Northern Forest Mesocosm (NForM) Climate Change Experiment: An analysis on N nutrient loss based on frequency of soil freezing and snow cover

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ABSTRACT

In order to understand additional sources of nutrient run off in the Champlain Watershed, and the role of forest communities in water quality, a mesocasm based soil freezing experiment was conducted at the George D. Aiken Forestry Sciences Lab. Mesocasms were randomly assigned a treatment group that included snow removal and incubation of 2-4 degrees higher than ambient conditions to better understand how a warming climate effects soil nutrient concentration and the overall health and productivity of forested areas. Leachate samples were collected from each mesocasm and nitrate and ammonium concentrations were determined using a microplate method. The overall goal in this study was to determine whether climate change and a warming environment has any significant impact on nutrient and water balance in forest communities. These results indicate that a more complete data set should be used in order to determine significance, and that more data collection should be completed to generate a stronger trend and result. Additionally, the results of this study indicate that nutrient composition of soil may not be the driving factor for nutrient leaching, but rather soil texture and water dynamics need to be considered when trying to explain nutrient loss. These results suggest that nitrate readily leaches from soil more easily than ammonium, there is a greater loss of nitrate from snow removal treatments than the control for low calcium soils, and there is an apparent difference in nitrate leaching when comparing soils with high and low calcium concentrations.

This image illustrates the set up and placement of the various mesocasms behind the Forestry Lab Center.

INTRODUCTION

Based off of the Northeast Climate Impacts Assessment of 2006, the Northern Forests of North America will face an expected increase in mean temperature of 2-7 degrees Celsius by 2100. Naturally, a warming a climate will alter and likely reduce the amount of snow fall and duration the Northeast endures yearly. With decreased amounts of snow, forest floors will be exposed to colder air temperatures as they will lack insulation, and soil freezing will occur. This phenomenon maybe deleterious to forest health as there will likely be a changes in carbon, water, and nitrogen balance (Adair, 2014). Nitrogen is of great importance to the Northeastern forests as it is the limiting nutrient of this ecosystem, and if balances are altered by climate change, productivity and health of the forest may deteriorate (Morse, et al., 2015).

Nitrogen loss due to soil freezing may have a multitude of negative effects on the general health of a Northern forested ecosystem. A warming climate is expected to amplify the effects of winter thaws which lead to the awakening of microbes who contribute to nitrogen buildup in the soils. This nutrient build up will become highly susceptible to leaching and can lead to problems involving the reduction of plant health and productivity as well as a decline stream and water quality (Juice, 2015). Water quality is important factor to consider, especially in Burlington Vermont where there are several forested areas that drain into the Lake Champlain Watershed, a system that has faced problems with water health, nutrient balance, and algal blooms for the last several years.

In order to quantify and analyze nitrogen losses from forested ecosystems due to a warming environment, a mesocasm based soil freezing experiment was performed at the Aiken Forestry Sciences Lab in Burlington Vermont. Soil treatment groups were used to determine if warming a mesocasm or removing snow from it would have any impact on the retention of nitrogen in the form of ammonium and nitrogen. It was hypothesized that conditions mimicking those predicted to happen as the environment faces climate warming would amplify the amount of nitrogen found in the collected leachate samples. It is believed that if the soil freezes as a result of a warming environment that plant activity will decrease even more so than it already does during the winter months, and thus nitrogen will remain in the soil as it won't be taken up by plants in a frozen environment. Results obtained from this study indicate that there is an apparent difference in nitrate leaching when comparing soils with high and low calcium concentrations. However, nutrient composition may not be the driving factor for the phenomena, but rather soil texture and water dynamics as a result of soil texutre.

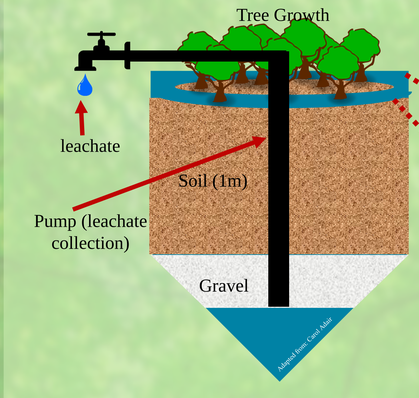
OBJECTIVE

- To quantify nutrient loss through periodic leachate collection and colorimetric analysis
- To determine the impact soil freezing has on nutrient loss and water balances in Northeastern North American forests
- To assess and analyze the health and productivity of forested ecosystems in the face of climate change as well as monitor the potential effects forest health and phenomena has on watershed biogeochemistry

https://www.researchgate.net/figure/Zs/8/1.891_fig1_Figure-1-Major-water-fluxes-in-a-forested-watershed-The-insets-describe-components-of

THE MESOCASM

Location: George D. Aiken Forestry Sciences Lab, 705 Spear Street, South Burlington, Vermont 05403



Mesocasm Parameters

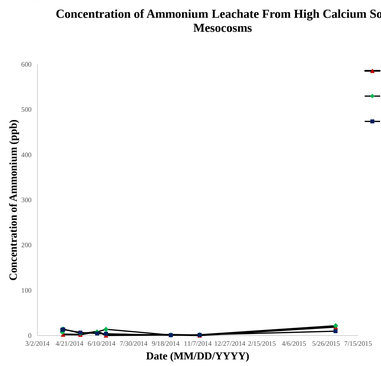
- 24 total, 2.44 diameter polyethylene tanks
- Hold 4.7 m^3 soil
- Conical section allows for leachate collection
- Tree species (cover extreme tolerances of native species): paper birch, quaking aspen, American chestnut, Black cherry
- Soil type: two types, coarse or fine (due to mineral composition)
- Treatments: randomly assigned, warming, snow removal, control, 4 replicates per soil type
  - Warming: 2-4 degrees higher than ambient using lamps
  - Snow removal: any fallen snow removed to induce soil freezing

Determining Nutrient Composition

- Leachate samples collected starting in June 2014 and ending August 2015
- Ammonium and nitrate concentrations were determined colorimetrically using the microplate reader BioTek Synergy HT
- Nutrient Concentration methodology were adapted from Allison, Barger, Hofmockel Lab Protocols (2003), using the low concentration method
- Statistical Analysis and ANOVA tests were performed using the software program Excel.

RESULTS

Figure 1: Nutrient Leachate Analysis for Soils with High Calcium Concentration



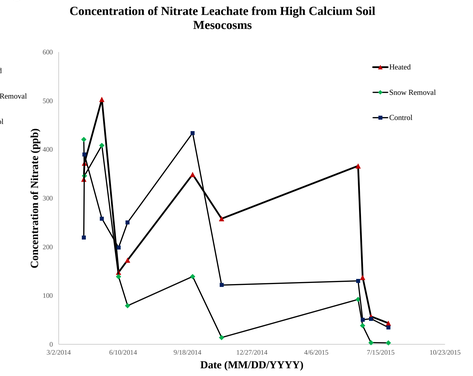
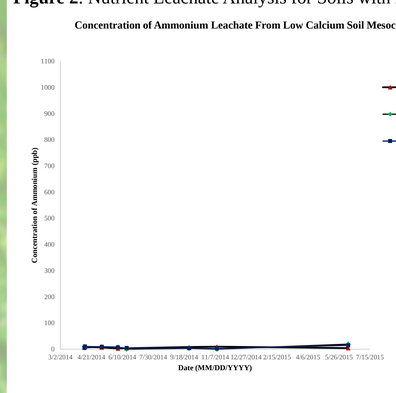


Figure 1: The above plots are a representation of ammonium and nitrate concentrations found in high calcium soil leachate versus time. The first plot indicates that very little ammonium was found in leachate samples, with little variance across time and treatment. The second plot illustrates that nitrate concentration was dependent on date sampled and varied through time and treatment. Maximum nitrate concentration found in a leachate sample was found in the heated treatment. The table to the left is a summary of noteworthy statistical results for the high calcium soil treatment. In all cases, there was significantly more nitrate in the leachate samples than ammonium. However, there was no statistical significance in the difference observed between nitrate concentrations for the heated and snow removal treatments.

Statisitcal Analysis of High Calcium Concentration Soils using ANOVA			
Nutrient	Treatments	p-value	
NO3	Heated and Snow Removal	0.159274	
NO3 and NH4	Control (Both)	2.55E-05	*
NO3 and NH4	Heated (Both)	2.94E-06	*
NO3 and NH4	Snow Removal (Both)	0.004038	*

Figure 2: Nutrient Leachate Analysis for Soils with Low Calcium Concentration



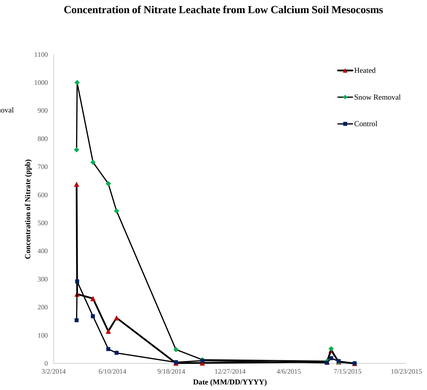


Figure 2: The above plots are a representation of ammonium and nitrate concentrations found in loq calcium soil leachate versus time. The first plot indicates that very little ammonium was found in leachate samples, with little variance across time and treatment. The second plot illustrates that nitrate concentration was dependent on date sampled and varied through time and treatment. Maximum nitrate concentration found in a leachate sample was found in the snow removal treatment. The table to the left is a summary of noteworthy statistical results for the high calcium soil treatment. In all cases, there was significantly more nitrate in the leachate samples than ammonium. As seen in the high calcium soil samples, there was no statistical significance in the differences observed between nitrate concentrations for the heated and snow removal treatments. However, the the differences in nitrate concentration observed between the control and snow removal treatment are statistically significant.

Statisitcal Analysis of High Calcium Concentration Soils using ANOVA			
Nutrient	Treatments	p-value	
NO3	Heated and Snow Removal	0.11924119	
NO3	Snow Removal and Control	0.032222962	*
NO3 and NH4	Control (Both)	0.042277008	*
NO3 and NH4	Heated (Both)	0.004849624	*
NO3 and NH4	Snow Removal (Both)	0.04137906	*

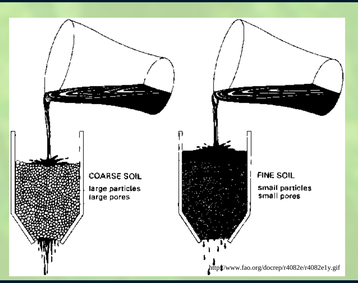
Table 1: Summary of Statistical Comparisons between Soil Types for Nitrate Concentration

Soil Type Comparisons for NO3 Concentrations using ANOVA		
Nutrient	Treatment	p-value
NO3	Heated	0.124577275
NO3	Snow Removal	0.145936347
NO3	Control	0.018752475 *

Table 1: The above table summarizes the differences seen in Nitrate concentrations due to differences in soil type. The only statistically significant result obtained were the differences seen in the control treatments for high and low calcium soil concentrations. The differences in the heated and snow removal treatments were not significantly significant.

CONCLUSIONS

- Differences observed between soil types may be better explained by soil texture and water dynamics. The high calcium concentrated soil was coarser than the sandier low calcium concentration soil. This likely has significant impacts on water dynamics and nutrient loss.
- A more complete data will likely yield stronger and more convincing results with greater statistical significance.



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