2010

The Effect of Soil Regimes and Topography on Tree Community Composition in the Gordon Natural Area

Calen Daugherty
West Chester University of Pennsylvania

William Hochella
West Chester University of Pennsylvania

Kyle Houser
West Chester University of Pennsylvania

Sarah Johnson
West Chester

Carolyn Keene
West Chester University of Pennsylvania

Recommended Citation

Daugherty, C., Hochella, W., Houser, K., Johnson, S., & Keene, C. (2010). The Effect of Soil Regimes and Topography on Tree Community Composition in the Gordon Natural Area. Retrieved from http://digitalcommons.wcupa.edu/gna_soils_series/2

The Effect of Soil Regimes and Topography on Tree Community Composition in the Gordon Natural Area

---

CALEN DAUGHERTY, WILLIAM HOCHELLA, KYLE HOUSER, SARAH JOHNSON, AND CAROLYN KEENE

Abstract: It is well known by many researchers that a correlation exists between soil characteristics and tree distribution in deciduous forests located in the United States. However, there is a dearth of current research dealing with the edaphic nature of forests in Southeastern Pennsylvania. Our research sought to fill the gap in current research and investigate the discrepancies in previous research. Our specific research question dealt with the Gordon Natural Area, which is located on the West Chester University of Pennsylvania South Campus. The goal of our study was to determine the effect of soil regimes and topography on tree community composition. We tested thirty sites, and failed to find a statistically significant relationship between soil type and tree community composition. However, we did find relationships between tree type and soil composition, which gives us cause to further our research.

Introduction

It is well known by many researchers that a correlation exists between soil characteristics and tree distribution in deciduous forests located in the United States. For example, research shows that soil and vegetation in southeastern Wisconsin differ significantly in both basins forested wetlands and floodplains (Dunn and Stearns, 1987). Another study in

Northwestern Connecticut found a relationship between soil nutrients, soil pH, and tree species distribution in forests (Bigelow and Canham, 2002).

Unfortunately, there is a dearth of current research specifically dealing with Southeastern Pennsylvania. Two papers, Keever (1973) and Kasmer et al (1984), do show a relationship between soil characteristics and forest composition in this region, but they were written over twenty years ago. Keever (1973), conducted research in the Pennsylvania counties of York, Lebanon, and Lancaster to determine the environmental factors that influenced the distribution of commonly found trees in the three counties (304). During her study, she examined the soil, slope, altitude, and aspect on which the trees were located. The results of her findings indicated a relationship between the environmental factors listed above and tree species distribution. She found that beech trees are more abundant on steep westward and northward facing slopes that contain limestone soils with a pH greater than six. Also, she concluded that white oaks prefer relatively flat lands and do not appear to have a preference in soil type (325).

Kasmer et al (1984), conducted their study east of Keever's (1973); in the Pennsylvania counties of Bucks and Montgomery. Similar to Keever's (1973) study, it focused on the relationship between environmental and edaphic factors to forest composition. They also found parallels between environmental gradients and vegetation gradients, but some of their finding contradicted that of Keever's (1973) study. For example, Kasmer et al (1984) found that beech trees grew better in acidic soils that had a pH between 3.8 and 4.4, a distinctive difference from the findings of Keever's (1973) study (Kasmer et al

1984, 154). Another contrast between the two studies is that Kasmer et al (1984) found no association between red oaks and sugar maples in a forested area, while the Keever (1973) study did find an association (Kasmer et al 1984, 155).

With discrepancies between the two southeastern Pennsylvania studies and the paucity of current soil and forest composition research in southeastern Pennsylvania, further research on the relationship between soil types and forest compositions in southeastern Pennsylvania is needed. An updated study could greatly assist academics, environmentalists, and researchers solve matters related to forest conservation and preservation.

Our study was conducted in order to determine the relationship between soil types and tree distribution in the Gordon's Natural Area (GNA), located on the campus of West Chester University of Pennsylvania. Our primary focus was on three statistically significantly different soil types found in the GNA. We sought to examine the trees located on those soil types, and determine if there was difference in tree species and groupings between these soil types. Keever (1973) and Kasmer et al (1984) mentioned that other environmental factors, such as slope and aspect, played a significant role in determining tree distribution in a forest. Therefore, we took the aspect of and slope of the thirty plots that we examined in the GNA to determine the severity of influence they have on tree distribution. We are also interested in determine if slope and aspect are stronger influences on tree distribution in the GNA than the three examined soil types.

Methods

Our study area was contained within the main parcel of the GNA. The GNA is comprised of about 150 acres of land on the South Campus of West Chester University in West Chester, Pennsylvania (WCU, 2007). West Chester University set aside the land in the early 1970's as an ecological preserve and an area for biological studies (Beneski, 2009). The land, which consists mainly of Eastern deciduous forest, is bordered by athletic fields, other wooded properties, residential areas, and transportation infrastructure (roads and parking lots). The GNA has experienced problems with very heavy deer browse, which has effectively eliminated the forest understory, and have allowed less palatable invasive species to become established in place of native vegetation (D'Angelo, 2009).

The plot areas were mapped using ArcMap 9.3.1 software. Transects were gridded at 120 meter intervals north of the base and trimmed to the study soils. The base point of the grid was located at the entrance to the GNA from R-lot parking lot, where a bridge that forges a small stream. The grid contained 5 transects. To ensure at least 30 sites (for statistical testing), the sites were spaced every 35 meters along the transects, resulting in 35 possible sites (ESRI, 2009). Two sites were abandoned due to unsafe terrain (steep stream banks) and three more were unreachable due to a property barrier which had not been marked in the GNA maps provided by West Chester University of Pennsylvania (WCU, 2007). This resulted in 30 total study sites (Figure 1).

The data was collected in the field over three full fieldwork days. The sites were located by pacing the 120 meters between transects, and 35 meters between sample sites. The plots were delineated by setting up a dowel rode at the center of our plot and measuring a 6 meter radius in order to ensure a plot size of at least 10 square meters. Once the plots were located the aspect was recorded.

Tree and soil data was collected for each plot. To collect tree data, each tree species within the sample plot was identified and measured for DBH. Trees less than one centimeter were counted and assumed to have a .5 cm DBH. Soil samples were collected using an auger. One auger's depth was taken and discarded, and the second auger's depth was put in a bag for sampling. This was done to ensure that each sample was taken at the same depth of thirty centimeters.

Once field data collection was complete, the 30 actual study sites were plotted in ArcMap based on orienteering. A 30-meter Digital Elevation Model (DEM) of the study area was used to calculate the slope near each site (ESRI, 2009; WCU, 2007). Aspects taken in the field were folded to range from 0° to 180° for ease of quantitative analysis. The folded range was aligned such that northeast, receiving the least sunlight lay at 0° while southwest, receiving the most, lay at 180° (Fritschle, 2009)

The analysis of the soil was done using an XRF (Niton, 2008) which provided spreadsheets which could be put into Excel and analyzed (Microsoft, 2003). The XRF is an x-ray fluorescence device which emits an x-ray that excites the atoms of the sample being studied. When the atom is excited electrons are transferred from one shell to another and the unique emissions produced can be measured (Niton, 2008). The soil samples were analyzed for light and heavy elements ranging from phosphorus to bismuth. The data was transferred from the XRF device to an Excel spreadsheet and from there the data was analyzed by the individual elements measured by the XRF. Analysis was conducted by sorting the elements by increasing values and then color coding the sites based on the soil type the site was located in. Any values in the data measured as less than zero by the XRF were set to zero for easier analysis (Microsoft, 2003).

To determine relationships among the tree communities and environmental factors, non-metric multidimensional scaling (NMS) was selected based on its widespread use and suitability to data sets such as forests (Kent, 2006). NMS is a nonparametric method of indirect ordination, performing gradient analysis along multiple axes to order plots in accordance with the associations between species (McCune and Grace, 2002). The tree DBH measurements taken in the field were recalculated to basal area and summed by plot to create the matrix for NMS analysis, which was run multiple times in PC-ORD v5.0 to confirm a consistent solution (McCune and Mefford, 1999). In each run, 250 iterations with the data were performed to create a 3-dimensional map of related communities using the recommended Sørensen's coefficient for distance, while 250 iterations were performed on randomized Monte Carlo data to provide and empirical comparison of random data for significance tests (McCune and Mefford, 1999).

These results were then compared with environmental factors measured for each plot, including slope, aspect, soil type, and selected soil elements. The non-parametric Kendall's tau was computed in PC-ORD for distribution of species within the 3-D ordination space and the selected environmental factors (McCune and Mefford 1999). Visual examinations along the 2-D plane of axis 2 and axis 3 were performed for each species and environmental variable for subjective analysis.

Soils: Results and Discussion

Results

The elements which showed the most visible grouping based on soil type were manganese, zinc, selenium, zirconium, barium, and lead. Manganese is the lightest element of those which exhibited the most grouping. The blue sites are grouped together at the top as seen in Figure 2. This means that they contain less manganese. The exception is site 24 which may be responding differently based on its close location to the creek running through the Gordon Natural Area. Red and green sites seemed to show equal correlation with manganese.

Zinc also predominately showed that blue sites contained less, green sites contained a moderate amount and the red sites contained the most, barring a few cases of intermixing most likely due to the close proximity of the sites to the soil type boundaries (see Figure 2).

Selenium displayed results which showed that green sites had less, blue sites were moderate, and the red sites contained the most, yet again; the intermixing of the colors was mostly sites where the sites were close to a soil type boundary (see Figure 2).

The zirconium results showed that red sites had the least zirconium, green sites had moderate values, and blue sites the most. Within these results there are smaller groupings in the soil where one soil may wrap around another and its chemistry may slightly change based on the chemistry of the surrounding soil types (see Figure 2).

Barium analysis displayed the same intermixing as the other elements did along soil boundaries with some slight differences in that the red sites were more evenly distributed between the blue and green sites. The blue contained less barium than the green sites did. The red sites, which were fairly evenly distributed between the blue and green soil types, are located in a soil which divides the blue and the green and therefore this distribution of the red sites makes more sense (see Figure 2).

Lead was the final element which exhibited the most visible grouping. Green sites contained the least amount of lead while blue sites contained a moderate amount and red sites contained the most (in most cases). As with barium, the more evenly distributed red sites may be related to the fact that the red sites are located within a soil which divides the other two (see Figure 2).

Overall these results seem to show that the red sites, located in the soil type found between the green sites and blue sites, have soil chemistries which are predominantly influenced by the neighboring soils. This suggests that perhaps the red soil type is losing its unique identity. There are definite differences between the soils found at the blue and green sites.

Discussion

For the purpose of the analysis the three soil types used in the study were assigned a color. The Wehadkee was blue, the Glenelg was green, and the Neshaminy was red. These color assignments made it easier to recognize when an element showed favoritism for a specific soil. The parent materials, although specific compositions are not always known, are very important to the soils which were studied because they have a great influence on the nature of the soils (Anderson 1988).

The Wehadkee is a poorly drained flood plain soil which is taxonomically classified as a thermic flavaquentic endoquept (Nation Cooperative Soil Survey, 2007). It contains few pebbles and inclusions of iron which can be observed as red-orange masses within the gray-brown soil. Beeches and poplars are two specific types of trees which are associated with this type of soil (Nation Cooperative Soil Survey, 2007). The parent rock of this soil is metamorphic or igneous. The Wehadkee soil sites that were analyzed showed that it was low in manganese, zinc, and barium and high in zirconium. This may be due to the parent rock or it may be due to the fact that it is a flood plain soil which is often hydrated with creek water which would be carrying sediments full of elements that would be left behind as the soil dehydrated.

The Neshaminy is a well drained, mesic ultic hapludalf located on the mid ridge to lower slope (Nation Cooperative Soil Survey, 2008b). It is a gravelly soil favored by mixed hardwood forests (Nation Cooperative Soil Survey, 2008b). The parent material of this soil is a dark mafic rock or diabase. The analysis showed that the Neshaminy samples taken were high in zinc, selenium, and lead and low in zirconium. The high zinc and low zirconium in the Neshaminy and the low zinc and high zirconium in the Wehadkee may show an exchange occurring between the two soils, but it is possible it is also due to the parent rock's composition and if the rock was subjected to metamorphism which may have changed the diabase's mineral configuration.

The Glenelg is a well drained mesic typic hapludult which does not contain much gravel or pebbles and is known to be specifically vegetated by the tulip poplar (Nation Cooperative Soil Survey, 2008a). The soil itself is recognizable by its numerous mica fragments. The mica fragments are what is left of the parent rock known as schist. Samples from the Glenelg had the least selenium and lead and the most amount of barium. In comparison to the other two soils, the Wehadkee and the Neshaminy, yet again there seems to be an exchange occurring since the three soils are all high in one element and low in another and they are all next to each other.

There is not necessarily an exchange of elements taking place amongst the three soils studied. As mentioned earlier, the differences in the levels could be the result of a different level of metamorphism taking place and changing the parent rock's mineral configuration. Additionally, Brinkley and Giardina (1998) found that chemical weathering rates of the parent material can affect the mineral/element outcome (90). This could also explain why so many minerals were similar and yielded almost no differences amongst the soils, the parent rock was very much the same except for a few elements present which may only be present due to different temperatures, pressures, rates of cooling, and the weathering which took place after the rock was fully formed. As discussed in Dr. Martin Helmke's 2008 Soils class, although samples were taken from the same depth that does not directly correlate to horizons and some minerals do have preferred horizons or horizons where they are more copious than others. The final, non-vegetative, consideration is that the Gordon Natural Area is experiencing a certain degree of erosion which was established in Dr. Martin Helmke's 2008 Soils class. This erosion is not only moving soil, but also the elements in it. The lighter minerals are more likely to be washed away first, while the heavier elements may have a better chance at sticking in the soil. The soils of the GNA which are being studied are located on a slope in an area which does receive a decent amount of rain and therefore the leaching of minerals and nutrients may be an explanation for the lower numbers between the soils as well (Anderson 1988). The differences in leaching between the soils would be dependent on the permeability of the soil horizons (Anderson 1988).

Vegetation of the area must be taken into consideration as it does minutely affect the nutrients in the ground. According to classroom lectures and discussion conducted by Dr. Martin Helmke of West Chester University, the care of this vegetation may also affect the soil content as fertilizers are known to contain elements such as titanium and zirconium. As compounds break down in the ground the elements essentially become "loose." Even if West Chester themselves did not use pesticides the location of streams and residential land surrounding the Gordon Natural Area could be enough that runoff from the area contaminated the soil.

No soil analyzed had levels of elements that exceeded what was the maximum expected concentration level was to be. As in Short's 1961 study the only way to differentiate between soils with similar parent materials, as in the case of the GNA, is the trace elements which will vary due to the individual processes the different parent materials undergo (539-546).

Vegetation: Results and Discussion

Results

NMS ordination of the plots by total basal area per species resulted in their clustering in the three-dimensional ordination shown in Figure 3. The computed overall P-value for the NMS ordination of plots by species was 0.34, indicating a confidence level for the ordination itself of only 66% and a weak ordination ranking. Accordingly, the program was unable to compute cumulative r^2 values or orthagonality of axes, and no results of the ordination can be considered statistically significant (McCune and Mefford 1999). However, analysis was continued in the interest of providing suggestive insights for further research.

No environmental factors were shown to correspond significantly to axis 1, as shown in Figure 4. Axis 2 corresponded most strongly to soil concentrations of Mn and Zr, with significant additional correlation to slope, Zn, and As. Only Fe was statistically significant along axis 3. The lack of a significantly correlated environmental factor along axis 1 and apparent clustering in the plane of axes 2 and 3 led to the labeling of groups shown in Figure 3.

By contrast, the basal area totals of *Fagus grandifolia, Quercus rubra, Carya ovata,* and *Carya tomentosa* strongly correlated to axis 1 as shown in Figure 5. *Acer rubrum* and *Liriodendron tulipifera* were strongly correlated with axis 2, and *Prunus serotina* and *Acer negundo* were statistically significant. *Fagus grandifolia* and *Quercus rubra* were statistically significant along axis 3.

In examining the 2-D graphs, several observations could be made as to the sorting of the 3 clusters in the plane of axis 2 and axis 3. Figure 6 shows that major *Acer rubrum* populations, particularly in group 3, coincided with low Fe concentrations. Figure 7 shows *Liriodendron tulipifera* to be entirely absent from groups 2 and 3. In Figure 8, it can be seen that group 3 appears to cluster around the junction of two streams, but group 2 is scattered.

Group 2, distinguished from the others along axis 3, was difficult to describe in any concise way. Several poorly represented species (*Fraxinus Americana*, *Ailanthus altissima*, and *Lonicera maackii*) appeared primarily within it, but themselves not commonly. The only environmental factor showing a statistically significant difference was iron, suggesting a slight iron richness for group 2. *Fagus grandifolia* showed greater populations in group 2 as well. The only *Alianthus altissima* and the most prominent population of *Lonicera maackii*, disruptively invasive species within the study area (Calen's cite), appeared in group 2.

Subjectively, it was apparent from the visual plots that there was some correlation between high soil iron and *Liriodendron* growth (see figures 6 and 7). The opposite held for *Acer rubum*. With group 1 and group 3 occupying similar positions along axis 3 but opposite along axis 2, other correlations – many statistically significant – along axis 2 seem to hold for them (see Figures 4 and 5). Group 3 is statistically significantly impoverished in Mn. While not statistically significant, Ca is present in lower concentrations on the group 3 side, while K is very slightly higher. Arsenic contamination was found to be less severe in group 3. The GIS-calculated slopes show group 3 to lie on areas of significantly lower slope as well.

Discussion

The GNA consists primarily of farmland abandoned early in the 20th century and, as such, is not an old-growth forest (WCU 2007). The forest is almost exclusively deciduous, with the canopy consisting mostly of *Liriodendron tulipiferi*, *Quercus* sp., and *Acer* sp. The understory was sparse to nonexistent in most plots and throughout much of the study area. *Fagus grandifolia* was observed to be the most common understory tree, often the entirety of the understory, while rarely part of the canopy. *Hamamelis virginiana* and the invasive *Lonicera maackii* were included as trees in the study as several specimens exhibited tree-like growth and grew tall in the sparse understory.

It is problematic to read too much into the results of the ordination as the ordination itself is not statistically significant. As such, several obvervations related to points of dispute in prior research (Keever, Kasner) and some points of obvious uncertainty will be focused upon.

There is some dispute as to whether the prolific *Liriodendron tulipiferi* should be included in analyses of forests in the region. In one local study, it was found to be ubiquitous and influenced primarily by succession, and thus discarded (Keever). This observation has been contested and *Liriodendron* has been found to form some indicative communities (Kasner). In this study, *Liriodendron* appeared to form the basis of a community type and did not appear in several plots. Accordingly, it was not removed from the data.

The findings regarding the environmental differences partly agree with a prior study that found *Acer rubrum* to be associated with low Ca levels, but disagrees with that same study by associating with slightly higher K levels (Kasmer). The distinctiveness of *Acer rubrum* within group 3 disagrees with another study (Keever) that found *Acer rubrum* to have little association with anything else.

Group 2 is largely an unknown. The increased *Fagus grandifolia* population of group 2 may be linked to increased iron, though another study suggested that they are found in nutrient-poor soils (Kasmer). *Alianthus altissima* and *Lonicera maackii* are disruptively invasive species (Invasive.org, 2009); though not present in all plots of group 2, this suggests that the group 2 plots might be linked by some form of disruption.

It must again be stressed that, without a statistically significant ordination, these observations are more hypothetical than anything else. Particularly troublesome is the lack of any environmental correlation along axis 1, but several strong species correlations. Whether this suggests a successional relationship or some environmental factor unaccounted-for is not clear. It could simply be an artifact of the poor ordination within the data (McCune and Mefford 1999). Other methods of analysis, such as an examination of species richness, might likewise reveal a more comprehensible picture.

Despite the lack of clarity in the data, some general results can be suggested. In response to the research question, it does not appear that soil type has a significant impact on tree growth within the GNA. However, concentrations of soil nutrients appear to be a significant factor in the growth and competitive survival of *Liriodendron tulipifera* and *Acer rubrum*. *Acer rubrum* may be more tolerant of iron and manganese deficiency in the soil, while it is possible that *Liriodendron* is more tolerant of arsenic contamination. A higher general slope, as calculated from the 30 meter DEMs, seems to favor *Liriodendron*, but a finer measurement of slope is necessary to see if that holds.

Opportunities for Future Research

Though this study failed to find a statistically significant difference in the composition of tree communities based on soil type, the results show us that other factors do contribute to a statistically significant difference. Based on the fact that the only discernable differences in composition between the soils are found in the trace elements, it is safe to assume that the difference seen so far is based on the parent material and more research is needed to fully understand the differences in the soils and how they are related to the vegetation. To further our research, our group intends to test more plots (ninety instead of thirty). Also, instead of focusing on soil type, we will focus on soil make-up and ph. Aspect and slope will again be taken into consideration, but our slope measurement will not rely on the DEM, because it is too coarse for the size of our study area.

Works Cited

- Anderson, D. W. 1988. "The Effect of Parent Material and Soil Development on Nutrient Cycling in Temperate." *Biogeochemistry* 5.1 71-97. *JSTOR*. Web. 7 Dec. 2009. <http://www.jstor.org/stable/1468630>.

- Beneski, J.T. 2009. Robert b. gordon natural area for environmental studies. http://www.gordonarea.org/ (last accessed 2 December 2009).

- Bigelow, S.E., and Canham, C.D. 2002. "Community organization of tree species along soil gradient in a north-eastern usa forest. *Journal of Ecology* 90 (1): 188-200.

- Brinkley, Dan, and Christian Giardina. 1998: "Why Do Tree Species Affect Soils? The Warp and Woof of Tree-Soil Interactions." *Biogeochemistry* 42.1/2 89-106. *JSTOR*. Web. 1 Dec. 2009. <http://www.jstor.org/stable/1469340>.

- D'Angelo, Gino J. 2009. White-tailed deer management plan Robert B. Gordon Natural Area of West Chester University, Chester County, Pennsylvania. U.S. Dept. of Agriculture Animal and Plant Health Inspection Service.

- Dunn, P.D., and Stearns, F. 1987. A comparison of vegetation and soils in floodplain and basin forested wetlands of southeastern Wisconsin. *American Midland Naturalist* 118 (2): 375-384. http://www.jstor.org. (last accessed 12 November 2009).

- ESRI. 2009. *ArcMap.* Version 9.3.1. ESRI Inc., Redlands, CA.

- Fritschle, J.A. 2009. Pre-euro american settlement forests in red wood national park, california, usa,: A reconstruction using line summaries in historic land surveys . *Land Ecology*.

- Invasive.org Center for Invasive Species and Ecosystem Health 2009. Amur honeysuckle. http://www.invasive.org/species/subject.cfm?sub=3040

- Kasmer, J., P. Kasmer, and S. Ware. 1984. Edaphic factors and vegetation in the piedmont lowland of southeastern pennsylvania. *Castanea* 49 (4): 147-157. http://www.jstor.org (last accessed 12 November 2009).

- Keever, C. 1973. Distribution of major forest species in southeastern pennsylvania. *Ecological Monographs* 43 (3): 303-327. http://www.jstor.org (last accessed 12 November 2009).

- Kent, M. 2006. Numerical classification and ordination methods in biogeography, *Progress in Physical Geography* 30 (3): 399-408.

- McCune, B. and J. B. Grace. 2002. *Analysis of Ecological Communities*. MjM Software, Gleneden Beach, Oregon.

- McCune, B. and M. J. Mefford. 2006. *PC-ORD. Multivariate Analysis of Ecological Data.* Version 5.17. MjM Software, Gleneden Beach, Oregon.

- *Microsoft Office Excel 2003*. Arizona/California: Microsoft, 2003. Computer software

- Nation Cooperative Soil Survey. 2008a. Glenelg Series. Last Updated 2/2008. http://www2.ftw.nrcs.usda.gov/osd/dat/G/GLENELG.html (last accessed 18 November 2009)

- ---. 2008b. Neshaminy Series. Last Updated 10/2008. http://www2.ftw.nrcs.usda.gov/osd/dat/N/NESHAMINY.html (last accessed 18 November 2009)

- ---. 2007. Wehadkee Series. Last Updated 7/2007. http://www2.ftw.nrcs.usda.gov/osd/dat/W/WEHADKEE.html (last accessed 18 November 2009)

- Niton 2008, Thermo Scientific. Billerica, MA

- Perry, G.L.W., B.P. Miller and N.J. Enright. 2006. A comparison of methods for the statistical analysis of spatial point patterns in plant ecology. *Plant Ecology* 187 (1): 59-82.Short, Nicholas M. "Geochemical Variations in Four Residual Soils." *The Journal of Geology* 69.5 (1961): 534-71. *JSTOR*. Web. 8 Dec. 2009.<http://www.jstor.org/stable/30056199>.

- West Chester University. *Gordon Natural Area GIS Datasets*. Last updated 7 October 2007. //geographia/work/GNA/ (internal network link). Last accessed 30 November 2009.

Figures

Figure 1: A map of the sampling plots selected from the transects and created in ArcGIS (ESRI 2009). Points represent the numbered plots, and the three-letter soil code for each soil class studied is shown within the appropriate polygon.

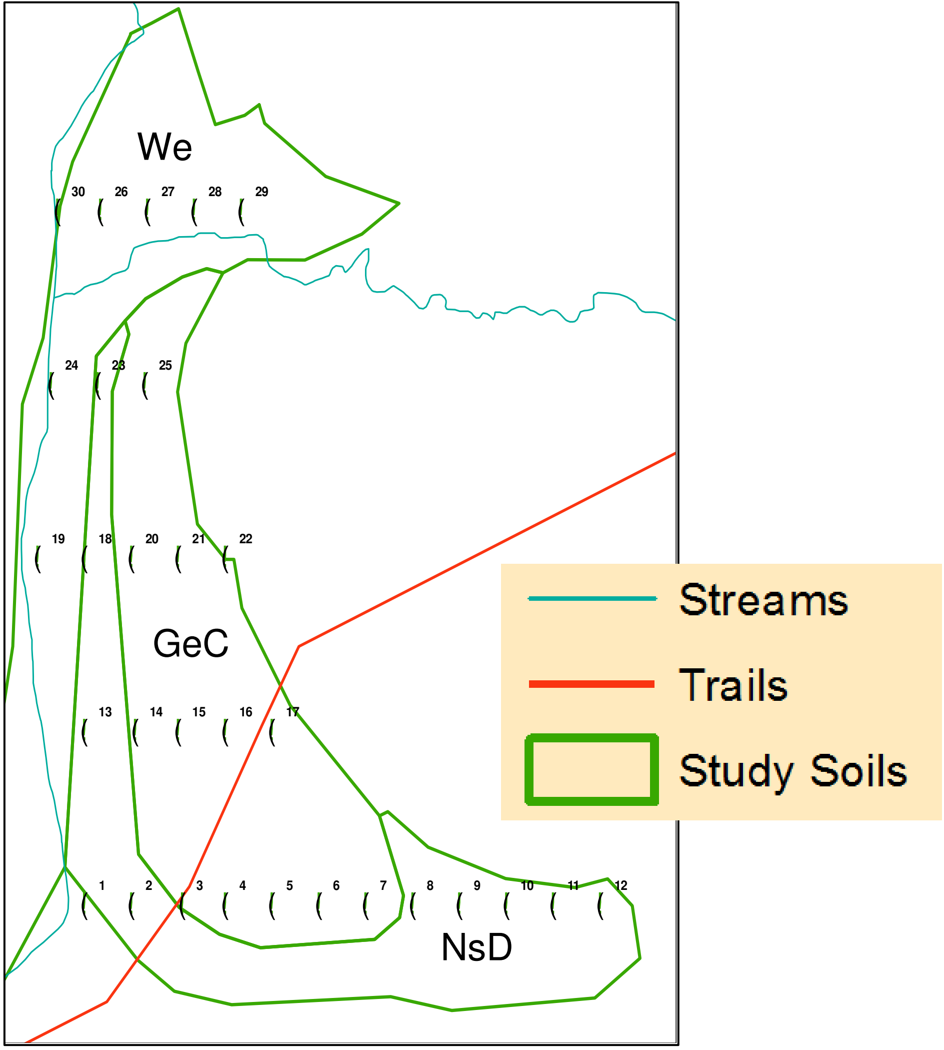
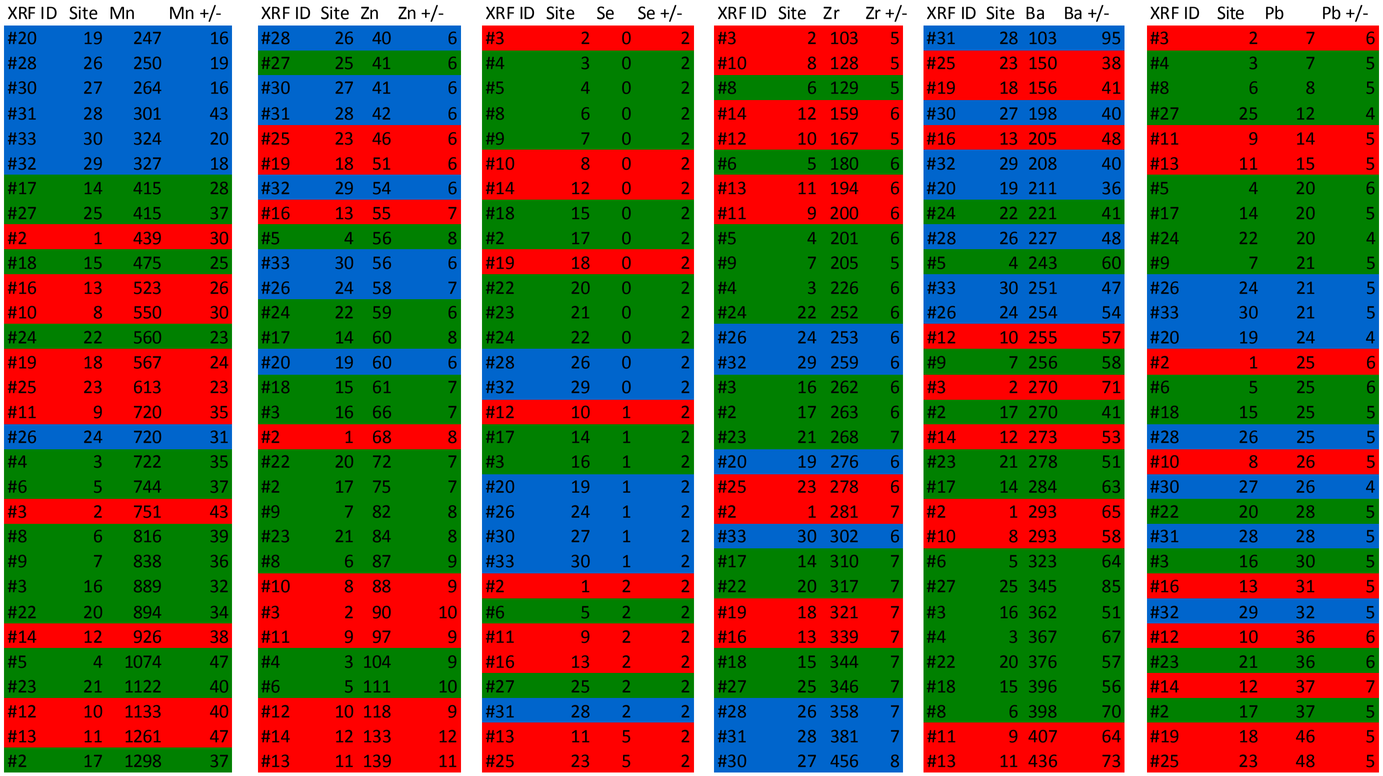


Figure 2 Results for trace elements which showed soil grouping generated from the XRF data and analyzed in Excel



XRF ID	Site	Mn	Mn +/-
#20	19	247	16
#28	26	250	19
#30	27	264	16
#31	28	301	43
#33	30	324	20
#32	29	327	18
#17	14	415	28
#27	25	415	37
#2	1	439	30
#18	15	475	25
#16	13	523	26
#10	8	550	30
#24	22	560	23
#19	18	567	24
#25	23	613	23
#11	9	720	35
#26	24	720	31
#4	3	722	35
#6	5	744	37
#3	2	751	43
#8	6	816	39
#9	7	838	36
#3	16	889	32
#22	20	894	34
#14	12	926	38
#5	4	1074	47
#23	21	1122	40
#12	10	1133	40
#13	11	1261	47
#2	17	1298	37

XRF ID	Site	Zn	Zn +/-
#28	26	40	6
#27	25	41	6
#30	27	41	6
#31	28	42	6
#25	23	46	6
#19	18	51	6
#32	29	54	6
#16	13	55	7
#5	4	56	8
#33	30	56	6
#26	24	58	7
#24	22	59	6
#17	14	60	8
#20	19	60	6
#18	15	61	7
#3	16	66	7
#2	1	68	8
#22	20	72	7
#2	17	75	7
#9	7	82	8
#23	21	84	8
#8	6	87	9
#10	8	88	9
#3	2	90	10
#11	9	97	9
#4	3	104	9
#6	5	111	10
#12	10	118	9
#14	12	133	12
#13	11	139	11

XRF ID	Site	Se	Se +/-
#3	2	0	2
#4	3	0	2
#5	4	0	2
#8	6	0	2
#9	7	0	2
#10	8	0	2
#14	12	0	2
#18	15	0	2
#2	17	0	2
#19	18	0	2
#22	20	0	2
#23	21	0	2
#24	22	0	2
#28	26	0	2
#32	29	0	2
#12	10	1	2
#17	14	1	2
#3	16	1	2
#20	19	1	2
#26	24	1	2
#30	27	1	2
#33	30	1	2
#2	1	2	2
#6	5	2	2
#11	9	2	2
#16	13	2	2
#27	25	2	2
#31	28	2	2
#13	11	5	2
#25	23	5	2

XRF ID	Site	Zr	Zr +/-
#3	2	103	5
#10	8	128	5
#8	6	129	5
#14	12	159	6
#12	10	167	5
#6	5	180	6
#13	11	194	6
#11	9	200	6
#5	4	201	6
#9	7	205	5
#4	3	226	6
#24	22	252	6
#26	24	253	6
#32	29	259	6
#3	16	262	6
#2	17	263	6
#23	21	268	7
#20	19	276	6
#25	23	278	6
#2	1	281	7
#33	30	302	6
#17	14	310	7
#22	20	317	7
#19	18	321	7
#16	13	339	7
#18	15	344	7
#27	25	346	7
#28	26	358	7
#31	28	381	7
#30	27	456	8

XRF ID	Site	Ba	Ba +/-
#31	28	103	95
#25	23	150	38
#19	18	156	41
#30	27	198	40
#16	13	205	48
#32	29	208	40
#20	19	211	36
#24	22	221	41
#28	26	227	48
#5	4	243	60
#33	30	251	47
#26	24	254	54
#12	10	255	57
#9	7	256	58
#3	2	270	71
#2	17	270	41
#14	12	273	53
#23	21	278	51
#17	14	284	63
#2	1	293	65
#10	8	293	58
#6	5	323	64
#27	25	345	85
#3	16	362	51
#4	3	367	67
#22	20	376	57
#18	15	396	56
#8	6	398	70
#11	9	407	64
#13	11	436	73

XRF ID	Site	Pb	Pb +/-
#3	2	7	6
#4	3	7	5
#8	6	8	5
#27	25	12	4
#11	9	14	5
#13	11	15	5
#5	4	20	6
#17	14	20	5
#24	22	20	4
#9	7	21	5
#26	24	21	5
#33	30	21	5
#20	19	24	4
#2	1	25	6
#6	5	25	6
#18	15	25	5
#28	26	25	5
#10	8	26	5
#30	27	26	4
#22	20	28	5
#31	28	28	5
#3	16	30	5
#16	13	31	5
#32	29	32	5
#12	10	36	6
#23	21	36	6
#14	12	37	7
#2	17	37	5
#19	18	46	5
#25	23	48	5

Figure 3: Three-dimensional ordination of sampling plots, visually sorted into three community-type clusters, output from PC-ORD v5.0 as a result of NMS performed on total basal area of species within each plot using Sørenson's distance measure (McCune and Mefford 1999). Groups were identified by visual clustering along axes 2 and 3, as no environmental variables corresponded strongly to axis 1. Points represent the sampling plots in three-dimensional ordination space.

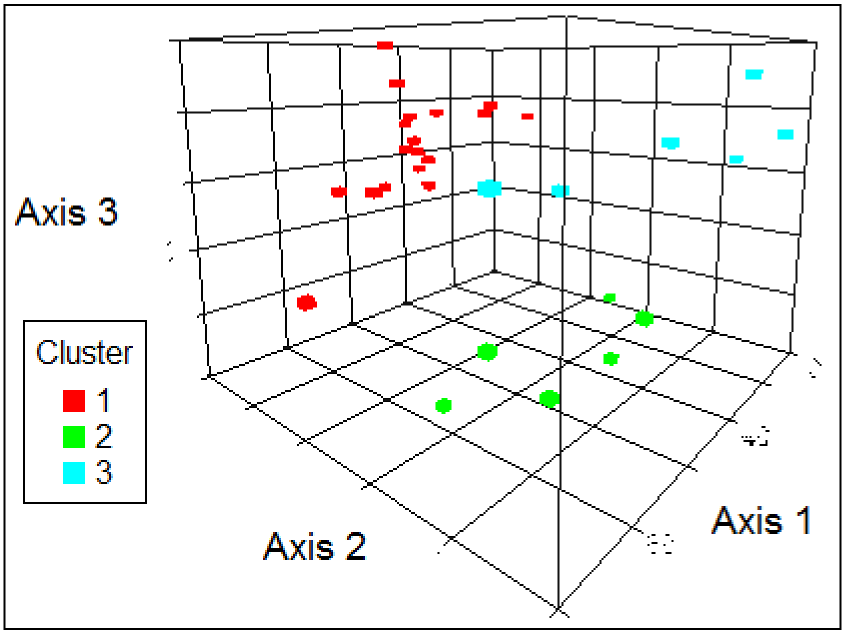


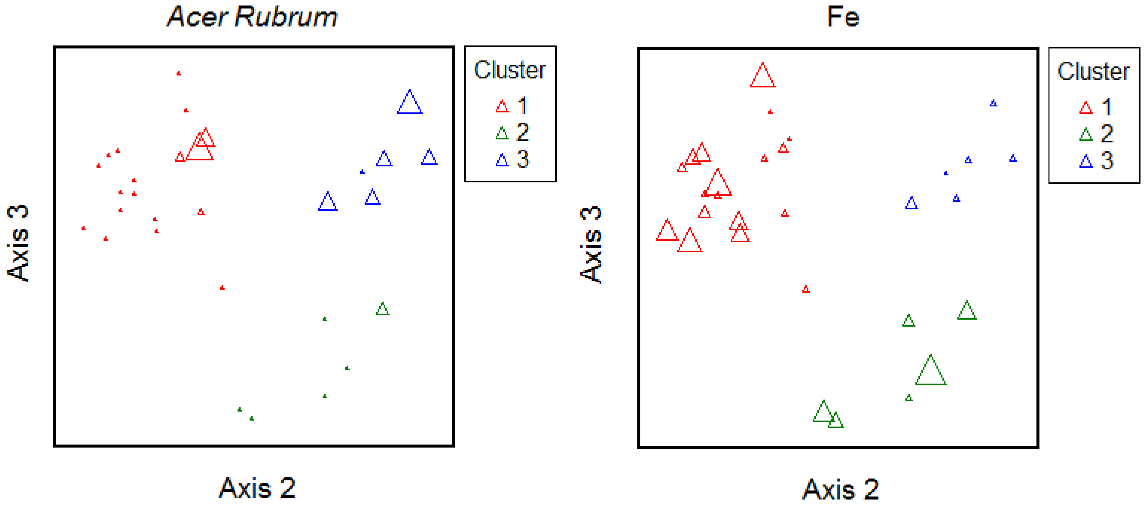
Figure 4: Kendall's Tau and the statistical significance of environmental factors along the three ordination axes as computed by PC-ORD (McCune and Mefford 1999). **Bold** indicates a .05 confidence level and ***bold italics*** represent a .01 confidence level. Notable is the absence of any significant relationship to environmental factors along Axis 1.

Axis:	1	2	3
	tau	tau	tau
Topography:			
Aspect	0.101	-0.059	-0.021
Slope	-0.012	**-0.3**	-0.102
Soil Element Concentration:			
K	-0.067	0.205	0.007
Ca	0.133	-0.212	-0.253
Ti	-0.016	0.071	-0.246
Cr	0.07	-0.153	-0.246
Mn	0.067	***-0.366***	-0.081
Fe	0.044	-0.237	**-0.278**
Co	0.028	-0.217	-0.212
Cu	-0.108	-0.042	0.009
Zn	0.083	**-0.314**	-0.221
As	-0.017	**-0.258**	0.081
Se	0.059	0.193	-0.014
Br	0.096	-0.171	-0.016
Rb	-0.075	0.014	0.009
Zr	-0.039	***0.333***	0.062
Sn	0.023	0.096	-0.111
Sb	0.08	0.022	-0.236
Ba	0.085	-0.094	-0.136
Hg	-0.03	0.063	-0.03
Pb	0.117	0.019	0.009

Figure 5: Kendell's tau and the statistical significance of tree species along the three ordination axes as computed by PC-ORD (McCune and Mefford 1999). **Bold** indicates a .05 confidence level and ***bold italics*** represent a .01 confidence level. Several tree species vary significantly along Axis 1, in contrast to Figure 3.

Axis:	1	2	3
	tau	tau	tau
Species			
Fagus grandifolia	***0.491***	0.17	**-0.286**
Acer platanoides	0.136	-0.252	0.092
Acer rubrum	-0.141	***0.369***	0.197
Quercus alba	0.083	-0.108	-0.133
Liriodendron tulipifera	-0.137	***-0.731***	0.077
Prunus serotina	0.103	**-0.285**	0.012
Carpinus caroliniana	0.031	0.073	-0.063
Cornus florida	0.062	-0.223	-0.134
Quercus rubra	***0.396***	-0.007	***-0.349***
Hamamelis virginiana	-0.015	-0.144	0.095
Fraxinus americana	0.167	0.146	-0.209
Quercus velutina	0.021	0.01	0.157
Lonicera maackii	-0.165	-0.091	-0.082
Carya ovata	***-0.369***	0.004	0.027
Carya tomentosa	***-0.349***	0.184	-0.171
Acer negundo	-0.248	**0.273**	-0.07
Nyssa sylvatica	0.009	-0.151	0.027
Ailanthus altissima	-0.134	0.116	-0.223

Figure 6: A visual comparison of Fe concentrations and red maple, *Acer rubrum*. Note that the iron-impoverished cluster 3 has the most consistent population of *Acer rubrum* and the red maple also appears in an iron-poor portion of cluster 1.


Acer Rubrum

Fe

Figure 7: *Liriodendron tulipifera* was found only at the sites sorted into group 1

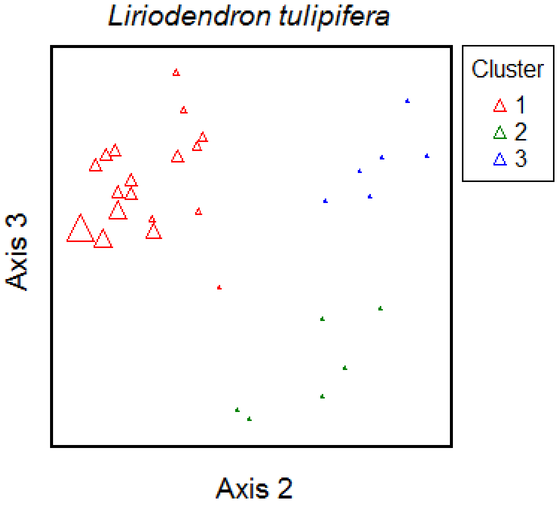

Liriodendron tulipifera

Figure 8 A map generated in ArcMap 9.3.1 shows the spatial distribution of the tree groups overlaid with the soil types (ESRI 2009). There is no apparent general spatial relationship between the tree communities and no relationship to the soil groups.