Effects of Acidic Deposition and Liming on Litter Decomposition Dynamics in a Calcium Deficient Southern Appalachian Forest

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Abstract

Decomposition of leaf litter is a critical component in nutrient cycling, carbon storage and release, and soil formation. Acidic deposition can alter nutrient dynamics and the decomposition of leaf litter by influencing nutrient mobility and decomposition rates. Liming of forests is implemented to combat negative effects of acidic deposition, such as low soil pH, cation depletion, and aluminum mobilization. However, decomposition rates following liming are poorly known. A litter bag study with a liming treatment was initiated in November of 2012 at four sites within the Nantahala National Forest, North Carolina, to examine the effects of liming on the litter nutrient dynamics of decomposing leaf litter. Total Kjeldahl Nitrogen and atomic absorption techniques will be conducted on leaf tissue collected at the initiation of the study and every three months for one year from randomly-collected litter bags to determine the nitrogen, calcium, magnesium, and aluminum content of decomposing leaf litter. Temporal changes in decomposition rates will be fitted by single and double exponential decomposition rate equations. Rates are expected to decrease following liming. Nitrogen can increase in leaf tissue for several months after senescence due to the incorporation by microorganisms during initial decomposition, therefore it is expected nitrogen will increase and then begin a gradual decline throughout the study. Calcium and magnesium are expected to increase following liming but aluminum is expected to be similar between treatments. Results will add to the existing knowledge on the management strategy of liming and litter decomposition dynamics.

Introduction

The decomposition of plant leaf litter contributes to nutrient cycling, soil formation, and the soil's capacity for carbon storage and release (Melillo et al. 1982). The rate of mass and nutrient loss of leaf litter is influenced by climate, the plant and decomposer community, initial litter chemistry, and soil properties (Melillo et al. 1982, Seastedt et al. 1983). In areas that experience elevated deposition of nitrogen and sulfur oxide as acid rain (Haines 1980), a lower soil pH may be linked to a decline in forest health and surface water quality(McNulty et al. 2007). Exactly how acid deposition affects litter decomposition is unclear. Some studies report increased rates of decomposition, while others report decreased rates.

The application of powdered calcium carbonate or lime to forest soil is a management practice implemented in order to mitigate negative effects associated with acidic deposition (Zelles et al. 1987). Benefits of liming soils include base saturation, and the reduction of inorganic aluminum released, as well as the supply of calcium and magnesium to vegetation. Liming increases soil pH (Blette and Newton 1996), and has positive effects on the soil microbial and faunal communities (Baath and Arnebrant 1994). The effects of liming and litter dynamics is heavily skewed towards soil microbial and faunal communities. Few studies examine the effect of liming on litter decomposition rates. Because of litter decomposition's substantial role in nutrient cycling and carbon storage and release it is important to understand how decomposition is affected by acid deposition and liming.

Purpose

This study aims to quantify litter decomposition rates and nutrient chemistry and the impact of a liming treatment within a forest ecosystem subjected to long-term acid deposition.

Methods

Four study sites are located within the southern Appalachian Mountains in the Nantahala National Forest, NC (Figure 1).

Figure 1. Map of the Nantahala National Forest North Carolina, USA. Image credit: modified after Sherpaguides.com

Elevation of the sites range between 1300 – 1450 m, in mixed oak and cove hardwood forests. Wet acidic deposition occurring as sulfate and nitrate was on average 11.3 and 8.7 kg/ha in 2011, respectively (Figure 2A and 2B).

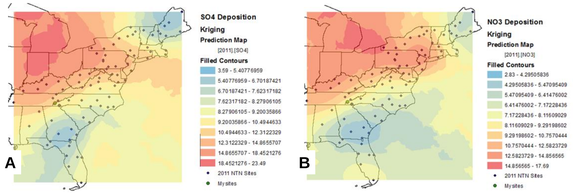

Figure 2. Total wet sulfate (A) and nitrate (B) acidic deposition (kg/ha) for 2011 (unpublished data).

To quantify decomposition, a total of 360 litter bags were divided equally into three types of bags: mixed site specific litter, *Quercus prinus* reference litter, and no litter (control). Bags were constructed of nylon mesh with a pore size of 1.0 mm and were 15 cm² in size. The bags were filled with 5 to 7 g of air dried litter, placed in a grid pattern, and secured with landscaping pins (Figure 3, A-C). Each of the four sites has a limed and an un-limed plot, with bags in limed plots receiving 15 g of dolomitic powdered lime. The study was initiated on November 12, 2012. Five litter bags of each type were collected in May and August 2013, and an additional set will be collected in November of 2013.

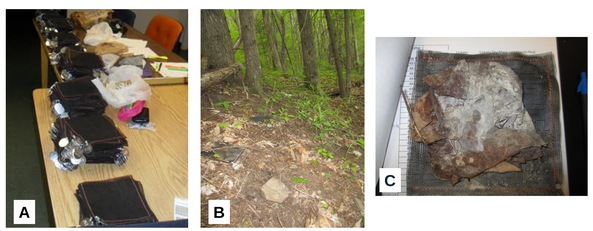

Figure 3. (A) constructed litter bags prior to incorporation of litter, (B) Example of litter bag placement, (C) A limed litter bag with mixed site specific litter after collection.

The dried leaf litter of each bag was ground and analyzed for % nitrogen using the Total Kjeldahl Nitrogen Procedure. One half gram of leaf tissue was digested at 460°C with 6 ml of concentrated sulfuric acid and a kjeltab (3.5 g Potassium Sulfate + 0.4 g Copper Sulfate). The digested samples were mixed with distilled water and 40% sodium hydroxide and distilled into a receiving flask containing 4% boric acid. The distillate was titrated with 0.1 N hydrochloric acid (HCl) (Figure 4A-4D).

Methods - con't

The % nitrogen was calculated using a standard equation:

$$\% \text{ Nitrogen} = \frac{(\text{mL standard acid - mL blank}) \times \text{N of acid} \times 1.4007}{\text{(weight of sample in grams)}}$$

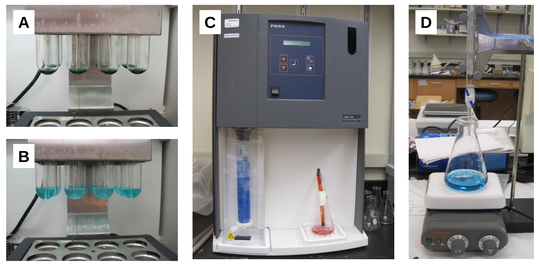

Figure 4. (A) Fully digested samples (B) Following digestion 10-20 mL of deionized water was added to prevent crystallization, (C) Samples were distilled using an automated distillation unit, (D) Titration of distillate with 0.1 N (HCl).

A Perkin Elmer 460 atomic absorption spectrophotometer was used to determine calcium, magnesium and aluminum concentrations of the leaf litter (Figure 5). Prior to analysis the litter was ashed at 550°C for 6.5 hours and brought into a 100 ml solution with 2 ml concentrated HCl and distilled water. Ten integrated readings of the samples were taken and averaged to determine the concentration using calibrated standards and a standard regression line for each element.

Figure 5. Perkin Elmer 460 atomic absorption spectrophotometer.

The average mass loss of dried leaf litter from each bag was determined for every collection date. Trends in decomposition rates will be established using the single or double exponential equations:

Single exponential: $x_t = x_0 e^{-kt}$

Double exponential: $x_t = x_L e_L^{-kL\,t} + x_R e_R^{-kR\,t}$

where x_0 is the original mass, x_t is the mass remaining after time t, k is the decomposition decay rate, x_L is the labile mass of the litter, x_R is the recalcitrant mass, x_t is the amount of litter remaining after time t, k_L is the decomposition decay rate of the labile fraction, and k_R is the decomposition decay rate of the recalcitrant fraction. Leaf tissue analysis will be conducted to determine the labile and recalcitrant fractions of the litter.

Methods - con't

The single and double exponential decay equation for the decay of litter in each plot will be fitted using linear least square estimation and possibly log transformed to test the underlying assumption that the decomposition rate of leaf litter is linear to compare of slopes, intercepts, and residual variances of the regressions obtained for each treatment.

The decomposition rates and litter nutrients obtained over time will be statistically analyzed using a single factor repeated measures ANOVA to test for differences in litter decomposition rates and nutrient composition between limed and un-limed treatments.

Expected Results

Due to the acid deposition history of the study area it is expected that decomposition rates of leaf litter in unlimed plots will be greater than those in limed plots. Studies of decomposition rates in areas with similar deposition suggest increased nitrogen levels may stimulate microbial activity, which could in turn stimulate decomposition.

Nitrogen can increase in leaf tissue for several months after senescence due to the incorporation by microorganisms during initial decomposition, therefore it is expected nitrogen will increase and then begin a gradual decline throughout the study.

Calcium and magnesium are expected to increase following liming but aluminum is expected to be similar between treatments.

Results will add to the existing knowledge on the management strategy of liming and litter decomposition dynamics.

References

Baath, E. and K. Arnebrant. 1994. Growth-rate and response of bacterial communities to pH in limed and ash treated forest soils. Soil Biology & Biochemistry **26**:995-1001.

Blette, V. L. and R. M. Newton. 1996. Effects of watershed liming on the soil chemistry of Woods lake, New York. Biogeochemistry **32**:175-194.

Haines, B. 1980. Acid rain: Threshold of leaf damage in eight plant species from a southern Appalachian forest succession. Water, Air, and Soil Pollution **14**:403-407.

McNulty, S. G., E. C. Cohen, J. A. M. Myers, T. J. Sullivan, and H. Li. 2007. Estimates of critical acid loads and exceedances for forest soils across the conterminous united states. Environmental Pollution **149**:281-292.

Melillo, J. M., J. D. Aber, and J. F. Muratore. 1982. Nitrogen and lignin control of hardwood leaf litter decomposition dynamics. Ecology **63**:621-626.

Seastedt, T. R., D. A. Crossley, Jr., V. Meentemeyer, and J. B. Waide. 1983. A two-year study of leaf litter decomposition as related to macroclimatic factors and microarthropod abundance in the southern Appalachians. Holarctic Ecology **6**:11-16.

Zelles, L., I. Scheunert, and K. Kreutzer. 1987. Bioactivity in limed soil of a spruce forest. Biology and Fertility of Soils **3**:211-216.

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