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Local Ecology Research Papers

Comparison of Soil Characteristics Between a Restored Maple-Basswood Forests and a Mature Maple-Basswood Forest

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Abstract:

In order to understand forest structure over time and to make appropriate management decisions, it is important for ecologists to consider the soil characteristics of a forest. This study examines the variation of soil moisture, organic matter, phosphate levels, nitrate levels, and ammonia levels in a 24 year old restored maple-basswood forest on the west side of the St. Olaf College campus, compared to Norway Valley, a mature forest on the southwestern side of campus. Soil cores were obtained from four sites in the restored forest and three sites in Norway Valley. These samples were used to record soil moisture and organic matter content. Soil extractions were conducted to determine the levels of ammonia, nitrates, and phosphates in the samples. A comparison between Norway Valley and the restored fields revealed that there was a significant difference in the percentage of organic matter and the phosphate levels of the samples. Further comparisons revealed there was a significant difference in the percent soil moisture and organic matter, but not in the phosphate level between the two restored fields. Nitrates and ammonia levels showed no significant difference between Norway Valley and the restored sites, or among the restored sites. The differences in soil moisture and organic matter in the restored forest suggest that the two fields are maturing at different rates due to other factors such as, previous soil conditions. The comparison between the restored forest and Norway Valley suggests that the restored forest is closer to maturation than in previous studies. Future research should continue observing soil characteristics, as well as examining micro-invertebrate populations and tree species composition, to better understand how these aspects of forest structure relate and inform management decisions.

Introduction:

It was not until 300 years ago that we started to see the domination of *Acer saccharum* (Sugar Maple), *Tilia Americana* (American Basswood), *Ulmus* (Elm), and *Ostrya virginiana* (Ironwood) in the present maple-basswood forests of Southern Minnesota (Grimm, 1983). Much of the land occupied by the maple-basswood forests has been turned into agricultural land since European colonization. Concerns about anthropogenic climate change due to carbon dioxide emissions and other extenuating circumstances, such as fluctuations in the agricultural market or degradation of soil quality, have led to the restoration of once forested land, as well as the abandonment of agricultural land. Research about soil carbon accumulation in abandoned fields found that these fields can act as moderate carbon sinks for about 100 years after abandonment and suggests time is more important than soil type when considering potential for carbon sequestration (Foote and Grogan, 2010). Researchers were also concerned with whether or not soil quality improves after abandonment. They found that organic matter, total carbon, total nitrogen, and available potassium all increased with years after abandonment, while potassium, total phosphorus, and available phosphorous did not change (Zhang *et al,* 2010). Furthermore, nitrates and ammonia increased for the first 50 years then decreased (Zhang *et al*, 2010). One plausible explanation is that untilled land increases soil aggregate size, which raises the organic carbon and soil nitrogen in the soil (Liu *et al*, 2010). To add to that explanation, total soil nitrogen and the carbon to phosphorous ratio were found to be related to soil organic carbon during restoration, suggesting a biochemical relationship between them (Gong *et al*, 2013). This evidence suggests that soil quality improves and carbon sequestration occurs in abandoned agricultural fields.

There was less research available about restoration projects and the impact they have on soil quality and carbon sequestration. One study did find that active restoration can improve soil carbon sequestration, and nutrient availability (Gong *et al*, 2013). They also found that soil organic carbon sequestration is regulated by soil nutrients supply (Gong *et al*, 2013). Another study that investigated whether soil horizon data from 30-50 years ago was still accurate in Iowa, found that 60% or more differed from their original classifications (Veenstra and Burras, 2012). Those results suggest the need for monitoring of soil characteristics to understand the effects that they have on restoration projects, as well as the other way around. They also suggest a need for more frequent monitoring, to understand gradual changes in soil classifications and to improve the validity of soil maps. Monitoring of soil characteristics will improve our understanding of management practices for proper forest restoration and improved efficiency in carbon sequestration.

This study's objective was to continue the soil comparison of a 24 year old maple-basswood restoration plot, with a 100 plus year old mature forest in the natural lands of St. Olaf College, in Southern Minnesota, USA. The space now occupied by the restored plot used to be agricultural land and was restored in 1990. Soil characteristics that were measured include percent soil moisture and organic matter, phosphate levels, nitrate levels, and ammonia levels.

Methods:

Study Site:

The two 1990 restored forests and Norway Valley are located on the St. Olaf Natural Lands in Northfield, MN. Norway Valley is 6 ha in size and located southwest of Regent's Hall as well as the oldest deciduous forest on campus. The restored forest is 3 ha on the western edge of the main campus, but on the eastern side of the natural lands. It is a long narrow strip that goes from Highway 19 until Tostrud. It is split into two fields. Field one is in the North, by Tostrud and field two is in the South, by Highway 19. Both fields are split into a North and South half. In the fields are 28 15x75m transects, of which, every other transect was sampled in each field. Field one had 6 transects sampled from the odd transects 1 to 12 and field two had 8 transects sampled from 13 to 28.

Field Work:

Two samples were taken 25m and 50m from the western edge of the restored forest transects. Three samples were taken from near the obelisk (North), path (West), and slope (South) sites in Norway Valley. A soil corer, with a diameter of 2cm and a height of 16.5cm, was used to collect two samples from each site. They were used for the measurement of soil moisture, organic matter, nitrates (NO3-N), phosphates (PO4-P), and ammonium (NH4-N) at each site.

Data Analysis:

All data analysis tests were performed using R commander. One-way analysis of variance tests (ANOVA) were used to compare the means of each sample site to determine if any significant differences were observed. The soil nutrient data (NO3-N, PO4-P, and NH4-N) for Norway Valley only has one data point for each site and should be treated as a poor representation of the population.

Results:

Between the restored plots and Norway valley, there were two soil characteristics that varied. Those two characteristics were percent organic matter and phosphates (Organic Matter:

p=7.17 e^-7; Phosphates: p=0.0433) (Table 1; Figures 2 and 3). Between the two restored fields, there were also only two characteristics that varied. Those two were percent moisture and percent organic matter (% Moisture: p=0.0303; % Organic Matter: p=2.11 e^-5) (Table 1; Figures 1 and 2). It is important to note that the standard curve for the nitrates result was incorrect. However, this would not affect differences among sites, only actual values. Norway Valley had a larger measurement for phosphates than the restored fields, but had measurements between the two fields for every other characteristic. Field two had larger measurements than field one for every characteristic except ammonium. There was no significant differences between nitrates or ammonium in either the comparison of the restored fields to Norway Valley or the comparison between only the restored fields (Table 1; Figures 4 and 5).

Discussion:

When comparing the restored fields to Norway Valley, since there were only significant differences in percent organic matter and phosphate levels, the results suggest that the restored plots are nearing maturity. This conclusion agrees with the conclusion reached by Nick Lund who compared the soil of the two areas in 2013. However, the difference between the two studies is that Nick found a significant difference in nitrate levels, while I found a difference in phosphate levels. Unfortunately, since the standard curve for the measurements of the nitrate levels is incorrect in this study, a comparison between years could not be made. Phosphate levels between the two years did decrease, but the significance was not tested. It is likely that there was no significance, based on a study that found no trend in phosphate levels in a natural restoration (Zhang, 2010). It should still be considered as a variable, because this is an active restoration. These data do agree with the conclusion that active restoration improves nutrient availability (Gong *et al.* 2013). Both of our results were more similar to the mature forest than in a study conducted in 2010 comparing these two sites (Henn, 2010).

When comparing only the two restored fields, the significant difference in percent organic matter and soil moisture suggests that the two fields are maturing at different rates. This conclusion also agrees with the conclusion reached by Nick Lund in 2013. A striking difference between the two years is that percent organic matter is approximately five times higher in field two than it was in 2013. I speculate that the difference is caused by a relatively open canopy compared to Norway Valley allowing the growth of an understory consisting of large bushes, grasses and forbs. The difference is important, because it means that field two has reached mature status in several characteristics before field one. The difference between fields one and two is likely due to soil type. No measurements were taken, but field one had a much sandier soil texture, which allows for nutrient and water leakage possibly causing a decrease in the amount of organic matter produced and captured. The sandiness of the soil would explain why field one is lower in every soil characteristic measured, except nitrates in field one, North. Official measurements should be taken to observe soil texture and retention capabilities.

Future projects may want to compare soil characteristics to tree composition. A study that investigated gap phase replacement in a maple-basswood forest found that there is something that is causing the numbers of saplings and seedlings to move towards a trend rather than a random distribution (Bray, 1956). It would be interesting to see if there is a correlation between the two. It would also be interesting to investigate how soil characteristics and vegetation composition influence aquifer recharge rates. A study investigating this topic in Hawaii found that a restored forest allows for water to penetrate to depths of 1m or greater, 13 times faster than in a grassland (Perkins *et al.*, 2014). Another research opportunity might compare the soil characteristics to patterns in the microbial community structure. Researchers found that in an 18 year old restored *Eucalyptus marginata* (Jarrah) forest, after bauxite mining, there was a similar bacterial structure to the surrounding community, but not so for fungal communities (Banning *et al.*, 2011). They also found that changes in the microbial structure were significantly related to size of the microbial biomass as well as pH, carbon, nitrogen, and phosphorous nutrient levels, which suggests that bacterial communities may follow a predictable successional pattern (Banning *et al.*, 2011). This pattern can then be described through these soil characteristics (Banning *et al.*, 2011). Another reason to keep monitoring soil characteristics is that soil conditions had a positive effect in explaining regeneration diversity, grouped species richness and number (Liu *et al.*, 2011). All of this information will improve our ability to achieve management goals, such as reducing the carbon concentration in the atmosphere or replenishing the water table.

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Tables and Figures:

Table 1: Means and p-values of the soil characteristic measurements of the four restored plots along with Norway Valley.

Site	% Moisture	% Organic Matter	NO3-N (mg/kg)	PO4-P (mg/kg)	NH4 (mg/L)
One North	9.648333	3.896667	2.105	3.465	0.39
One South	11.345	4.115	-0.09167	2.855	0.035
Two North	20.0675	20.0675	1.16375	4.85375	0.11625
Two South	21.72125	21.72125	0.82625	4.565	0.08
Norway Valley	16.53	7.29	1.45	6.93	0.033333
P-Value (Restored and Norway Valley)	0.0894	7.17 e^-7	0.9	0.0433	0.668
P-Value (Restored)	0.0303	2.11 e^-5	.592	0.45	0.309

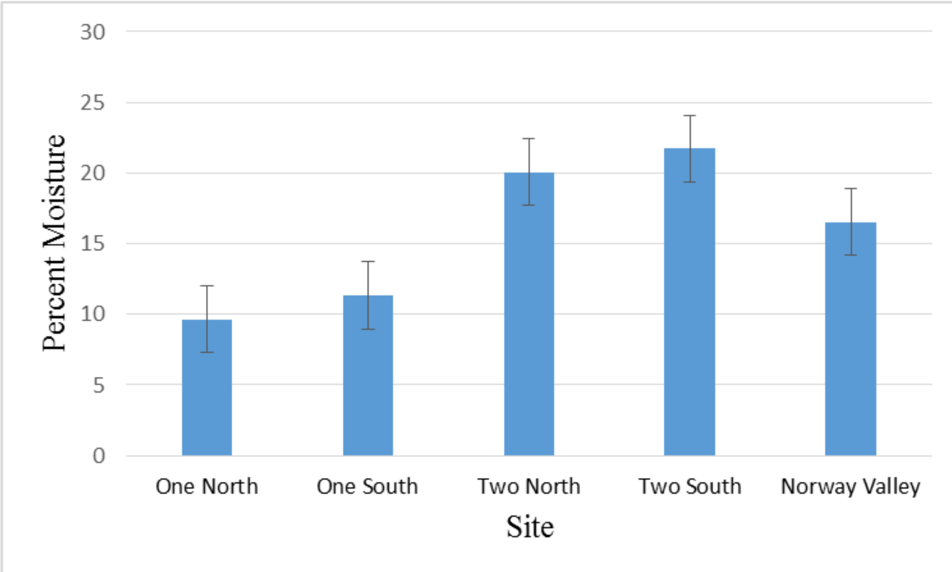

Figure 1: Percent moisture levels of the four restored plots and the three Norway Valley plots. **P-value = 0.0894** for comparisons of the restored plots and Norway Valley. **P-value = 0.0303** for comparisons of only the restored plots.

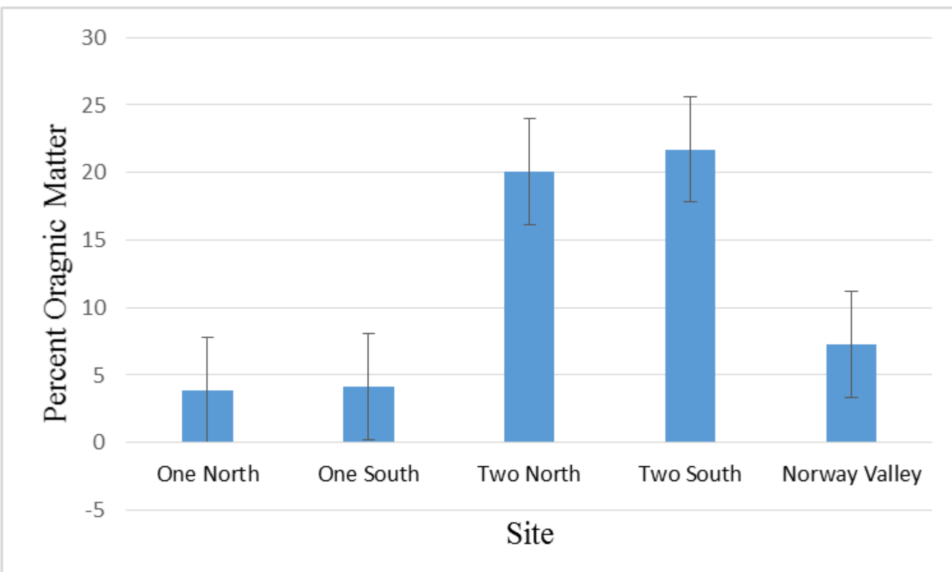

Figure 2: Percent organic matter levels of the four restored plots and the three Norway Valley plots. **P-value = 7.17 e^-7** for comparisons of the restored plots and Norway Valley. **P-value = 2.11 e^-5** for comparisons of only the restored plots.

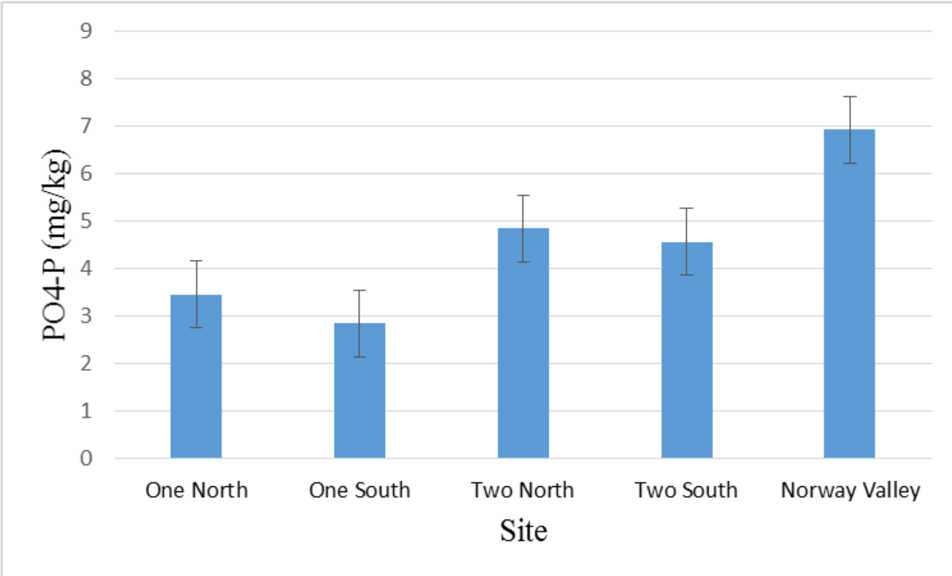

Figure 3: Phosphate levels of the four restored plots and the three Norway Valley plots. **P-value = 0.0433** for comparisons of the restored plots and Norway Valley. **P-value = 0.45** for comparisons of only the restored plots.

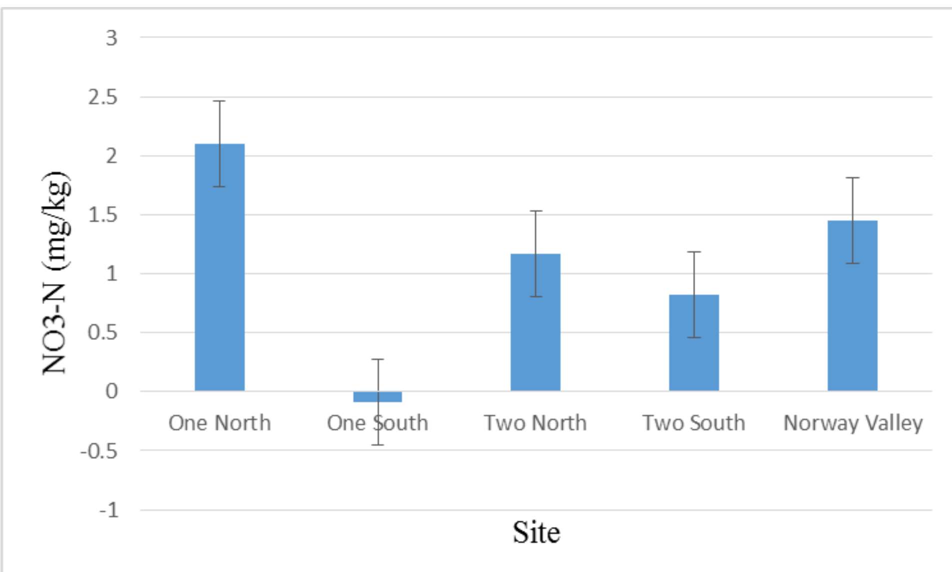

Figure 4: Nitrate levels of the four restored plots and the three Norway Valley plots. **P-value = 0.9** for comparisons of the restored plots and Norway Valley. **P-value = 0.592** for comparisons of only the restored plots.

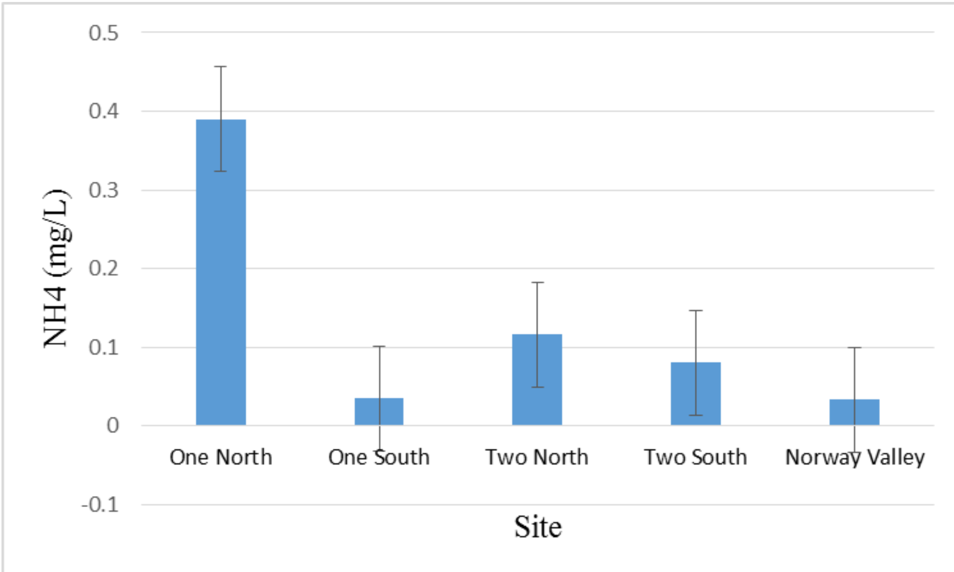

Figure 5: Ammonia levels of the four restored plots and the three Norway Valley plots. **P-value = 0.668** for comparisons of the restored plots and Norway Valley. **P-value = 0. 0.309** for comparisons of only the restored plots.

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