Unexpected Responses of an Oak Forest to Nitrogen Amendment

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Abstract

Excess nitrogen deposition can have multiple effects on forests, including alteration of growth, nutrition and carbon allocation by trees and increased leaching of nitrate through the ecosystem. Nitrate leaching can cause depletion of base cations in the soil such as calcium (Ca), magnesium, potassium, and sodium and lead to soil acidification and increased aluminum (Al) concentration and mobility. Experimental addition of nitrogen (N) to an upland oak-hickory forest near Millbrook, New York has revealed several unexpected results. First, nitrate leaching began to increase within a year after the start of N fertilization, before there was evidence of increased nitrification. Control plots showed little N leaching. Second, the fertilized plots experienced significant tree mortality, especially after two summers of moderate drought. The mortality appears be associated with soil acidification. Third, surviving trees in the fertilized plots had higher relative growth rates than those in the control plots, indicating that the fertilization and N saturation effects of excess N deposition can occur simultaneously in the same forest stand.

Nitrogen Amendment Experiment

- The site is a ridgetop oak-hickory forest with thin soil over glacial till and shale bedrock. This forest was selectively cut until about 70-80 years ago but was never used for agriculture.
- There are six pairs of plots. One plot of each pair is fertilized with NH_4NO_3 in May, June, July and August each year, and the other plot is a control.
- 100 kg N/ha/yr added each year 1996 – 1999
- 50 kg N/ha/yr added each year 2000 – present
- Measurements included foliar N, tree growth, soil C, N and exchangeable cations, soil solution chemistry, N mineralization and nitrification (14-day lab assay). Leaching losses were estimated from B-horizon soil solution chemistry and water fluxes calculated from the BROOK90 model.

Background photo: Canopy of one of the fertilized plots showing tree mortality

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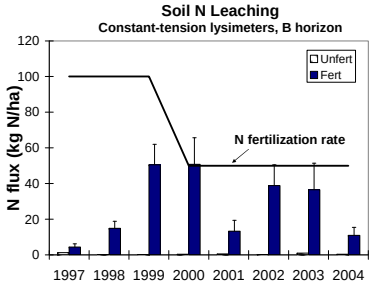
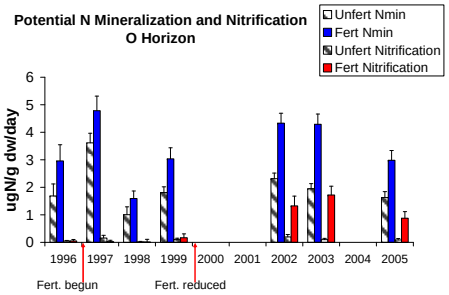
Unexpected Response #1: Nitrate leaching was observed after 1 year of fertilization, before nitrification increased.

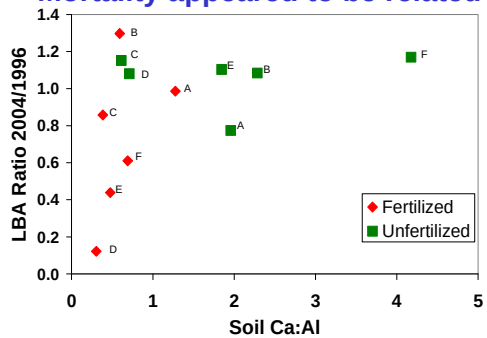


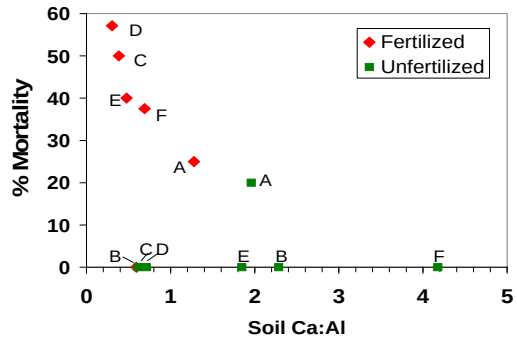
Leaching loss of N in fertilized and unfertilized plots. Solid line is N addition rate; plots also received ~10 kg N/ha/y from atmospheric deposition. Note rapid leaching in fertilized plots and low losses in unfertilized plots.



Potential N mineralization and nitrification rates. Note that nitrification in fertilized plots did not increase until after 2000, while N leaching was significantly higher than control plots by 1997.

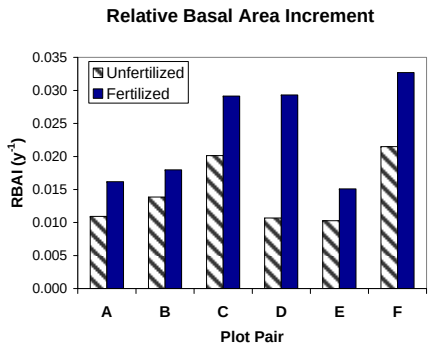
Unexpected Response #2: Tree mortality was severe in some of the fertilized plots, especially after two summers of moderate drought. Mortality appeared to be related to soil acidification.





Ratio of live basal area in 2004:1996 (left graph) and % mortality (right graph) on the plots as a function of the ratio of exchangeable soil Ca:Al, an index of soil acidification. Fertilization decreased soil Ca:Al, and most fertilized plots with Ca:Al <1 had significant mortality and lost live BA over the period. Most control plots, even those with Ca:Al < 1, gained live basal area (Wallace et al. submitted).

Unexpected Response #3: Surviving trees in fertilized plots had higher relative growth rates than trees in control plots. Thus, the fertilization and N saturation effects of N addition occurred simultaneously.



Relative basal area increment (RBAI, y^{-1}) of trees alive in 2004 in 6 pairs of plots. Plot RBAI is the sum of mean annual BAI (1996-2003) (cm^2/y) for all surviving trees in the plot divided by the sum of 1995 basal area (cm^2) for those same trees. Across all plots, RBAI is significantly higher in fertilized plots compared to unfertilized plots ($p<0.05$).

Wallace et al. 2007 Forest Ecology and Management 243:210-218