Looking at the Lake's Edge of UNDERC: Varying Soil Moisture and Organic Material in Hemlock and Sugar Maple Forest

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Shirley LeClair-Bernal

Advisor: Kelly Heilman

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Abstract

Soil moisture and organic material are essential to the ecosystem of a forest. Both are the bloodline of soil, where organic matter contains decomposing carbon and nutrients that are needed for continual forest growth and carbon storage. oil moisture represents water available to plant life and also can influence decomposition of organic matter. The content of both soil moisture and organic matter can both be affected by the surrounding forest community and alter the community of a forest.Because anthropogenic changes such as continual of increasing temperatures and decreasing rainfall can alter forest composition and soil processes, the future of these forests soils are unsettled. Edges of a forest define the habitat of the community, which could hold differences in content of organic matter and soil moisture. The purpose of my research is to explore how forest edges and species composition affect soil moisture and organic matter. Specifically, I explore whether there are differences in soil moisture and organic matter from the lake-forest edge to the interior of the forest between the two species that dominate Northwoods Forests: Hemlock, *Tsuga canadensis* (L.) Carr. and Sugar Maple, *Acer saccharum* Marsh. at the property of UNDERC in Michigan. Soil samples were taken from both exterior (closest to the lake) and interior, (at the forest's center) for measurements. The data found indicates that *T. canadensis* is a high ranking species over *Acer saccharum* in both soil moisture content and organic matter more so on the exterior edge of the forest. Further research may be essential at UNDERC on soils in the future, measurement of temperatures in the soils as well as a collection of pH data are necessary.

Introduction

The forest's edge is the entrance to what lies within a forest habitat. Forest edges created by fragmentation make up 23% of the North American landscape (Smith *et. al.* 2018), and evidence indicates that edges function very differently from interior of the forests. At the edge, life is exposed with the competition of non-native species from the host of neighboring forest or non-forest. Different environmental challenges come to life at the edge in the act of extreme currents of wind damages, including an excessive amount of light availability. The magnitude of these differences - and even whether productivity is enhanced or diminished as a function of proximity to an edge (Smith *et. al.*). As you move from the edge to the interior there are changes in microclimate (Young and Mitchell 1994; Davies-Colley *et al.* 2000; Gehlhausen *et al.* 2000); biogeochemistry and resource availability (Weathers *et al.* 2001; Pohlman *et al.* 2009; Remy *et al.* 2016); and forest productivity and structure (Chen *et al.* 1992; Laurance *et al.* 2011; Reinmann and Hutyra 2017).

Furthermore, prominant edge effects can impact carbon storage and cycling within the forest ecosystem. Organic matter at the edge is often higher rather than interior, due to the advantage of more availability of light. However, Reinmann and Hutyra (2017) stated that biomass densities in a temperate broadleaf forest were 64% higher near the forest edge than the forest interior, which scales to a 10% increase in regional estimates of biomass southern New England in the US. When looking in a temperate coniferous forest, biomass density was 31% higher near the edge relative to the interior (Bowering *et al.* 2006). These icreases in biomass with proximity to the edge could be attained (1) through faster-growing individual trees at the edge or (2) through higher density of trees at the edge, with the growth rates of each tree equal to the growth rates of trees within the forest interior (Smith *et al.* 2018). Forest biomass is in increasing demand for energy production, and organic matter has been considered as a potential supply (Wei 2012). Organic matter can assist soil to hold more water, thus, making it relevant to study organic matter at the edge.

Soil moisture, and carbon are important parameters of a forest. Soil respiration rates are sensitive to changes in both soil moisture and temperature (Davidson *et al.* 1998), as well as spatial gradients in soil respiration are likely. Soil moisture can influence a number of soil physic-chemical properties, such as redox potential, pH, O2 and CO2 levels (Barros *et al.,* 1995) and the concentrations of mineral nutrients in soil solutions (Misra and Tyler, 1999), which in turn influences biomass activity. Increasing soil moisture might increase tree growth and decrease in carbon storage in the soil may decrease tree growth.

Indirect edge effect might be differential fire vulnerability, combined with direct impacts on soil moisture and organic matter. Forest edges have the ability to affect vulnerability to fire by enhancing flammability through desiccation of fuels and greater exposure to potential human ignition sources (Cochrane and Laurance 2002; Laurance and Curran 2008). After carbon dioxide is converted into organic matter by photosynthesis, carbon is stored in forests for a period of time in a variety of forms before it is ultimately returned to the atmosphere through respiration and decomposition or disturbance (U.S. EPA, 2015). A substantial pool of carbon is stored in woody biomass (roots, trunks, and branches). Another portion eventually ends up as organic matter in forest floor litter and in soils. The amount of organic matter stored in a forest is important for several reasons. A net change in forest biomass can indicate whether forest ecosystems are stable, growing, or declining U.S. EPA, 2015). Returning nutrients to the soil, maintaining forest productivity and creating habitats in forest ecosystems.

Though numerous studies explore forest productivity and ecosystem processes affecting carbon storage, important work remains to understand how edge effects impact forest function. Specifically, to understand how forests function, ecologists typically study intact forests, but most of the region forests are within a short distance of a forest edge. This represents an important gap in our understanding and modeling of the terrestrial carbon cycle and its response to disturbance, climate, land-use or land-cover changes, and land management policies (Schmidt *et al.* 2017). To study the forest edge at UNDERC is beneficial because *A. sacchrum* (which now makes up a large portion of Northwoods forests) and *T. suga* ("Old growth" species that historically dominated the Upper Midwest). Land use history at UNDERC is also a characteristic of the region as a whole, where logging was extreme showing species more adequate in varying locations across the property. The data from the area will increase understanding of these forests.

In the study, we ask: Is there higher soil moisture and organic matter at the lake forest-forest edge or more in the interior? Is the amount of soil organic matter related to forest composition? Finally, when comparing the species *Tsuga canadensis* and *Acer saccharum*, if there is a difference in soil moisture and organic matter that is correlated with forest type? We are exploring differences in soil moisture and organic matter from the lake-forest edge to the interior of the forest between the two species that dominate Northwoods Forests: Hemlock, *Tsuga canadensis* (L.) Carr. and Sugar Maple, *Acer saccharum* Marsh. at the property of UNDERC in Michigan.

Materials and Methods

Located in the Upper Peninsula of Michigan, near Land O' Lakes, Wisconsin, research was conducted on the grounds of the University of Notre Dame Environmental Research Center (UNDERC). The lakes chosen on the property were Crampton, Plum, Roach, and Bay Lake. Each lake was used as the exterior edge for each forest. *T. canadensis* and *A. saccharum* dominated forests were chosen for this study because they are both dominant Northwood species that have both different functional properties and face different challenges with impending climate changes. The layers of feathery branches also effectively intercept incoming rain and snow, leading much of it to evaporate back into the atmosphere and greatly reducing the moisture that reaches the ground (Baiser *et al.* 2014). *A. saccharum* could be arguably the most ecologically and economically important species in the northern hardwood forests of eastern North America. Ecologically, *A. saccharum* provides nutrient-rich litter to forest soils (Long *et al.* 2009, Lucash *et al.* 2012). Economically, the tree provides the raw materials for a profitable maple syrup industry, provides durable hardwood for furniture and flooring, and offers aesthetically pleasing fall foliage (Millers *et al.* 1989).

My study design included a selection of 2 sites per species of *T. canadensis* and *A. saccharum*. A 10 m radius was measured for both at the exterior and interior. From the lake forest edge plot a second plot was place into the center of the forest, (150 ft or so). Measurements of soil moisture and carbon content in the soil will be extracted from the samples of soil. Since intact hemlock forests are both rare difficult to find on UNDERC property, we were limited to randomly sampling multiple soil cores within the same overall forest. We would want to sample multiple hemlock forests across a wider area to prevent pseudo-replication, but are limited by hemlock site availability. Therefore, we focus on making inferences on two of the hemlock plots that we do have. We measured soil moisture and organic matter at different locations (the edge and interior) of forests of different composition (both *T. canadensis* and *A. saccharum* forests). To determine if soil moisture and organic matter vary across location and compositions, and whether there is an interaction between the two, we perform a Two-Way ANOVA.

To quantify soil moisture and organic matter, all 8 samples in each plot were sieved before measuring out 5 grams from each sample and weighed on an open top-loading balance then placed into the oven to be dried. At the end of each 24 hour limit in the oven and 3 hours in the muffler furnace for ashing the samples were weighed, from which data was calculated. The following equations were used to calculate the percentages. Soil Moisture Content - is measured by how much mass a soil sample loses when it is oven-dried:

$$\% \text{ moisture} = ((\text{wet weight} - \text{dry weight})/(\text{wet weight})) * 100$$

Organic Matter Content - is measured by ashing the soil sample at 550°C for three hours:

$$\% \text{ organic content} = ((\text{dry weight} - \text{ashed weight})/(\text{dry weight})) * 100$$

The Two-Way ANOVA test was run using RStudio, my variance showed no similarity, along with non-normality. Logically, I removed the known outliers which contained sand samples from each of the plots that had any known outlier samples. Even having removed the outliers my variance still showed no similarity. My sample number reaching to 60 leads me to allow my statistical data to be relevant according to the Essential Limit Theorem.

Results

The data supports my hypothesis, there was a significant difference in soil moisture and organic matter between the two species *Tsuga canadensis* and *Acer saccharum*.

Soil Moisture

We have found 11% more soil moisture in *Tsuga canadensis* than *Acer saccharum* species (F value=14.37, p=0.000370). There is a significant effect in the location where there is 14% more soil moisture at the exterior than the interior (F value=31.17, p=7.16e-07). Importantly, there is also an interaction between the two factors of composition and location (F value=0.000501, p=0.000581), where the effect of the location depends on the species. The exterior, near the lake, *Tsuga canadensis* holds greater soil moisture. Whereas, the interior, *Acer saccharum* holds greater soil moisture.

Organic Matter

We found a significant difference in location (F value=14.27, p=0.000386) where 58% more organic matter at the exterior. Including species (F value=12.63, p=0.000780) where *T. canadensis* holds more organic matter. As well as the interaction between the two (F value=12.43, p=0.000852). *Tsuga canadensis* dominates over *Acer saccharum* in amount of organic matter in both exterior and interior locations. However, the size of the differences in OM between species depends on location: Tsuga OM is XX% greater than Acer at XX location, but only YY% greater than Acer at YY location..

Discussion

The final results support the hypothesis that soil moisture and organic matter vary between the lake-edge and the interior of the forest and depend on *T. canadensis* and *A. saccharum* species. Due to having increasing percentages at the lake forest edge, the differences can lead to the probable cause that *A. saccharum* species have greater population numbers than the Northeastern *T. canadensis*. The findings are consistent previous literature where soil biomass was greater at the edge plots than the forest or gap plots (Scharenbroch 2007). Significant difference has shown *T. canadensis* holds more soil moisture at the exterior of the forest than *A. saccharum,* this could lead to opening research of how either of the two species can survive in different locations of lakes.

A reason for these results is possibly caused from the texture and structure of the soil found at the edge of these lakes. At Roach Lake on the interior of the *A. saccharum* we found the loamy soil, which does very well at holding high amounts of water. Whereas, the *T. canadensis* at the exterior, we found more clay soils versus the interior at the location of Plum Lake. *T. canadensis* leaves are flat and bendable. This flexibility reduces breakage and lends a soft feel to the foliage (Baiser *et al.* 2014). Out of my chosen forest species, the deep and spongy forest floor results from the progressive accumulation of a thick layer of needles that can be more than a foot deep and hundreds to thousands of years old. This accumulation of needles effect both the organic matter and soil moisture at the forest floor. In our forests of oak, birch, or maple, only a thin layer of the previous year's leaves persist (Baiser *et al.* 2014)

Further research can be made not only on temperature and pH, but focusing on location of the two species surrounding the lakes. Considering the large number of lakes at at UNDERC, and the large impacts solar aspect can have on soil moisture at high latitudes , it might be useful to explore different types of lake edges. Finding differences between the north side of the lake versus the south side of the lake, rather than using samples from one end of a designated lake. Surrounding lakes may be in effect because more clay soil is found at the edge, inclination of more soil moisture in certain areas.

Ultimately the study of lake edges brings the possible outcomes of being a key source to a healthy forest, surrounding lakes can find more soil moisture. A species with a lake as its' edge may in fact improve the quality of the forest as a whole. High soil moisture and organic content of forests could be a byproduct of the high number of lakes here. The lakes were here first and created mostly by glacial movement. These lakes bring hold the future historical answers of environmental research scientists wish to seek for.

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Figures

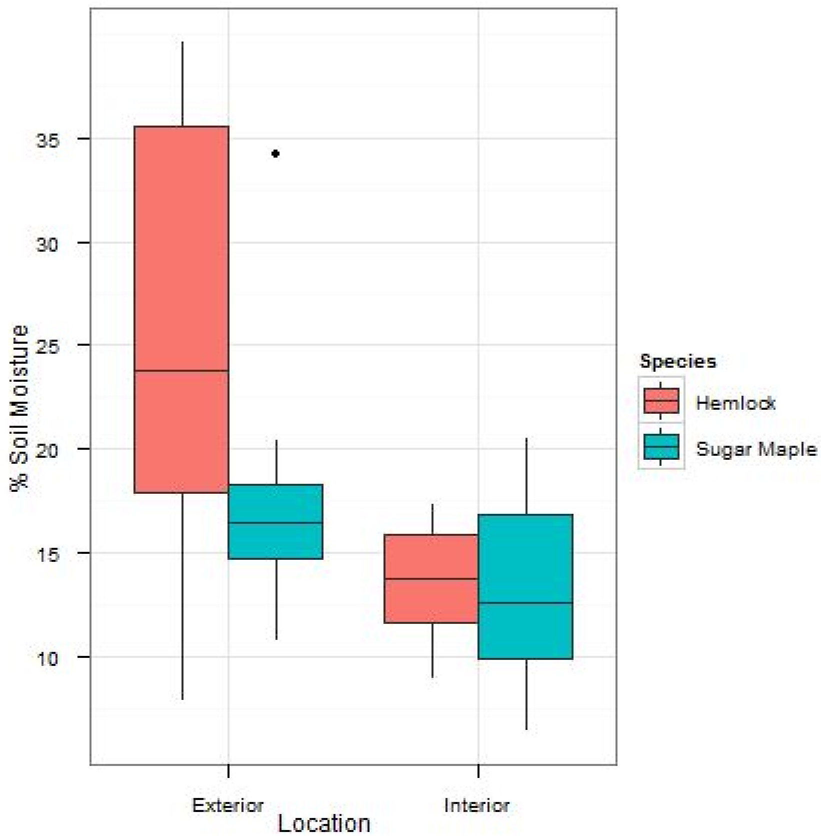

Figure 1: Soil Moisture. Differences in species and location. An ANOVA test showing differences in both *T. canadensis* and *A. saccharum* displaying the interactions between the two. The effects of the locations depends on the species, presenting the values: F value = 000501 and p = 000581.

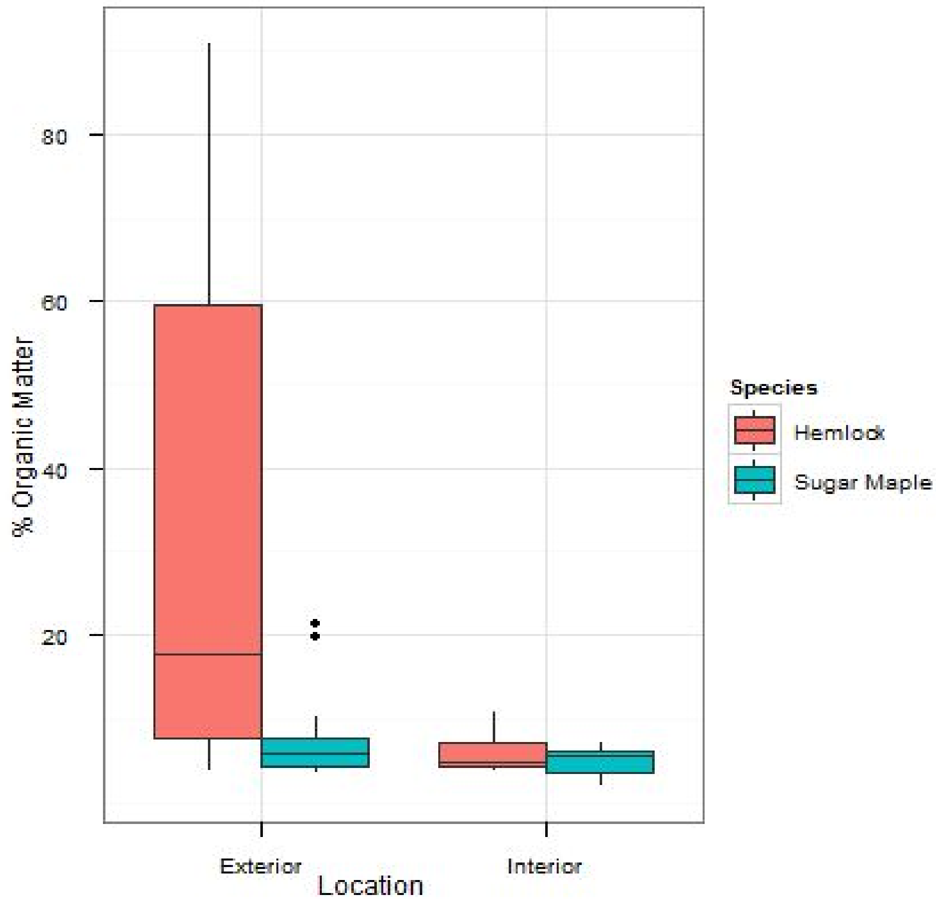

Figure 2: Organic Matter. Differences in species and location. An ANOVA presenting Organic matter differences, *T. canadensis* contains greater percentages than *A. saccharum* at both the exterior and interior.

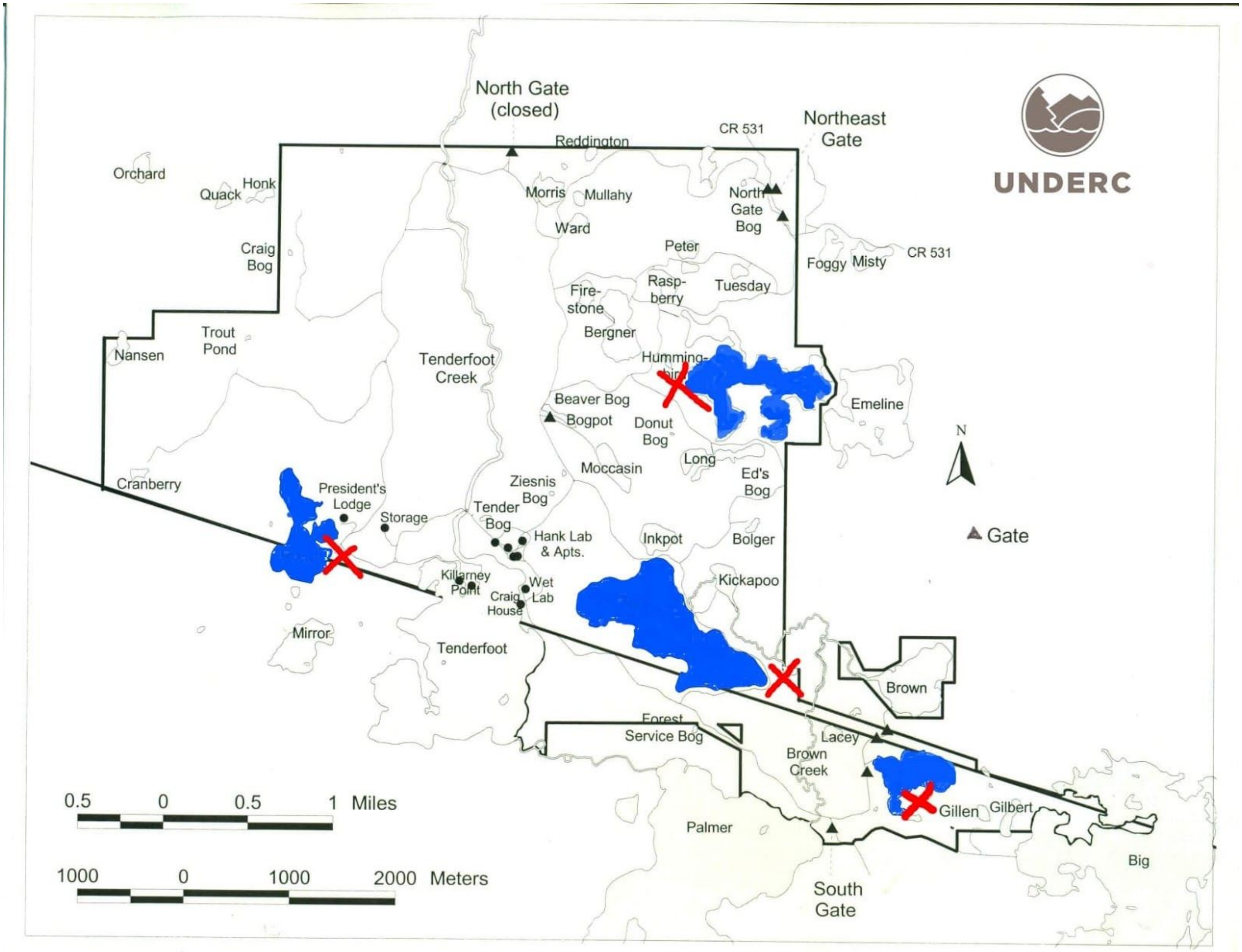

Figure 3: Property Map. Locations marked with X's are sites. Within each site there are 2 plots, one located at the exterior (closest to the lake) and interior (further away from the lake).

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