An Examination of Post-Glacial Landforms and the Subsequent Variation in Floral Communities at Two Sites in Northern Michigan

Neale Batra, Aly Baumgartner, and Sam Mosier

University of Michigan Biological Station

EEB 381 General Ecology

May-June 2010

Professor: Joel Heinen

Abstract

Post-glacial topographic features are an integral part of northern Michigan geography. This study utilizes two predominantly aspen forest sites of roughly equivalent age to examine differences between moraine and outwash plant communities. We found significantly higher tree diameter, species richness, soil moisture, and canopy coverage at the moraine site. Suspected reasons for this variation include the presence of underlying clay in the moraine which may cause the increased moisture content.

Introduction

During the Wisconsonian glacial episode, particularly the Tioga glacial maximum, ice up to five thousand meters high carved major features of North America including the Great Lakes, eastern seaboard, and much of the Mississippi watershed (Ives, 1978). This most recent glaciation peaked roughly 23,500 years ago, and concluded about 10,000 years ago (Nadelhoffer, 2010). The long-term effects of these glacial phenomena not only include geological formations, but their subsequent ecological communities as well.

Glacial lobes in the Midwest extended as far south as central Illinois and southern Indiana, and featured multiple retreats and advances. One product of these fluctuations and ultimate retreat is the presence of numerous moraines, outwash plains, and other glacial landforms. Moraines consist of ridges of unsorted glacial till scraped from the surface by glacial advances and deposited laterally, sub-glacially, or at the glacial terminus. Moraines typically have a base of loamy sand (soil containing a mixture of sand, silt, and clay) which grades upward into more pure sand and organic topsoil (Wilde, 1958). Comparatively, outwash plains are created by the deposition of sand and gravel sorted by glacial melt water (Nadelhoffer, 2010). Outwash plains typically contain relatively porous sand covered by organic matter (Benninghoff et al. 1962). The Pellston area features numerous north-south interlobal and lateral moraines interspersed with contrasting outwash plains.

The hardwood forests that covered these glacial landforms were subject to intense logging which peaked in 1896. When the University of Michigan first purchased its Pellston property much of the land was clear cut (Nadelhoffer, 2010). Severe fires burned across the area throughout the early 1900s, and the most recent fire occurred in 1918 (Benninghoff et al. 1962).

We decided to compare the differences in plant communities between a local outwash plain and interlobate moraine. We hypothesize that the additional clay content in the moraine soil will result in increased tree diameter, nutrient and moisture content, canopy coverage, and number of species. This clay should retain moisture, prevent loss of nutrients, and instigate significant differences between the two sites. Our examination of the plant communities of the two sites involves a variety of analyses and tests in order to better understand the ecological interactions at the sites.

Materials and Methods

Our intent was to compare these two glacial land formations in a multitude of characteristics. We made a series of visits to our two sites, located roughly 0.5 mile and 1.5 miles west of the entrance road of the University of Michigan Biological Station (Figure 1). Both sites were clear cut and burned at roughly the same time; this ecological marker serves as a baseline for the study.

We established four random 20x10m plots in each site. We used a soil auger to core five soil samples from each plot. From each core we extracted samples of the A layer, B layer, and the lowest point our soil auger could reach. These samples from each horizon were then bulked to create the final samples from each plot. After collection we weighed and dried the soil at room temperature for 24 hours before weighing the samples a second time to obtain total percent moisture. We then ground the samples and tested for total nitrogen, carbon, and bio-available phosphorous. These tests were run because nitrogen, carbon, and phosphorous are nutrients crucial to plant growth (Wilde, 1958).

At each plot we took a sample of duff and live aspen leaves. We placed an 8.5x11" notebook at the southwest corner of each plot and collected the duff underneath. The live leaf samples were taken from three random aspen trees on each plot and bulked to create one sample per site. We dried the duff and live leaf samples at 20 degrees Celsius. We then ground these samples and tested them for total nitrogen, phosphorous, and carbon.

To examine tree growth at the two sites we recorded the DBH (Diameter at Breast-Height) and species of every tree in each plot with a DBH greater than 10cm. We evaluated species richness between sites by surveying each plot for the number of distinct species present in the undergrowth. Additionally, we measured canopy coverage using a spherical densiometer. These measurements were taken from the center of each plot while facing east.

We ran Mann-Whitney tests to compare DBH of all trees and aspens at the two sites as well as percent soil moisture. We also ran t-tests to compare total nitrogen, carbon, and bio-available phosphorous in the soil and leaf samples, as well as canopy coverage and number of species present across sites. Additionally, to discover any site effect that may skew our data, we ran an ANOVA or Kruskal-Wallis test per site per variable.

<u>Results:</u>

We found statistically significant results for average percent canopy coverage, percent soil moisture, number of species, DBH for all sampled trees, and DBH for aspens specifically, but not for percent nutrient content in leaf and soil samples. Our first test looked at percent soil moisture across the two sites and found that the moraine site had an average percent soil moisture of 7.4%, while the outwash site only had an average of 0.89% (Figure 3, $p=0.001$).

Our analysis of mean percent canopy coverage found a significant difference in the amount of light available at each site (Figure 2, $p=0.002$). The moraine site had an average of 95.32% canopy coverage while the outwash site only had an average of 84.92%.

Our comparison of tree DBH at the two sites showed that the trees at the outwash site had an overall average DBH of 46.95cm, whereas the overall average at the moraine site was 67.13cm (Figure 4, $p=0.001$). A further comparison of the two sites revealed that specifically the outwash aspens averaged 19.68cm in DBH and those at the moraine averaged 51.74cm in DBH (Figure 5, $p<0.000$).

Statistical analysis revealed that the moraine site had significantly higher number of species than the outwash site (Figure 6, $p=0.001$). The moraine site had on average 15.75 distinct species, while the outwash site had an average of 8.50 species. Additionally, ANOVA and Kruskal-Wallis tests showed no significant site effect.

Our analysis of nutrient content in the respective soils and duff drew no statistically significant results (Figure 7). Despite these results, we did notice a slightly higher average percent phosphorous in the moraine soil samples (Figure 10). Due to limited sample size we were unable to run statistical tests on the live leaf samples; however, the available samples showed a higher percentage of nutrients in the moraine live leaves than in those from the outwash site. There was 0.07% more total phosphorous, 0.63% more total nitrogen, and 1.63% more total carbon in the moraine site live leaves than the outwash site live leaves (Figure 8).

Discussion:

We observed significant differences between the two floral communities of the moraine and outwash. We found results consistent with our hypothesis when comparing percent canopy coverage, overall and aspen DBH, number of species, and percent soil moisture.

The significantly higher soil moisture content observed at the moraine site could be a cause of the differences in floral communities. One possible explanation for the higher moisture content is the presence of clay in the C horizon of the moraine. This clay could decrease rainfall percolation rates and result in greater moisture availability (Tunstall, 2005), which is crucial to high levels of floral growth.

Although other studies such as Bradfield's (1922) demonstrate the ability of clay to prevent leeching of cations between soil layers, our soil and leaf nutrient analysis proved insignificant as a result of procedural errors. A miscommunication led us to dry the soil and leaf samples at approximately 60 degrees Fahrenheit instead of the recommended 60 degrees Celsius. We suspect the excess moisture may have prevented the mass spectrometer from obtaining an accurate reading. Additional problems were the inability of the soil auger to penetrate shallow outwash roots, and the presence of root fragments that may have affected sample nutrient compositions. Consequently, though our nutrient analysis was inconclusive, we expect that if the procedure was revised our study could produce results consistent with Bradfield's (1922).

The expected differences in soil composition and moisture content at the two sites could have led to the observed greater average DBH for all trees and aspens at the moraine site. Considering that the aspens at the two sites are approximately the same age, this variation in growth suggests differences in soil fertility. This difference in soil fertility may also affect species composition. At the outwash site, pines better suited to the dry, acidic, and sandy soil are succeeding the dominant aspens (Barnes et al. 1981; Voss, 1985). Mesic soil present at the moraine site limits the growth of dry soil indicator species, such as bracken fern and blueberry (Hellum et al. 1966). We also found significantly more species per plot at the moraine site than the outwash site, suggesting that the moraine site has a greater ability to support a variety species.

Our results for canopy coverage show that the outwash canopy permits significantly more sunlight than the moraine canopy. More canopy coverage indicates larger trees, which is consistent with our DBH data. This increased coverage may also have an effect on the species composition. Shade intolerant species such as pine and aspen are present at the outwash site, while more shade tolerant species such as sugar maple and American beech prefer the moraine (Lorimer, 1983). Greater canopy coverage can also cause increased soil fertility via reduced soil evaporation and increased water vapor retention (Isichei, 1992), which is also consistent with our percent moisture findings.

This study is relevant to those researching land uses across northern Michigan. Moraines and outwash plains are prominent features of the topography of the region and may be used for agriculture, residential, and commercial purposes. Our findings could have effects on the decisions of potential farmers, mining enterprises, and other land use specialists. Knowledge of the underlying soil composition and its ability to support vegetation are important for anyone investing in property.

These findings are also a reminder to all scientists that the geologic origins and resulting topography of an area can have considerable effects on current ecosystem interactions. The impacts of glaciers on northern Michigan are representative of the effects long-term geologic forces can have on current biomes. The scientific community would benefit from taking geologic history into account when conducting studies of temporal environments.

Acknowledgments:

We would like thank Dr. Joel Heinen, Luke Bell-Dereske, and Marshall McMunn for their expertise and revisions. We would also like to thank Michael Grant, Kat Williams, and Sherrie Webster for their assistance in equipment selection and sample analysis. Of course, this endeavor would not have been possible without the support of the University of Michigan Biological Station and its director Knute Nadelhoffer, to whom we extend our utmost gratitude.

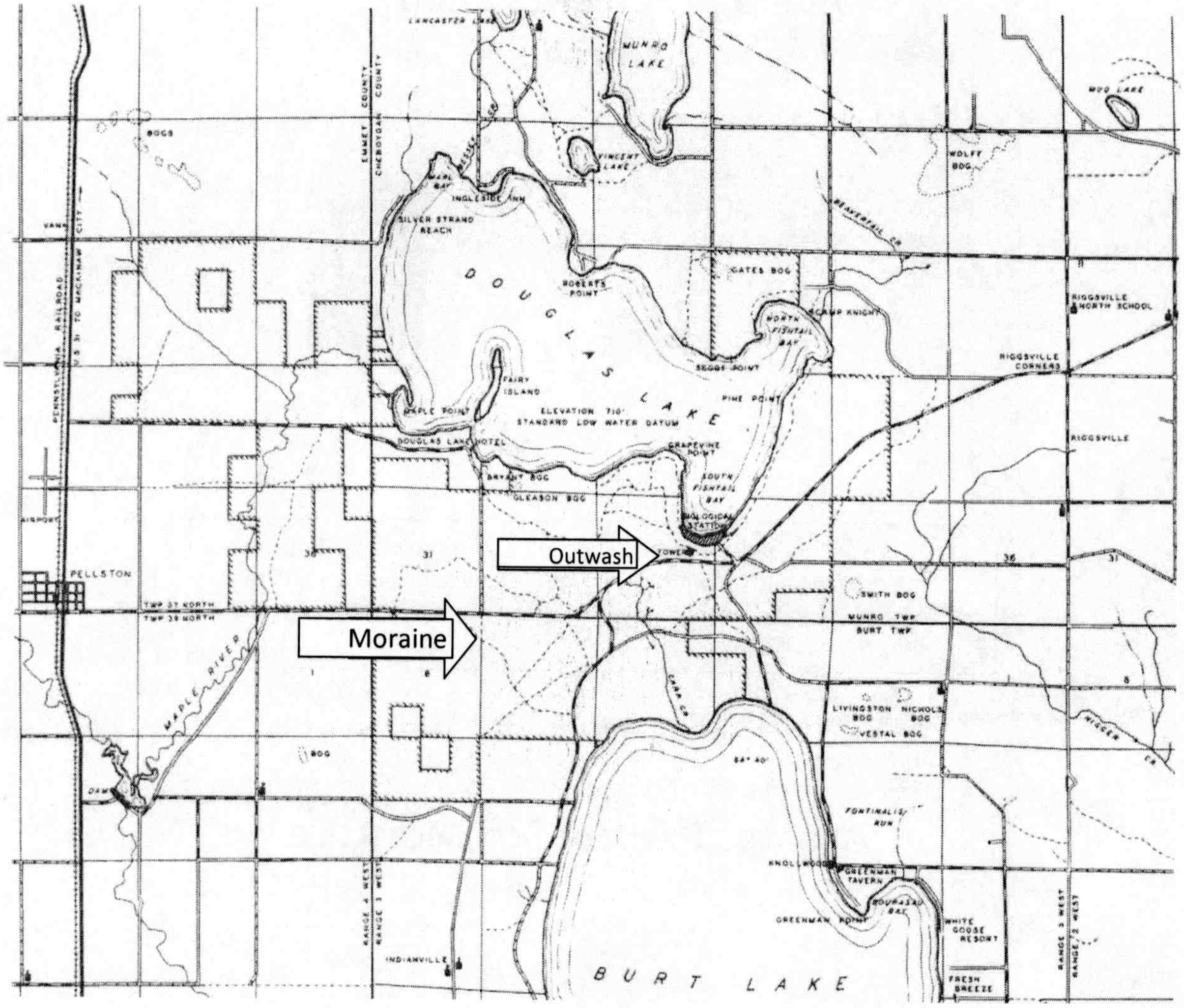

Figure 1: Map of the area surrounding the University of Michigan Biological Station near Pellston, MI, USA with moraine and outwash study sites indicated.

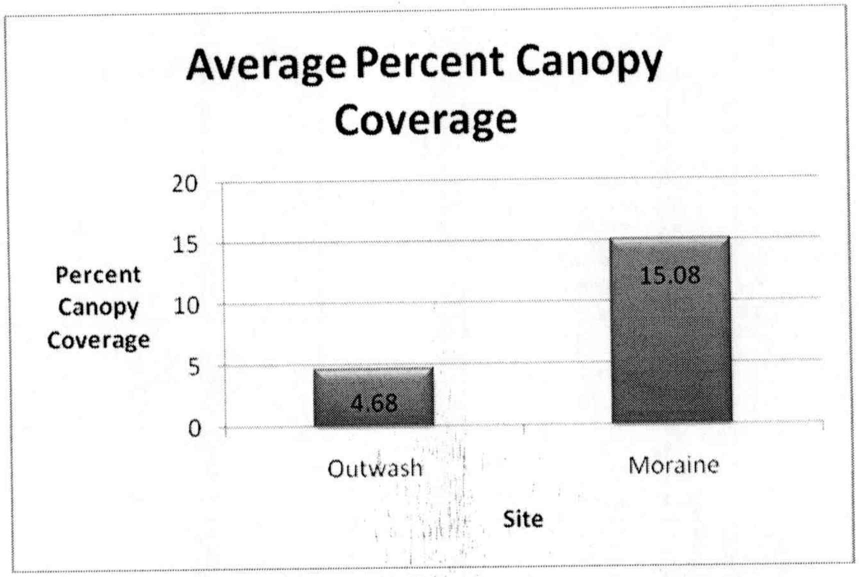

Figure 2: Comparison of mean percent canopy coverage between the moraine and outwash sites. Figure shows significantly greater percent canopy coverage at the moraine site than at the outwash site. P-value=0.002.

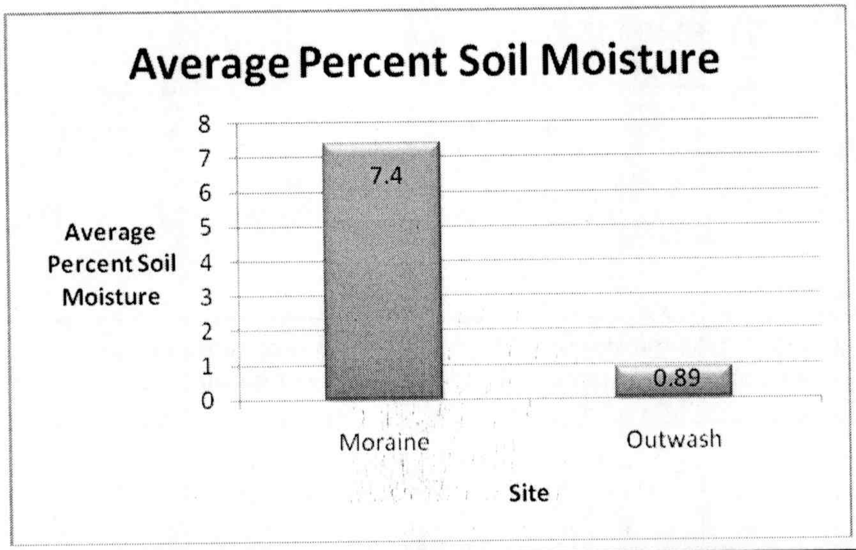

Figure 3: Comparison of mean percent soil moisture content between the moraine and outwash sites. Figure shows significantly greater percent soil moisture content at the moraine site than at the outwash site. P-value=0.001.

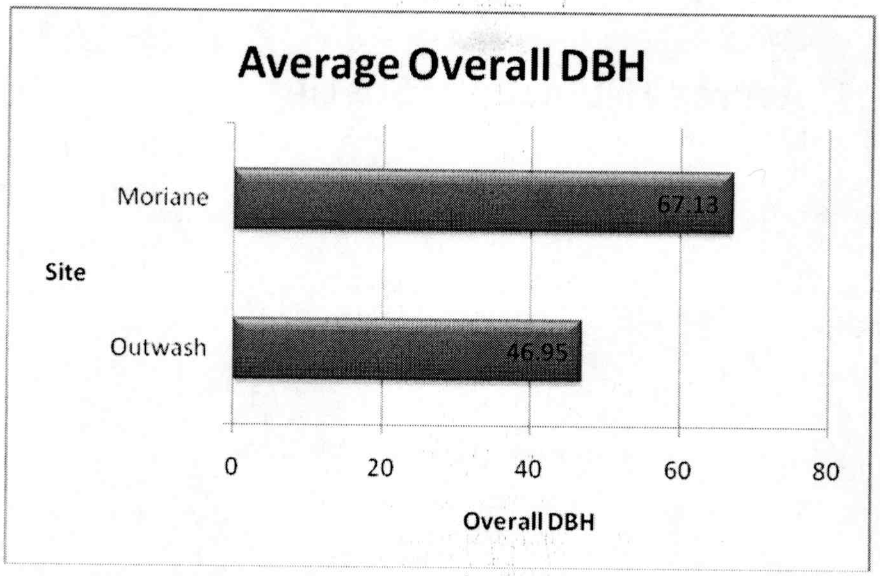

Figure 4: Comparison of overall mean tree DBH between the moraine and outwash sites. Figure shows significantly larger average DBH for all trees sampled at the moraine site than at the outwash site. P-value=0.001.

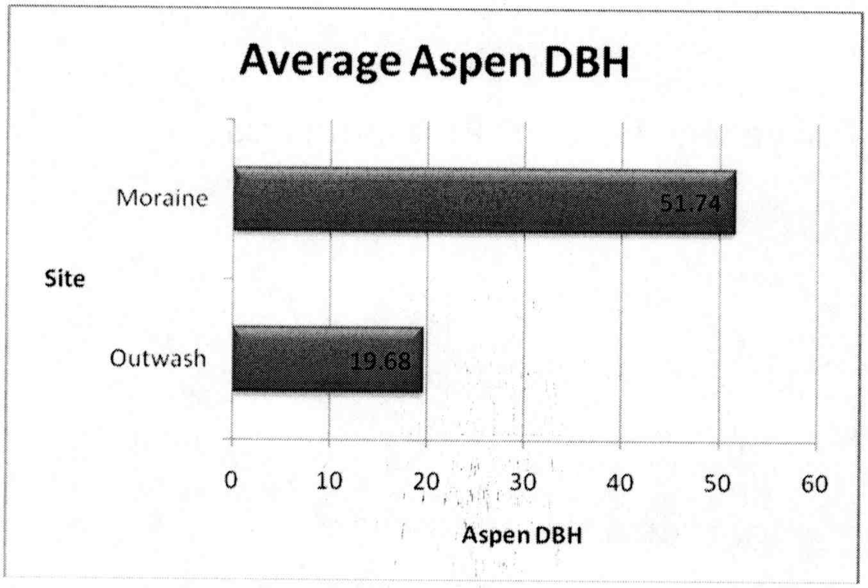

Figure 5: Comparison of mean aspen DBH between the moraine and outwash sites. Figure shows significantly larger average DBH for aspens sampled at the moraine site than at the outwash site. P-value<0.000.

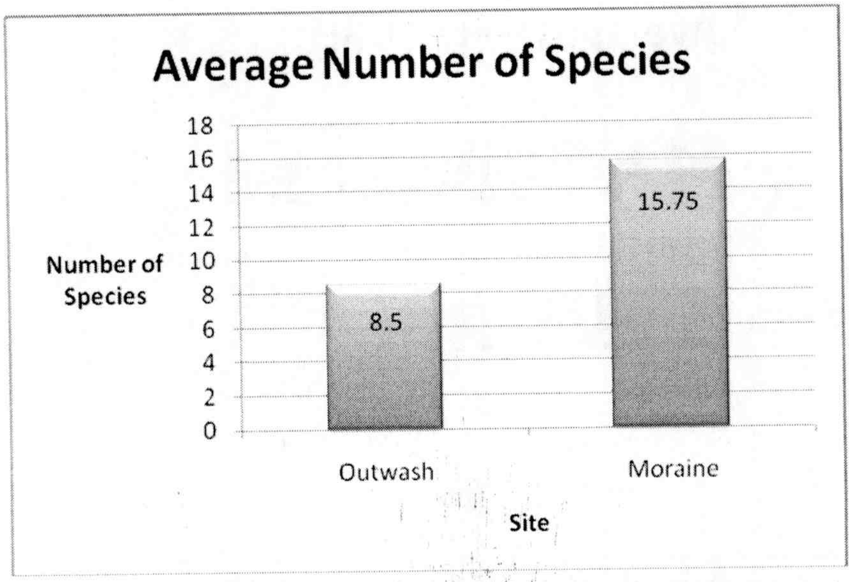

Figure 6: Comparison of mean number of species between the moraine and outwash sites. Figure shows significantly larger average number of species at the moraine site than at the outwash site. P-value=0.001.

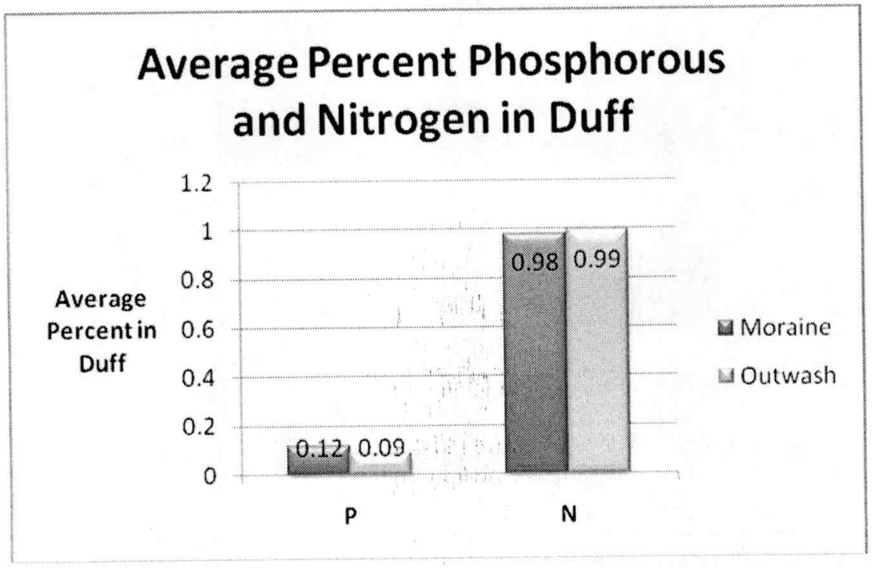

Figure 7: Comparison of mean percent phosphorous and nitrogen content of duff between the moraine and outwash sites. Figure shows no significant difference between the duff levels at the two sites.

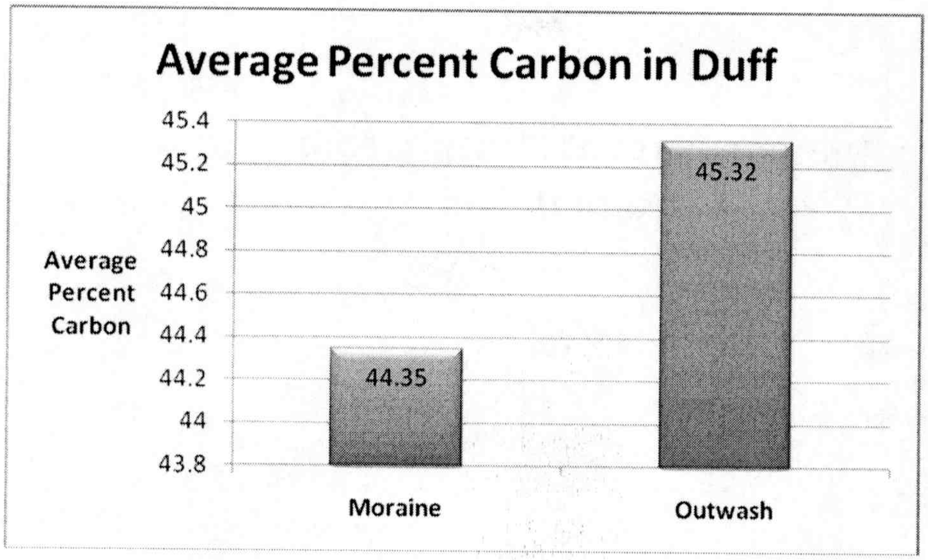

Figure 8: Comparison of mean percent carbon content of duff between the moraine and outwash sites. Figure shows no significant difference in average percent carbon in duff samples from the two sites.

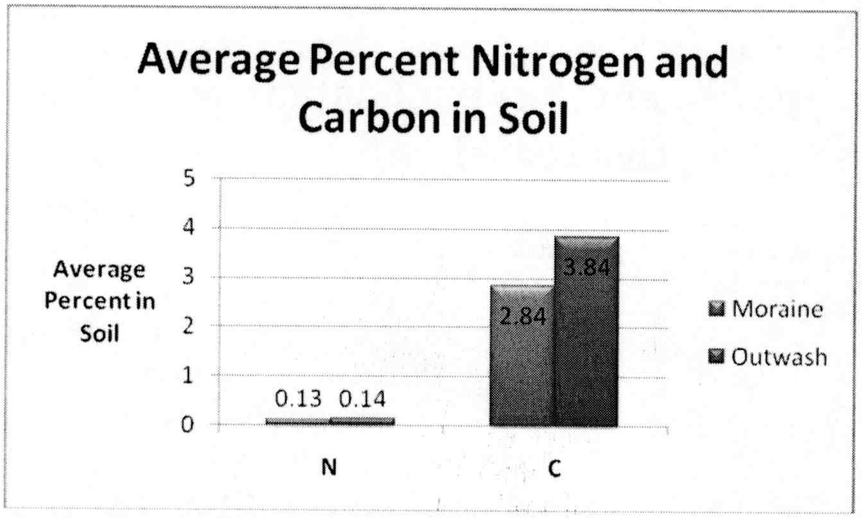

Figure 9: Comparison of average percent nitrogen and carbon content of soil between the moraine and outwash sites. Figure shows no significant difference in average percent nitrogen and carbon levels between the two sites.

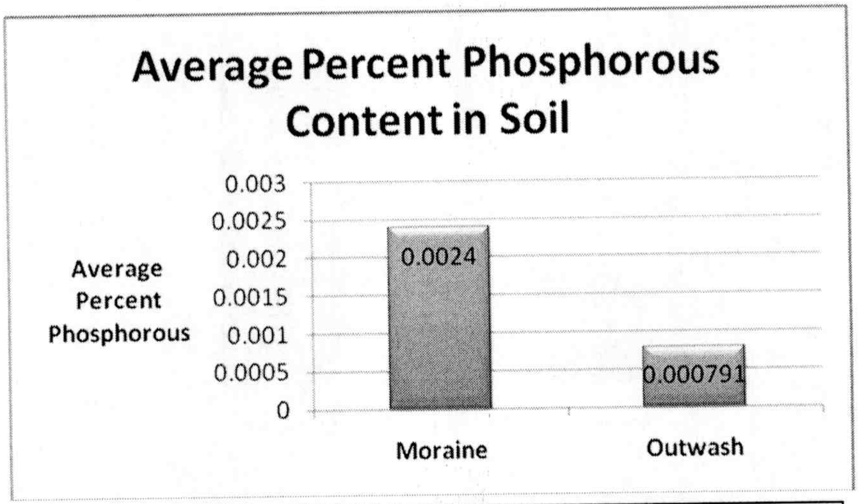

Figure 10: Comparison of average percent phosphorous content of soil between the moraine and outwash sites. Figure shows no significant difference in average percent phosphorous content in soils between the two sites.

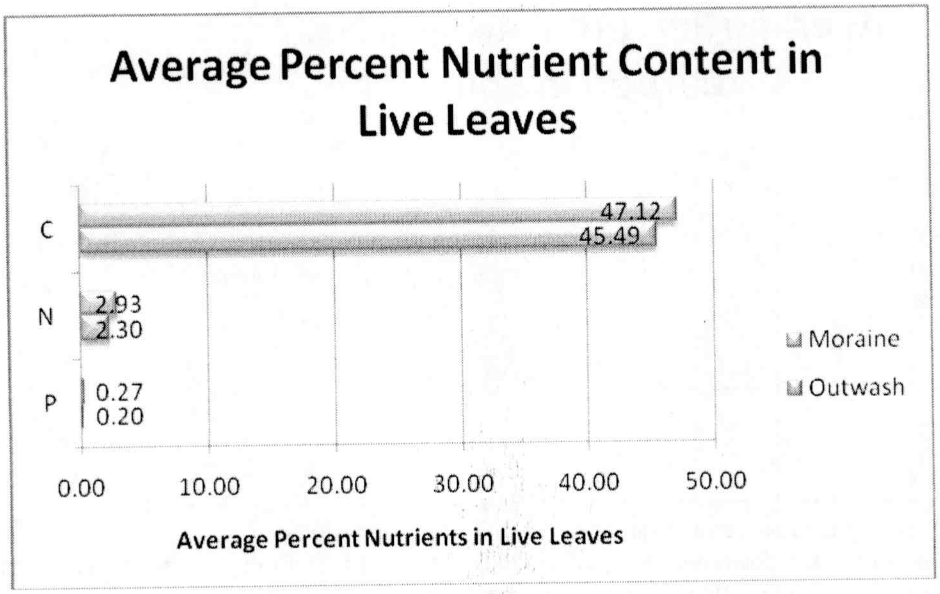

Figure 11: Comparison of mean percent content of carbon, nitrogen, and phosphorous of live leaves between moraine and outwash sites. Figure shows no significant difference in average percent nutrients (C, N, P) in live leaf samples between sites.

Sources:

Barnes, B. V., and W. H. Wagner. 1981. Michigan Trees. University of Michigan Press, Ann Arbor, Michigan, USA.

Benninghoff, W. S., and K. J. Cramer. 1962. Phytosociological Analysis of Aspen Communities on Three Site Classes for *Populus grandidentata* in Western Cheboygan County, Michigan.

Bradfield, R. 1922. The Chemical Nature of Colloidal Clay.

Gates, D. M. Introduction: A History of the University of Michigan Biological Station. 2010. Pages 1-14 *in* K. J. Nadelhoffer, A. J. Hogg Jr., and B. A. Hazlett, editors. The Changing Environment of Northern Michigan. University of Michigan Press, Ann Arbor, Michigan, USA.

Hellum, A. K., and R. Zahner. 1966. The Frond Size of Bracken Fern on Forested Outwash Sand in Northern Lower Michigan. Soil Science Society of America Journal **30**: (520-524).

Isichei, A. O., and J.I Muoghalu. 1992. The Effects of Tree Canopy Cover on Soil Fertility in a Nigerian Savanna. Journal of Tropical Ecology **8**: 329-338.

Ives, J. D. 1978. The Maximum Extent of the Laurentide Ice Sheet Along the East Coast of North America during the Last Glaciation. Arctic Magazine.

Lorimer, C. G., and A. G. Krug. 1983. Diameter Distributions in Even-aged Stands of Shade-tolerant and Midtolerant Tree Species. American Midland Naturalist **109**: (331-345).

Tunstall, B. 2005. Soil Factors Affecting Competition between Trees and Grasses. Environmental Research and Information Consortium.

Voss, Edward G. 1985. Michigan Flora: Dicots, volume 2. Cranbrook Institute of Science Bulletin 59 & University of Michigan Herbarium, Ann Arbor, MI, USA.

Wilde, S. A. 1958. Forest Soils: Their Properties and Relation to Silviculture. The Ronald Press Company, New York, New York, USA.