, P., Goodale, C., Christenson, L. 2012. Heterotrophic respiration in northern hardwood forest soils after 14 years of N addition. Ecological Society of America Meeting, August 2013, Portland, Oregon.

Peer-reviewed Journal Article: Rodriguez, A., G. M. Lovett, K. C. Weathers, M. A. Arthur, P. H. Templer, C. L. Goodale, and L. M. Christenson. 2014. Lability of C in temperate forest soils: Assessing the role of nitrogen addition and tree species composition. *Soil Biology & Biochemistry* **77:129-140.**

Journal Article in Preparation: Rodriguez, A., G. M. Lovett, K. C. Weathers, M. A. Arthur, P. H. Templer, C. L. Goodale, and L. M. Christenson. Estimated 2015 submission. Effects of nitrogen addition and tree species composition on nitrogen cycling and retention in forest soils.