Effects of Flooding on the Carbon and Nitrogen Cycles in the Cedar, Maple, and Pine Bogs of Western Cape Cod

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Abstract

In order to better understand the carbon and nitrogen cycles under the duress of flooding and drainage, a manipulative experiment was set up using soil cores. Samples were taken from four different swamps within the same nature preserve in Falmouth, Massachusetts and were brought back to a lab for manipulation and data collection. In addition to a drainage experiment, the soils were analyzed for their C:H:N ratios and pH values. The experiment was not able to fully assess the carbon and nitrogen cycles, but it did show that theses systems are very rich in carbon and very poor in nitrogen. It also showed that soils from pine swamps have lower carbon percentages than the other swamps.

Key Words: Cedar Swamps, Pine Swamps, Maple Swamps, Carbon Cycle, Nitrogen Cycle, Soils, Microbial Communities, Ecosystems, Microbial Ecosystems, Leaching, Runoff

Introduction

Cedar, maple, and pine swamps are three complex and fascinating ecosystems found on Cape Cod. While these ecosystems are readily present in the region, they are not widely studied. These ecosystems are of particular interest to the area because they were once even more predominant, but their prevalence declined with increased development and land demand. Cedar swamps are catastrophe dependent on fires, hurricanes, drought, and logging. (Laderman 1998) The paradox is that the cedar trees themselves are easily out-competed if limiting nutrient concentrations increase (Atkinson 2001). When richer nutrient concentrations appear, these swamps often progress towards a different dominating biota, such as the red maple. In addition, these ecosystems cannot sustain extended periods of flooding or drought. The sustainability of these ecosystems may be dependent on the fluxes of the carbon and nitrogen cycles.

My manipulative experiment investigates the fluctuations in the carbon and nitrogen cycles due to a consistent state of flooding. My experiment also examines if the defining biota is correlated with the resilience of the two cycles among the three ecosystems. In addition to an established cedar swamp, my study includes a developing swamp composed of young cedars. I chose to add the young cedar swamp in order to better understand to conditions that are favorable for saplings and seedlings. A better understanding of these conditions may allow for more successful attempts at regenerating cedars in New England.

Methods

I sampled at four different sites within the Falmouth's nature preserve off of Blacksmith Shop Road. (Figure 1) I chose one established cedar swamp, one maple swamp, one pine swamp, and one developing swamp that contained many cedar saplings growing in very moist ground. (Figures 2 through 5) At each site I collected four ten-centimeter-deep organic soil samples. Two samples were taken from the tops of hemic mounds and two were taken from hollow depressions (Figure 6). The hemic mounds are typically above the water line while the hollow depressions are typically below the water line. I wanted to also investigate the effects of flooding and drought between these different sediment locations. I placed the four samples from each site into separate plastic bags and homogenized each one.

Once I transported these samples to the lab, I split the contents of each bag into two sediment cores and added distilled water (Figure 7). I drained the cores within 24 hours. I chemically preserved the leachates for dissolved organic carbon (DOC) and NH_4^+ and froze the leachates for NO_3^- and total dissolved nitrogen (TDN). I designated one of the two samples from each bag as a "dry" sample and the other as a "wet" sample. The distinction of dry and wet is in reference to the residence time of the water sitting in the cores, or in other words, the treatment during the course of the experiment. I did not add the DI water to the dry cores until immediately before I leached them. For the wet cores, I would refill them with DI water immediately after each leaching and let the water remain there until the time of my next leaching.

All of the samples were incubated at 20 degrees Celsius in a growth chamber during the course of the experiment. I conducted this leaching process three times during the project: once at the beginning, once in the middle, and once at the end. (Table 1) At the time of a leaching I took respiration measurements using the Li-Cor 6200. (Figure 7)

I ran my chemical analysis on the leached water. I quantified the concentrations of dissolved organic nitrogen (DON) and dissolved inorganic nitrogen (DIN) in order to assess the nitrogen mineralization and availability for the drained water. In order to attain the DON and DIN values I ran the leachates for NH_4^+, NO_3^-, and TDN (Strickland and Parsons 1972). The DIN is the total of the NH_4^+, NO_3^- and the DON is the difference between TDN and the DIN. I also tested for the dissolved organic carbon (DOC) (Peltzer protocol) and the dissolved inorganic carbon (DIC). I tested for DIC and DOC in order to assess respiration rates and labile carbon in the drained water.

I also ran a small portion of these samples through the CHN analyzer in order to determine the C:H:N ratios in the sediments.

Results

Expected Results

I expected to see the carbon and nitrogen cycles of the hemic mound soils to be more variable under the flooded conditions. The microbial communities in the hollow depression locations are likely to be reliant on a consistent presence of water whereas the community present in the hemic bog may not be.

The cedar swamp samples would have the greatest changes due to the consistent flooding because the overall system collapses under this condition. On the other hand, I predicted that the cedar sites would be more resistant to leaching. I believed that the soils would strongly hold onto nitrogen compounds and so the leaching rates would be less likely to change over the course of my investigation. I believed that the maple sites, since they are typically richer in nitrogen than their cedar counterparts, would have higher rates of losses. I was less certain for making predictions concerning the pine sites, but I did believe that the soils in the pine sites would have lower carbon and nitrogen percentages than the maple sites. I believed that the pine samples would be more similar to the cedar sites than the maple sites. However I also predicted that these percentages from the pine sites would still be lower in the cedar percentages. Given that the defining biota is sensitive to over-saturated conditions, the pine sites would also be greatly affected by the consistent flooding.

Actual Results

In terms of the physical analysis, the all of the pH's were within the upper 3.50 to 4.50. (Figure 8) The hemic mounds had an average pH of 4.10 while the hollow depressions had an average pH of 4.24. The mounds in the cedar and maple sites clearly had a lower pH than their depression counterparts while the mounds and depressions in pine sites were statistically identical. The pH of the young cedar samples was closest to that of the pine samples as opposed to those of the cedar samples. The low pH of all the sites is caused by cation exchange. (Laderman 1998) For water percentage of fresh soil, the depressions had the higher average of 82% while the mounds had 76%. (Figure 9)

My prediction concerning the carbon and nitrogen percentages in the pine swamps was correct; the percentages for both elements were lower than both the cedar and maple swamps. (Figure 10) While my experiment cannot prove that this is due to leaf loss, it indicates that there is generally less litter present in the pine site. Although these percentages decreased, the C:N ratio remained close to that of the cedar and maple swamps.

The samples taken from my sites are clearly grouped when organized on a C:N graph. (Figure 10) The young cedar samples are mixed in with the maple sites. This suggests that the cedar saplings and seedlings can rise from former maple sites. The pine samples are the most spread out of the four sites, but all remain on the lower carbon and nitrogen percentages of the rest of the sites.

The NH_4^+ data did not show clear trends or differences among the sites. (Figure 11) It appears as though the pine soils were more resistant to leaching losses than the other swamps, and perhaps the depression soils were even more resistant than their mound counterparts. All of my samples had very low readings of NO_3^- of less then 0.3 uM and their rate of release did not change with time nor treatment. (Table 2) Since the levels were so low, I could not statistically tell the difference between concentration differences and the instrument's static.

The treatment had a clear effect on the soil respirations of maple and pine sites. (Figure 12) The treatment clearly caused the respiration rates to be lowered. The cedar mounds also reflected this trend, but the treatment appeared to increase the respiration in the cedar mounds.

The DIC numbers appear to contain no distinct trend. (Figure 13) The data suggests that there may be an exception concerning hemic mounds that are kept under wet conditions.

Discussion

My results were not successful at fully addressing my scientific questions, however they do show that the more dynamic and massive cycle in these ecosystems is the carbon cycle. While I would like to look towards past studies of nitrogen cycling in northeastern forested wetlands, no such studies exist. (Golet 1993) I was disappointed that the DOC instrument went out of order, the little bit of data that I was able to collect from it showed that my samples were extremely high in dissolved organic carbon compounds. (Table 3)

What was particularly interesting was to see that all of the samples had very similar C:N ratios. (Figure 10) Even in samples where the carbon percentages were lower, the nitrogen percentages declined along with them. What probably happened was that my pine sites contained less litter. This means that they contained more top soil and less organic matter.

My CHN analysis showed that there was some nitrogen present in the soils. Pure peat generally contains few nutrients and when present, they are extremely low. (Laderman 1998) Despite this fact, all of the samples contained nitrogen. This indicates an outside source of nitrogen into this ecosystem. Some important sources of nitrogen are surface-water and groundwater inflow and atmospheric deposition. (Golet 1993) This also could be leaf litter, but anthropogenic sources may also add to this available nitrogen.

Future Recommendations

Since these ecosystems are typically nitrogen poor, leaching with DI water is probably not the best method for assessing nitrogen. Instead, I would recommend digging multiple soil cores, bagging them, and then leave them in the field for the incubation. Then the researcher would collect these bags at different times during the experiment and perform a KCl extraction for nitrogen. This method removes all of the nitrogen in the soil at once. This would give you actual soil concentrations in which one could attain rates from.

I would also recommend that future investigations focus on the carbon aspects of the ecosystems instead of the nitrogen aspects. These systems are extremely rich in carbon and extremely poor in nitrogen. Therefore, it is challenging to assess nitrogen levels and fluctuations because it is difficult to attain enough nitrogen in a given sample. A method to consider for adding more to the carbon assessment of this experiment is a sequential extraction of carbon (Ricca and Neill 1992).

Respiration measurements should also be studied in greater detail. I intended to assess respiration rates throughout the experiment. This would allow me to investigate the changes that the ongoing treatment caused. Unfortunately, due to an instrument error, the data collected from my first two sessions was not usable. Therefore all of my respiration figures are based on one time slot and therefore may not be representative of the respiration over the course of the whole experiment (Figure 12). If future investigators choose to focus on the carbon cycle, it is critical to better understand the respiration of the microbial communities in order to construct a more complete image of the carbon cycle.

Acknowledgements

This research would not be possible without the help of many people. I would like to thank my advisors who guided me through all of my tasks. Dr. Aimlee Laderman's help early on in the project helped me set the course that I wanted to take. She showed me around to many potential cedar and maple swamp sites and gave me access to the swamps off of Blacksmith Shop Road. In addition, during the course of the research she made sure that I stayed on track with my goals and that I did not omit important and interesting information. Dr. Gaius Shaver helped me to design my experiment and understand my data. He also helped me to narrow down my scientific question and to select the correct lab analyses in order to attain my carbon and nitrogen data. His suggestions helped me assemble useful charts and graphs that allowed me to use my data to their fullest. My collaborators helped me in my lab work and offered advice for how to best use my time. Ellen Herbert also was of great help out in the field the day that I collected my samples. (Ellen can be seen in the first picture in Figure 12.) The TAs, Allison Burce, Clara Funk, Rich McHorney, and Laura Wittman, gave me all the information I needed for running the lab instruments and they were of great help when I desperately needed trouble shooting on some of those tougher days. And finally, I would like to thank Mark Patton, the Director of the Falmouth Department of Natural Resources, for taking the time to show me and the MBL group around in the forests off of Blacksmith Shop Road. Due to him, I was able to select my sites and plan my sampling.

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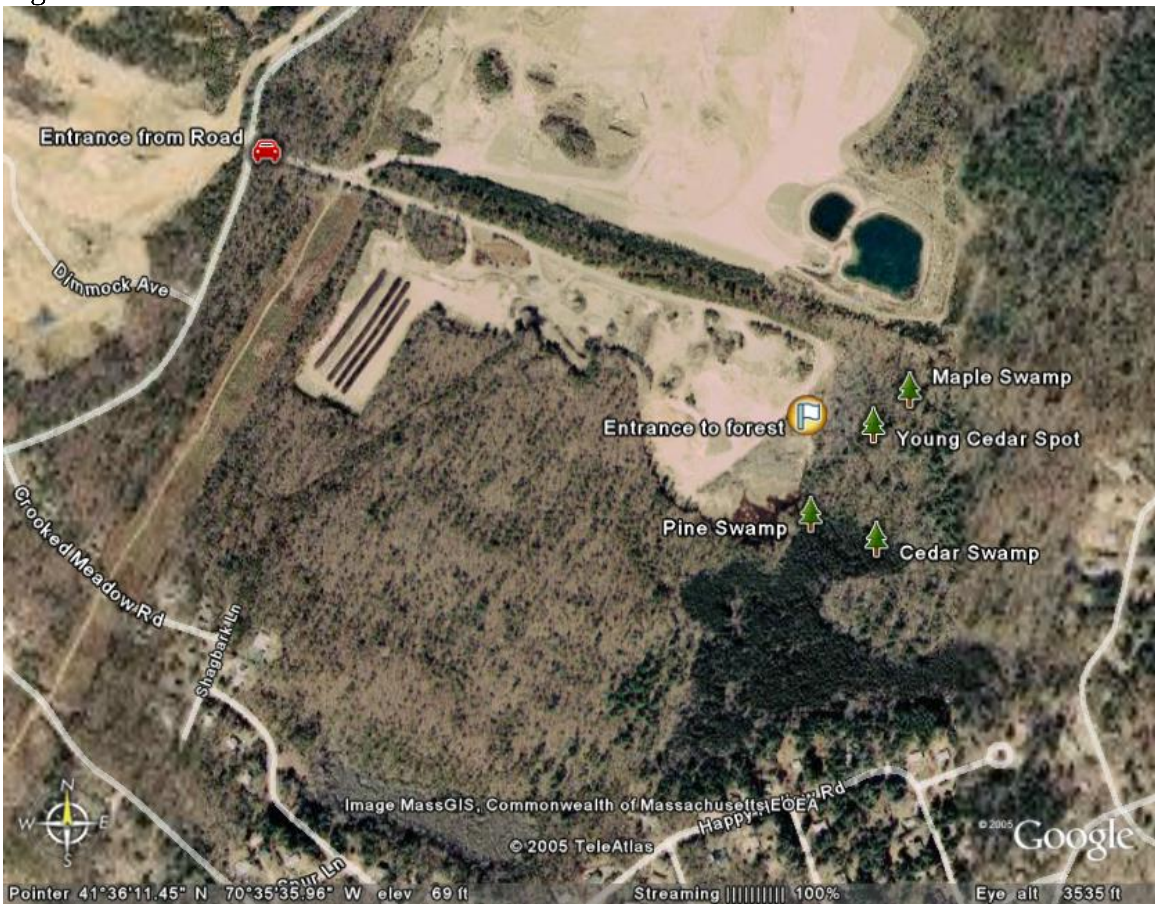
Figures

Figure 1



Overview of the Nature Preserve off of Blacksmith Shop Road Site locations and other spots of significance are marked on this map generated on Google Earth.

Figure 2

Cedar Site Pictures taken at my cedar site.

Figure 3

Maple Site Pictures taken at my maple site.

Figure 4

Pine Site Pictures taken at my pine site.

Figure 5

Young Cedar Site Pictures taken at my young cedar site.

Figure 6

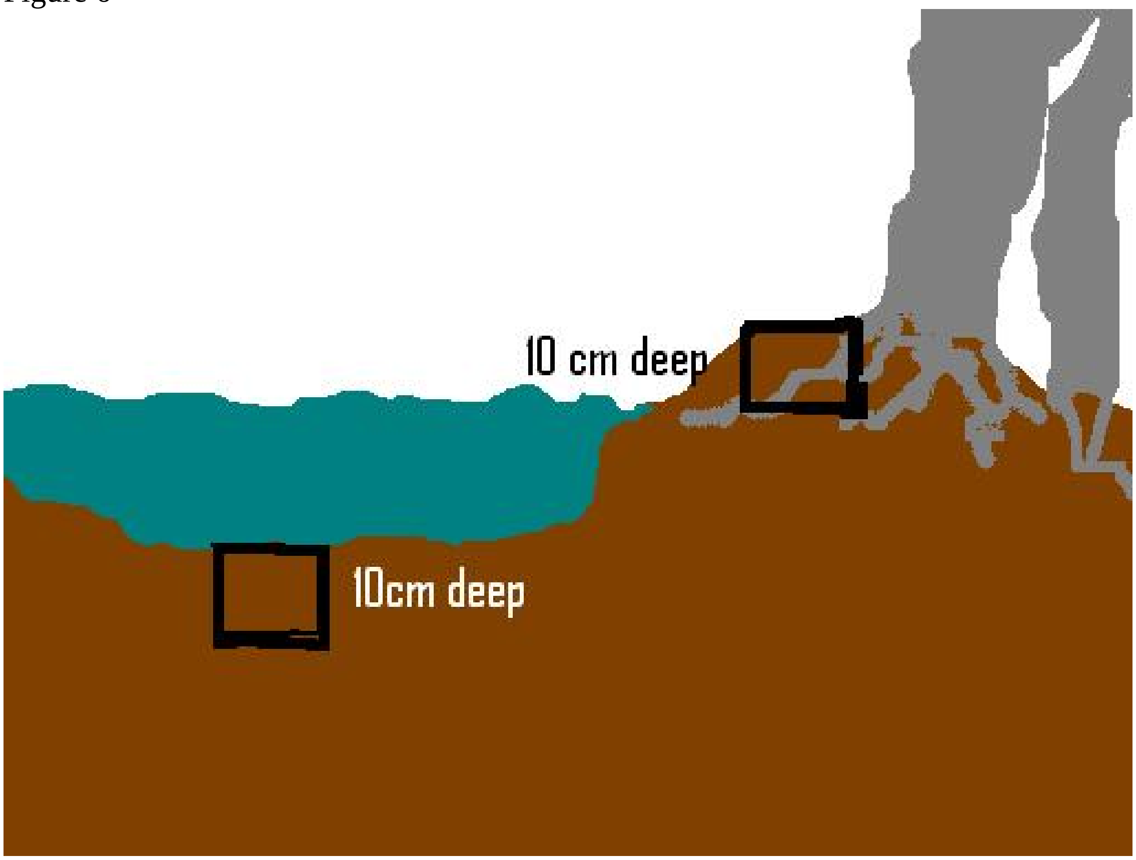


Illustration of Sample Locations within Each Site I took my soil samples from four locations within each site: two from hollow depressions (left) and two from hemic mounds (right). Each sample was a randomly selected spot in which I withdrew a fifteen by fifteen centimeters square that was ten centimeters deep.

Figure 7

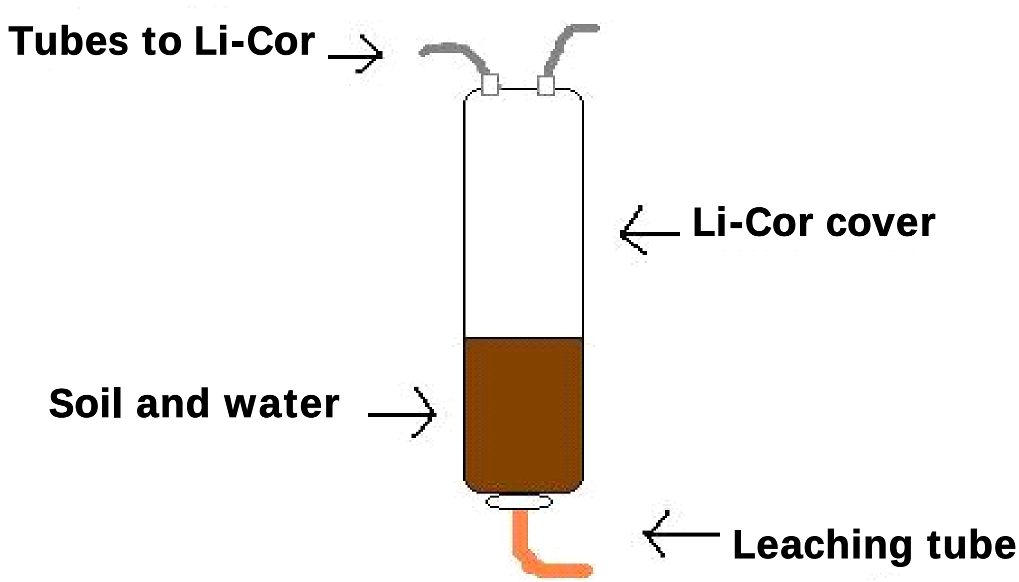
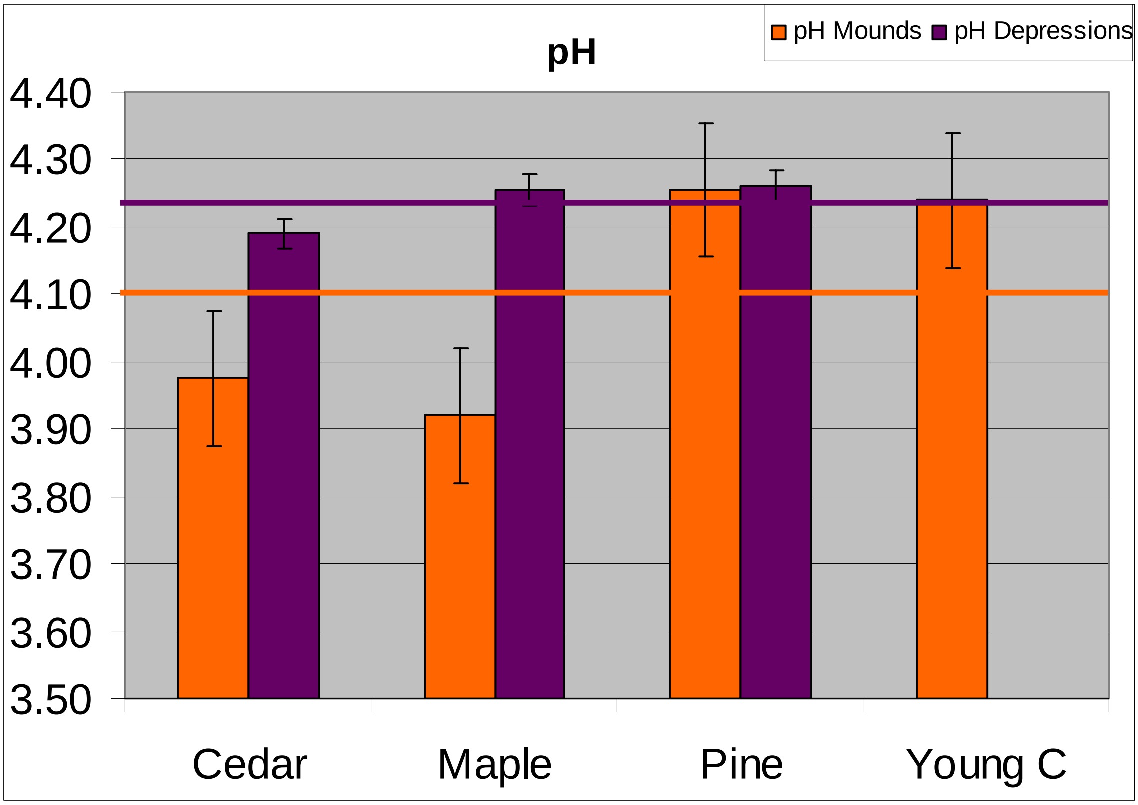


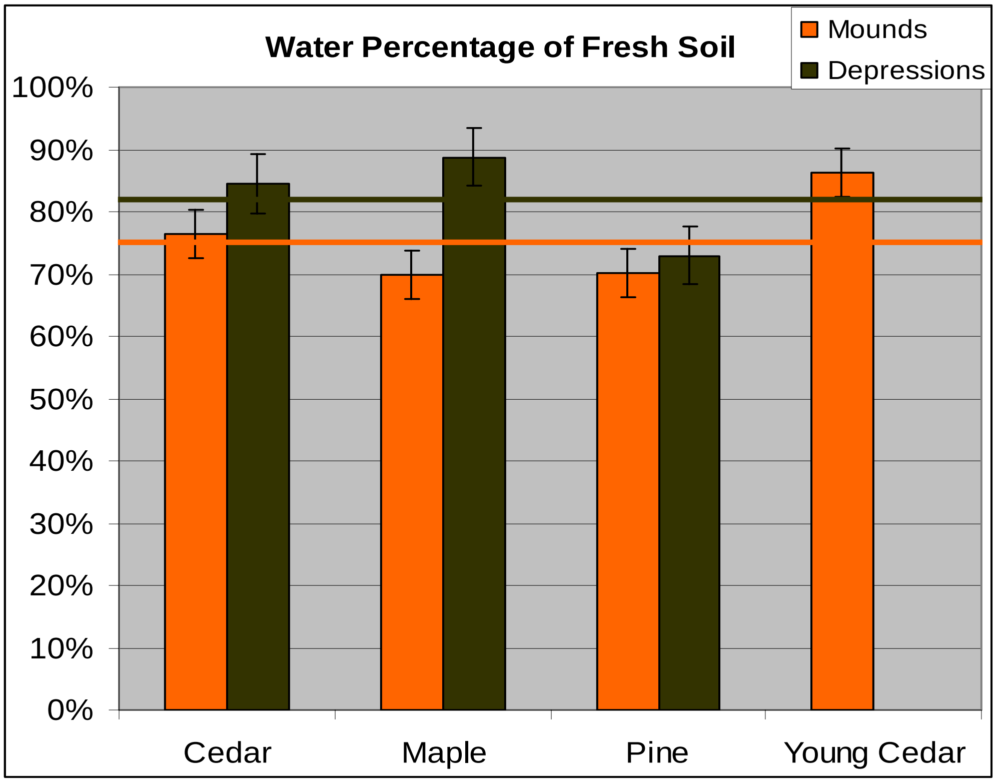
Illustration of a Core The cores used in the experiment were set up as shown here. The tubes at the top were used for the purpose of connecting the cover to the Li-Cor 6200 in order to take respiration measurements. It was critical to have the all tubing and the cover air-tight. The leaching tube at the bottom was used to drain the water with a syringe.

Figure 8



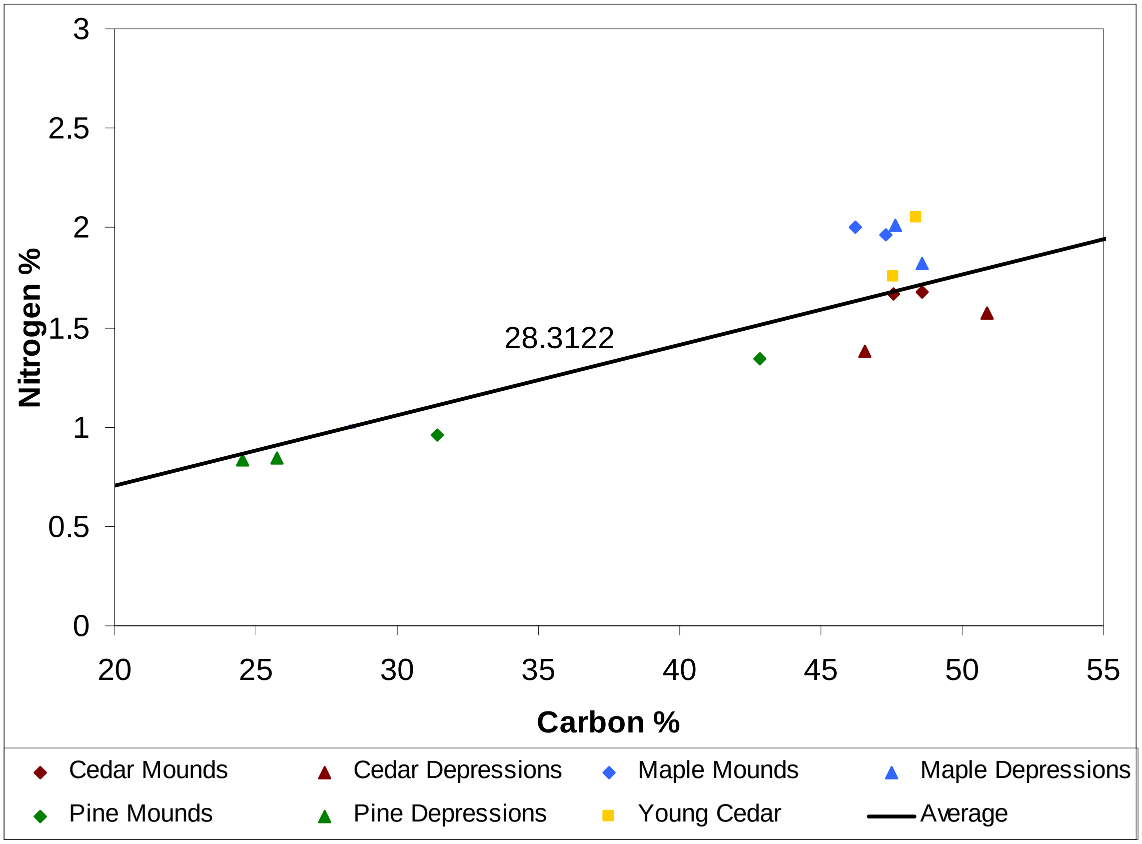
pH of Soil Samples Bars indicate average for the mounds and depressions within each site. Lines indicate averages for all mounds (4.10) and depressions (4.24) that were used in the study.

Figure 9



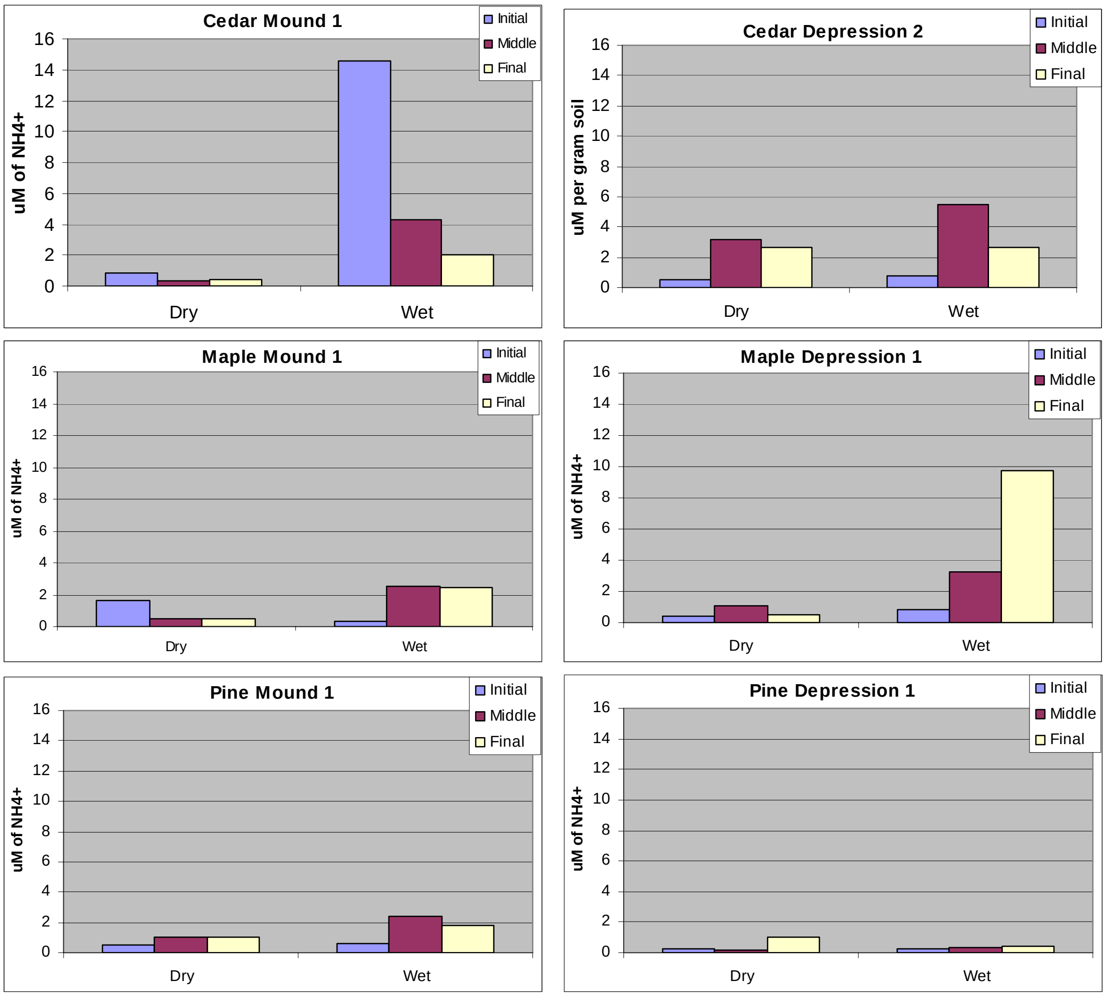
Water Percentages of Fresh Soil Samples All of the samples had percentages over 55% with an overall average of 87%. Generally the depressions had the higher percentages with an average of 82% while the mounds had an average of 76%.

Figure 10



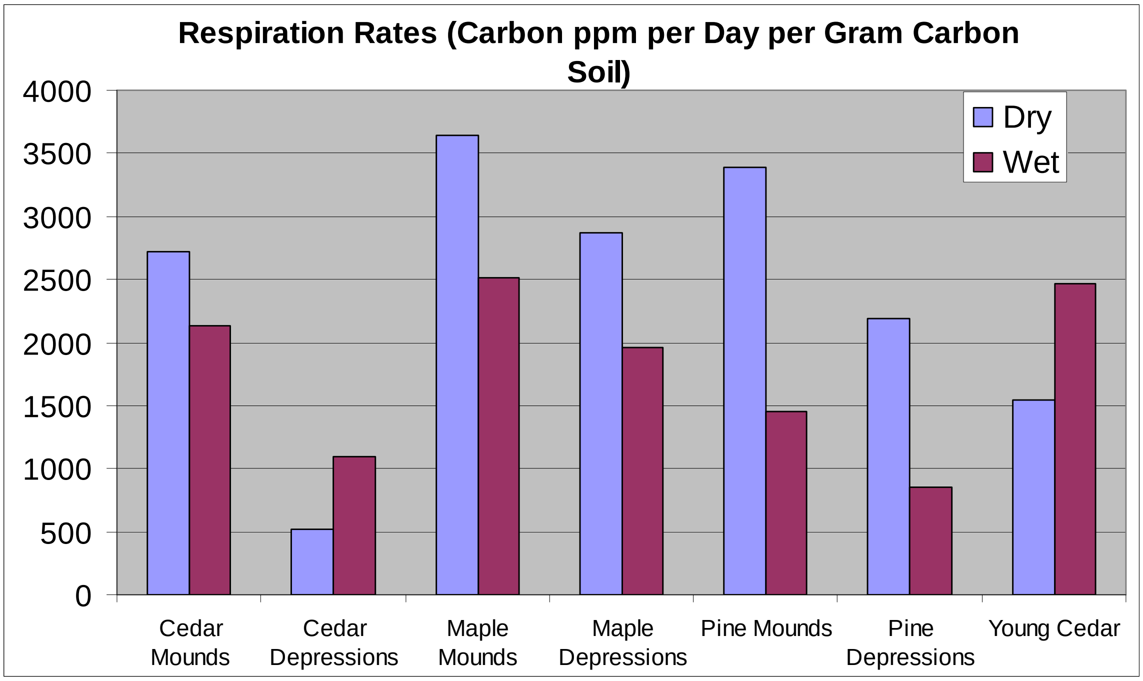
Carbon to Nitrogen Percentages This graph runs carbon percentages on the x-axis and nitrogen percentages on the y-axis in order to assess carbon to nitrogen percentages and grouping within each ecosystem. The black line indicates the data's average of 28.3122. While the carbon and nitrogen percentages differ, the C:N ratios are all close to the data's average.

Figure 11



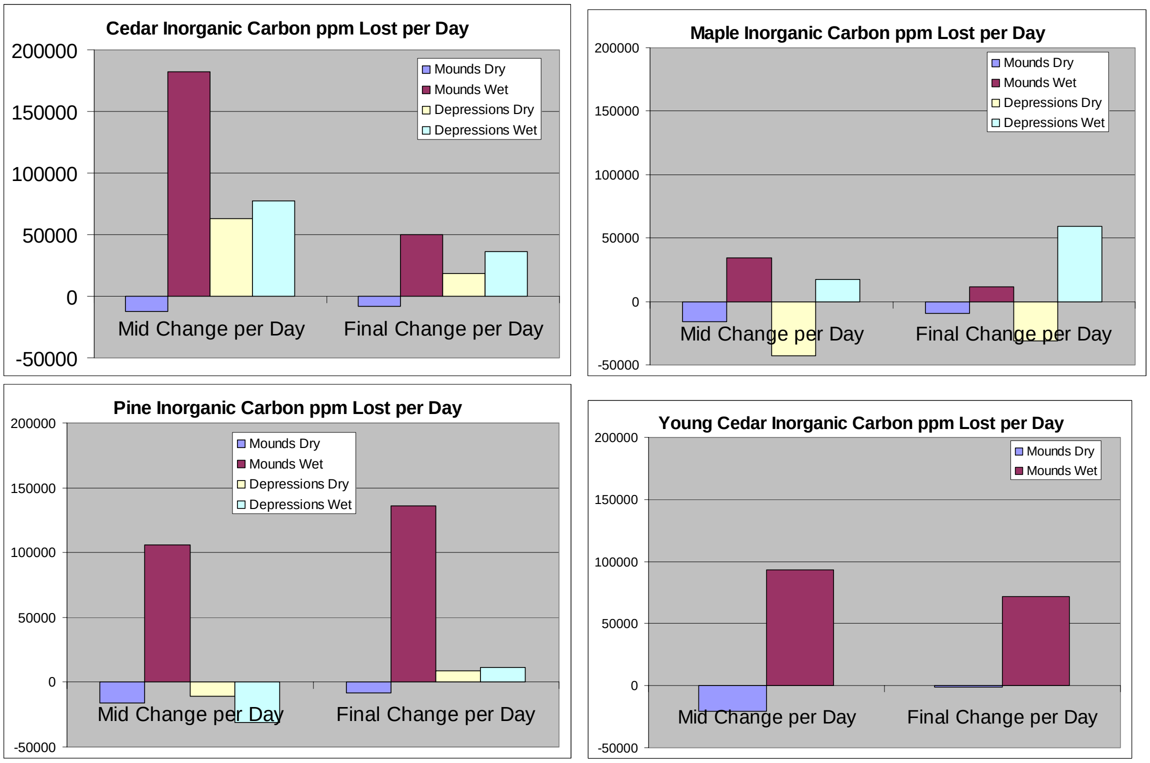
NH_4^+ Graphs for Samples NH_4^+Leaching loss rates for selected soil cores.

Figure 12



Respiration Rates Respiration rates of each core. Units are carbon ppm per day adjusted by gram carbon in the soil.

Figure 13



Dissolved Inorganic Carbon in Leachates Amounts are in µM per day per unit carbon in soil cores.

Tables

Table 1

Dates of Leachings				
			Days pasted since start	
Time 0:	November 16th		0	
Time 1:	November 30th		14	
Time 2:	December 7th		21	

Experiment's Time Sheet Above are the time listed with their respective dates.

Table 2

Sample ID	Concentration of NO_3^-	Sample ID	Concentration of NO_3^-
C D2 Dry Fin	1.791003499	P M1 Wet In	1.791006187
C D2 Wet In	1.791004211	P M1 Wet Mid	1.791006214
C D2 Wet Mid	1.791005633	P M1 Wet Fin	1.791004261
C D2 Wet Fin	1.791004069	P M2 Dry In	1.791005989
M M1 Dry In	1.791004441	P M2 Dry Mid	1.791003369
M M1 Dry Mid	1.791003104	P M2 Dry Fin	1.791002363
M M1 Dry Fin	1.791003258	P M2 Wet In	1.791020888
M M1 Wet In	1.791003444	P M2 Wet Mid	1.791006715
M M1 Wet Mid	1.791012168	P M2 Wet Fin	1.791003552
M M1 Wet Fin	1.791006877	P D1 Dry In	1.791003698
M M2 Dry In	1.79100369	P D1 Dry Mid	1.791003281
M M2 Dry Mid	1.79100409	P D1 Dry Fin	1.791007626
M M2 Dry Fin	1.791003992	P D1 Wet In	1.791004255
M M2 Wet In	1.791003692	P D1 Wet Mid	1.791011069
M M2 Wet Mid	1.791012659	P D1 Wet Fin	1.791003216
M M2 Wet Fin	1.791009721	P D2 Dry In	1.791004866
M D1 Dry In	1.791003838	P D2 Dry Mid	1.791002927
M D1 Dry Mid	1.791002874	P D2 Dry Fin	1.791002646
M D1 Dry Fin	1.791002901	P D2 Wet In	1.791007959
M D1 Wet In	1.791007116	P D2 Wet Fin	3.582007292
M D1 Wet Mid	1.791002461	YC 1 Dry In	1.791006801
M D1 Wet Fin	1.791004443	YC 1 Dry Mid	1.791003379
M D2 Dry In	1.791003844	YC 1 Dry Fin	1.791003024
M D2 Dry Mid	1.79100236	YC 1 Wet In	1.791004953
M D2 Dry Fin	1.791002566	YC 1 Wet Mid	1.791002516
M D2 Wet In	1.791004333	YC 1 Wet Fin	1.791003719
M D2 Wet Mid	1.791004348	YC 2 Dry In	1.791002902
M D2 Wet Fin	1.791003163	YC 2 Dry Mid	1.791002743
P M1 Dry In	1.791113282	YC 2 Dry Fin	1.79100361
P M1 Dry Mid	1.791001428	YC 2 Wet In	1.791005054
P M1 Dry Fin	1.791002743	YC 2 Wet Fin	1.791005898

Raw NO_3^- Data for my Leachates Due to the trace amounts of nitrogen present in these samples, the concentration readings were small and did not show differences that could be statistically distinguished from static within the instrument. All values shown are in µM of NO_3^- and are not adjusted to mass carbon per soil core.

Table 3

Sample Name	Result/Peak Area		Sample Name	Result/Peak Area
C M1 Dry In	7.239929		M D2 Dry In	18.015633
C M1 Dry Mid	5.675933		M D2 Dry Mid	6.794294
C M1 Dry Fin	6.528399		M D2 Dry Fin	3.724567
C M1 Wet In	5.723868		M D2 Wet In	19.014235
C M1 Wet Mid	22.720543		M D2 Wet Mid	16.799881
C M1 Wet Fin	15.042337		M D2 Wet Fin	9.736564
C M2 Dry In	5.967615		P M1 Dry In	46.205311
C M2 Dry Mid	5.02026		P M1 Dry Mid	5.454617
C M2 Dry Fin	5.036134		P M1 Dry Fin	3.728659
C M2 Wet In	9.400642		P M1 Wet In	5.801906
C M2 Wet Mid	32.018555		P M1 Wet Fin	18.56864
C D1 Dry In	20.811922		P M2 Dry In	6.883414
C D1 Dry Mid	8.874821		P M2 Dry Mid	8.919703
C D1 Dry Fin	4.53289		P M2 Dry Fin	6.076697
C D2 Dry In	12.03941		P M2 Wet In	5.931563
C D2 Dry Mid	9.371995		P M2 Wet Fin	13.049946
C D2 Dry Fin	9.301417		P D1 Dry In	15.158954
C D2 Wet In	10.028541		P D1 Dry Mid	6.235943
C D2 Wet Mid	21.085295		P D1 Dry Fin	17.893398
C D2 Wet Fin	13.421184		P D1 Wet In	14.150679
M M1 Dry In	9.583601		P D1 Wet Fin	11.924286
M M1 Dry Mid	6.514877		P D2 Dry In	14.884914
M M1 Dry Fin	5.32272		P D2 Dry Mid	6.778773
M M1 Wet In	7.491403		P D2 Dry Fin	3.360968
M M1 Dry Mid	3.790459		P D2 Wet In	13.107645
M M1 Wet Mid	24.023977		P D2 Wet Fin	18.103584
M M1 Wet Fin	17.215141		YC 1 Dry In	17.087318
M M2 Dry In	9.905155		YC 1 Dry Mid	4.82216
M M2 Dry Fin	8.1282		YC 1 Dry Fin	3.876522
M M2 Wet In	10.071725		YC 1 Wet In	7.709509
M M2 Wet Mid	38.051754		YC 1 Wet Mid	12.73804
M M2 Wet Fin	42.845512		YC 1 Wet Fin	8.405556
M D1 Dry In	11.008032		YC 2 Dry In	10.315687
M D1 Dry Mid	7.417738		YC 2 Dry Mid	7.817226
M D1 Dry Fin	6.207206		YC 2 Dry Fin	9.516868
M D1 Wet Mid	11.616961		YC 2 Wet In	15.047213
M D1 Wet Fin	26.232077		YC 2 Wet Fin	14.787975

Total Dissolved Nitrogen Data This chart is the output from the Latchet in uM. Output is not adjusted to mass carbon per soil core

Table 3

Sample	Reading	Conc uM	
CM1DryIn	42875738	1673.3215	dillute
CM1DryIn	43360484	1692.7114	dillute
CM1DryMid	14359289	532.66356	
CM1DryMid	13800090	510.2956	
CM1DryFin	25009998	958.69192	dillute
CM1DryFin	24403524	934.43296	dillute
CM1WetIn	46059762	1800.6825	dillute
CM1WetIn	46609000	1822.652	dillute
CM1WetMid	273992352	10917.986	dillute
CM1WetMid	242816528	9670.9531	dillute
CM1WetFin	201385328	8013.7051	dillute
CM1WetFin	191258160	7608.6184	dillute
CM2DryIn	power flash	lost data	
CM2DryIn	power flash	lost data	
CM2DryIn	68965712	2716.9205	ignore
CM2DryIn	64240660	2527.9184	ignore
640 uM stanc	18573290	701.2236	standard
640 uM stanc	17977026	677.37304	standard
640 uM stanc	15900613	594.31652	standard
640 uM stanc	15313302	570.82408	standard
CM2DryIn	50128940	1963.4496	
CM2DryIn	malfunction		

Analyzed DOC Data I collected this data from the DOC instrument before it went out of order. While this data is incomplete and most of the numbers are beyond the scopes of the instrument, this data does show that the leachates were carbon rich and that further investigation in this area has the potential to show interesting results.