Edaphic effects of Eastern Hemlock (*Tsuga canadensis*)

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Introduction

- Hemlocks are an integral part of late-successional forest dynamics.
- Hemlocks have been shown to influence the characteristics and quality of streams.
- They are the preferred tree species for dozens of species of wildlife and offer a unique habitat for these species. They are also a key source of winter seed.
- Soil acidity has also been shown to greatly impact the structure of plant, animal, fungal and microbial communities in forest systems.
- A high concentration of tannins in hemlock litter and bark slow decomposition and acidify organic compounds in the soil litter, resulting in more acidic soil around hemlock individuals (adjacent photo).
- In this observational study we examined the relationship between the size and age of *T. canadensis* and surrounding soil acidity.
- Specifically, how does soil acidity change in soils at increasing distances from the stem of the tree and how are these changes related to the size and age of individual trees?


Photo taken by J. Bellemare

Methods

We investigated soil pH around isolated hemlock trees growing in a deciduous forest at the MacLeish Field Station in Whately, MA. In our study site, *T. canadensis* are interspersed in a primarily black birch (*Betula lenta*) stand in the central, eastern portion of the MacLeish Field Station in Whately, Massachusetts (Fig. 1). All *T. canadensis* in our study site less than 10m from another hemlock were identified and 10 individuals were chosen at random for further study.

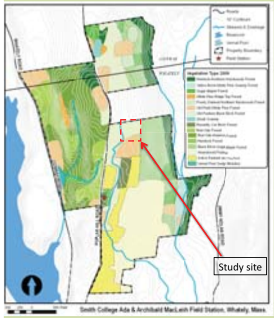

Fig. 1 Our study site, outlined in red, is located in the central portion of the MacLeish Field Station.

- We measured tree characteristics of diameter at breast height (dbh), average canopy radius, height, age and lifestage (sapling, sub-emergent and emergent).
- pH was measured by marking three transects radiating from the base of the tree and measuring at sampling intervals that were regular proportions of canopy radius.
- A total of 18 samples were taken per tree at increasing distance from the base; nine samples under the canopy and nine samples outside of the canopy.
- Each pH sample was obtained by measuring a solution of 50 ml of mineral soil combined with 50 ml of deionized water with a pH meter.
- Sampling was carried out on 9/26, 10/17, 11/7 and 11/13, 2010.

Data analysis: Statistical analyses were conducted in parallel using Minitab and Stata IC 11.

Acknowledgements

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Results

Table 1. Descriptive data of the ten observed trees.

Canopy Radius (m)	Height (m)	DBH (cm)	Age (years)
5.40	14.5	41.3	69
5.25	16.2	31.3	76
4.32	13.8	29	45
3.39	6.7	18.5	36
3.36	6.9	15.8	28
3.18	8.1	16.4	31
2.68	4.3	16.5	36
2.46	6.6	13.6	28
2.24	6.3	10.8	25
1.59	3.9	6.5	24

	dbh	height	radius	age	ph	location	samp_d~t
dbh	1.0000						
height	0.9050	1.0000					
radius	0.9646	0.9355	1.0000				
age	0.9119	0.8939	0.9199	1.0000			
ph	0.6534	0.6101	0.6323	0.6155	1.0000		
location	-0.0000	0.0000	0.0000	-0.0000	-0.1543	1.0000	
samp_dist	0.5213	0.4912	0.5470	0.5214	0.4524	-0.6858	1.0000

Figure 2. Correlation matrix of measured variables. The very large, positive correlations between DBH, Height, Radius, and Age allowed us to use a regression model using DBH as the only measure of tree size.

- We found a small but significant association between pH and sampling location (see Regression Analysis).
  - pH is greater outside the canopy vs. inside (0.08 difference; t-test, p=0.039), suggesting an association between hemlock trees and higher mineral soil acidity.

Regression Analysis: pH versus DBH, Location

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The regression equation is
pH = 4.37 + 0.0160 DBH - 0.0760 Location

Predictor      Coef    SE Coef       T      P
Constant    4.37035    0.03341  130.81  0.000
DBH        0.015973   0.001362   11.73  0.000
Location   -0.07601    0.02745   -2.77  0.006

S = 0.184107   R-Sq = 45.1%   R-Sq(adj) = 44.5%
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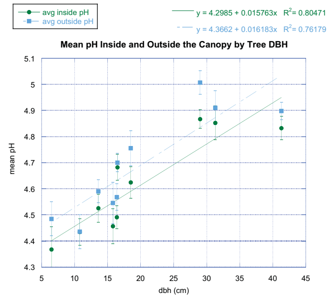

Figure 3. Graph of the mean pH of each tree, separated by inside and outside the canopy arranged in ascending order by DBH. This confirms that the pH under the canopy is generally more acidic than outside the canopy. The similarity in slopes indicates that the average change in pH with increasing DBH is the same both inside and outside the canopy.

- Our data also show a pattern of decreasing acidity with increasing distance from the base, which holds true in the majority of our sample (Fig. 3).
- On a tree-by-tree basis, our data show a trend toward higher soil pH with increasing distance from the base of the tree (Fig. 4).

The below graphs illustrate the relationship between distance from tree and soil PH for each individual tree. When the slopes are plotted in a histogram, it is clear that while the steepness of the slope varies between trees, the slopes are centered above zero and have a positive skew that indicates that pH increases with distance from tree.

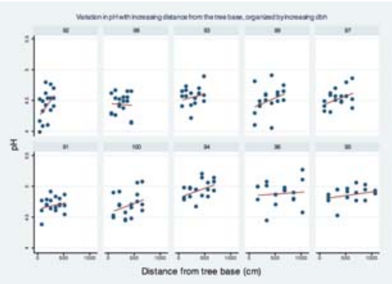

Figure 4

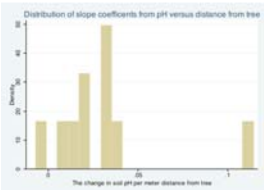

Figure 5

Discussion

- Hemlocks are associated with a more acidic microenvironment underneath their canopies; mineral soil becomes more acidic with increasing distance from the tree base. However, contrary to our initial hypothesis, larger trees are associated with higher pH, both inside and outside the canopy.

Why are bigger trees found in less acidic environments?

- The lowest branches of larger, older trees are higher up in the canopy, possibly resulting in a wider range of leaf litter dispersal and a less concentrated effect of leaf litter on soil pH around the base.
- Conversely, the leaf litter of smaller trees may have a more concentrated effect on soil pH near the stem where the majority of needles fall.
- Younger, smaller trees are uniformly associated with lower pH. Perhaps small trees are establishing in more acidic microenvironments. Larger, older trees may have established while the site was still pastureland and did not experience any competition/selective pressure for specific microenvironments.
- By choosing a sampling distance relative to the canopy radius of each tree, we hoped to have a measure that was comparable between trees, regardless of tree size. However, we might have missed effects of stemflow or leaf litter acidification very close to the base of larger trees because the closest sample to the base of larger trees was farther away than that of smaller trees.

Implications

- Hemlocks are threatened by a devastating invasive insect, the Hemlock Woolly Adelgid (HWA), a small aphid-like insect introduced from Asia in the 1950's.
  - HWA can completely eliminate a hemlock population in a few years.
  - Defoliates trees of all ages; defoliated hemlocks cannot re-sprout or re-foliate.
  - Damage makes hemlocks vulnerable to other pests/pathogens
  - Smaller trees have higher mortality rates, so those trees with the strongest edaphic effects would be the most easily eliminated.
- The Future is Grim - if you're a hemlock tree
  - Hemlocks and the microenvironments they create are disappearing
  - This disturbance allows other species, both natives and invasives, to take hold in previously hemlock-dominated areas.
  - Answering questions like how hemlocks affect soil characteristics can help inform management plans, predict patterns of regeneration, and shed light on other changes which may occur in forest community dynamics as a result of hemlock mortality.

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