The Effects of Size, Distance and History on Urban Forest Patches

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Abstract

The urban forest is composed of varying sizes of patches of trees across the landscape with different histories. The literature in urban ecology has found a correlation between size of these patches of forest and species homogeneity (Hobbs 1988, Godefroid and Koedam 2003). The purpose of this study is to find the effects of three variables on the urban forest: distance from a continuous forest, area of the patch, and site history. The study investigates how these variables can affect the species diversity, composition, and growth. Several sites within the City of Bloomington and on Indiana University campus have been selected. The study expected to find a relationship between higher species diversity, greater number of invasive species and larger edge habitats. However, the study found no correlations between species diversity, site history, site area and distance from the rural forest.

Introduction

Biodiversity is an important subject when exploring and observing the urban forest. This can be used to evaluate the health of the ecosystem as well as help the resilience of the same. In recent history, humans have altered the forests compositions through changing the regime of disturbances in which these trees have evolved to live, allowing some species to decline and allowing other species to thrive (Redmend et al. 2012).

Species of oak (*Quercus*) and hickory (*Carya*) dominate the forests of southern Indiana and the suppression of natural processes is causing the forest to change, having more shade tolerant species of maple (*Acer*) and beech (*Fagus*) (Pierce et al. 2006). In the urban environment, practices of fire suppression and fragmentation of forest patches are more frequent creating many challenges for the urban forest. These regimes allow the composition of the forest to change over a period of time (Pierce et al. 2006).

The urban environment has allowed invasive species to thrive with little preventing them from taking over completely. The loss of the urban forest due to invasive species overrunning it will be a loss for all of us. The urban forest provides us with many ecosystem services from carbon sequestration, water purification, aesthetic benefits, and many more (Fisher et al. 2009). These services are provided to us all at little to no cost, making the urban forest a communal resource can receive many benefits (Fischer and Steed 2008).

Because invasive species of the varying impacts towards our forests, the resilience of the urban forest is key to preserve the forest against these attacks (Parker et al. 1999). Invasive plants are also outcompeting the native flora for nutrients and space. The introduction of these invasive species can lead to large declines in native species or even the local disappearance of species (Oduor 2013). These factors are a large problem for the future of our forests, urban and rural. These pressures from invasive species will decrease biodiversity in the future (Sala et al. 2000).

The species richness and diversity of the urban forest may be a way to help overcome the problem of invasive species infesting the urban forest (Hejda et al. 2009). Species richness is linked to a few easily measured variables such as area and isolation, and the evaluation of these simple variables can be measured and used to predict the health of the urban forest (Hobbs 1988, Godefroid and Koedam 2003). An analysis of the health of the urban forest can help its managers to increase species richness.

Biodiversity is an important factor in determining the health of an ecosystem (Mack 2000), this study wants to find easy ways to be able to assess the potential health of urban forest by finding if area, site history and distance from rural forest are determining factors for diversity. If one of these variables is linked to diversity in the patches of urban forest, a quick evaluation and overall health of the urban forest can be determined.

This study aims to answers the following research questions:

1) In patches of urban forest, how do species composition and diversity change with patch area?
2) How does site history affect the urban forest change species composition and diversity?
3) How does increasing distance from rural forest change species composition and diversity?

The previous conditions of the site, how it was used and what it was may have lasting affects on the ecology (Foster et. al 2003, Lindborg & Eriksson 2004). The study expects to find that as the area of the urban forest patch increases, the diversity and species evenness will increase as well. The distance of the urban forest patch from the rural forest will not affect the diversity of the sites. No particular hypothesis was made for history of these sites due to this study is analyses of history being more qualitative in nature, although it is believed that the historical background of any site is critical to understand any driving force of how the sites succession is proceeding.

Methods

Study Area

City of Bloomington Urban Forester Lee Huss was consulted to help in identifying 26 sites with varying size and distance from the rural forest (figure 1). Sites were chosen to fall within the boundaries of south of State Road 45/46, east of Walnut Street and north of Hillside Drive. A total of 9 sites were studied: 2 classified as small (figures 2 and

3) 4 classified as medium (figures 4, 5, 6, and 7), and 3 sites classified as large (figures 8, 9, and 10). The Bloomington Urban Forester has provided some information on site history as well as information obtained by talking to locals and via the Internet.

Field Methods

The sampling units were selected using a random number table: a random order of compass direction was paired with a random distance in meters from top to bottom. While collecting data, when approaching the edge of the studied area, I made a 45° angle turn. One sampling unit consisted of a circular $314 m^2$ area. In each quadrat, the tree species was identified and the DBH and height of the tree were measured. The tree DBH was measured with a DBH tape and tree heights was measured using mainly a hypsometer or clinometer if the treetops cannot be accurately measured with hypsometer. Trees under 2 cm in diameter were grouped together and an average height was determined.

Data Analysis

All data was entered into a Microsoft Excel spreadsheet and later analyzed using the Shannon Diversity Index ($H = \sum_{i=1}^{s} -(P_i * \ln P_i)$, species richness, proportional abundance ($p.a. = \frac{\#\, of species}{total\ number\ of\ species}$), and Pielou's J species evenness ($J = \frac{H}{H_{max}}$) (Heip et al. 1998). ESRI ArcGIS was used to find all areas of urban forest patches and distances. The northwest corner of Park Ridge East Park, which is the closest point to the continuous rural forest, was used as a point of reference to determine distance.

Site Description

The first site is Fess and 12th and it is located on the corner of Fess Avenue and 12th Street (figure 3). The site is not maintained or managed and it has a railroad track located to the north and with Fess Avenue bordering it to the west. The site Fess and 12th was classified to have a major invasive species problem; it had three forms of invasive species, herbasous ground cover, shrubs and trees.

The site Atwater and Rose is located at Atwater Avenue and Rose Avenue (figure 7). The site has residential homes to its south and west boundaries. Mowing is the primary method of maintenance of the understory.

The site Ballantine Woods is located on the campus of Indiana University (figure 4). The site is a flat area in close proximity between two tall buildings; the Chemistry building to the west and Ballantine Hall to the east and bordered by Simon Hall to the south. The site has paths crisscrossing through it, has constant human activity and is maintained by ground crew for safety purposes.

Woodlawn and Weatherstone is a long narrow track of land with residential homes to the north and Weatherstone Ln. to the south (figure 2). The site is mounded with a single washout running down the center, it is minimally maintained for safety purposes only and had many piles of brush throughout the area.

SPEA Woods is located on the campus of Indiana University, to the northeast of the SPEA building, west of Jordan Avenue and south of the railroad tracks (figure 6). The site is located on a hillside with a southern facing exposure and it is not maintained or managed. The site has heavy human presence and it currently has construction along the railroad tracks.

The site 17th and Fee is located on the campus of Indiana University on Fee Lane, north of the campus swimming pool and south of the Indiana University Student Foundation (figure 5). The site has a flat terrain and a single path running through it that brings human activity to the area. Like the other sites on campus, IU grounds crew maintain this site.

Dunn's Woods is an area inside the Indiana University campus (figure 9). The site has brick paths crisscrossing throughout and it is a heavily trafficked area on campus. IU ground crew maintains the area. Dunn's Woods has an active invasive species removal programs and had minimal invasive species present (Indiana University office of Sustainability 2014).

Latimer Woods is located south of the mall along Buick Cadillac Blvd (figure 10). The site has continuous human activity and City of Bloomington Parks and Recreation crew maintains it for safety purposes only. Latimer Woods has an active invasive species removal programs and had minimal invasive species present (Indiana University office of Sustainability 2014).

The site 45/46 and 17th is located at the corner of State Road 45/46 Bypass and 17th Street (figure 8). It is an area with residential properties on the west side, State Road 45/46 Bypass on the east side and 17th Street to the south. This site was not maintained or managed to my knowledge at the time of data collection.

Results

This study finds no relationship between average tree DBH or height and the distance of the urban forest patch from the rural forest increases (figure 11). No trend was found with the average DBH of the sites, however a slight positive trend upward indicating that as the area increases the average heights of the forest patches also increases, which indicates that this may be due to competition for space and resources (figure 12).

Figure 13 shows that the evenness of Ballantine Woods, it is the least even patch. However, it has medium-to-low species richness, while Latimer Woods, which is the largest site, has moderate evenness and it has the highest species richness. Fess and 12th is the smallest site and has the lowest species richness and highest species evenness.

A slight negative trend was found between the basal area and the area of the sites: as basal area decreases, the area of the sites increase (Figure 14). A slight positive trend was indicated: as the distance from the rural forest increases, the basal area also increases (Figure 15). Although there are slight trends, these trends are not conclusive and more data is needed to determine any significant relationship.

Figure 16 shows that as the area of the urban forest patch increases the evenness decreases and richness increases as the patch area become larger as well. Shannon diversity index shows no pattern or slight trend related to area. Figure 17 shows a slight negative trend between species richness and site distance from the rural forest. No pattern was found between the Shannon diversity Index or evenness index and the distance from the urban patch to the rural forest increases. Although a full history was not available for all of the sites, some of the histories are well documented including Dunn's Woods and Latimer Woods. Latimer Woods is known to be an oldgrowth forest within the city limits. It was previously a family farm and into 2005 the site began to be actively manage for invasive species (City of Bloomington n.d. and Indiana University office of Sustainability 2014). The University purchased Dunn's Woods in 1883 from the Dunn family; the site was previously a part of a family farm similarly to Latimer Woods (Bracalente 2012). The forest patch was allowed to stay a natural and remnant forest patch.

All other sites did not have such well-constructed histories. According to the City of Bloomington Urban Forester, the Woodlawn and Weatherstone site was to be developed by the city to become a street; however, the street was never constructed. This site is now used by wildlife as a corridor to move within and between neigborhoods and to a Bryan Park. An elderly gentleman told the history of the site Atwater and Rose. The site at one time had a single-family home, which was eventually donated to the Indiana University and after the original owners had passed, the house was finally torn down.

The site Rose and Atwater had the highest diversity than any other site. The history of the site may plays a role in its diversity, since it previously was a yard where uncommon species were found, and due to being artificially planted, which also may have contributed to the increase of the diversity of the site. Two species dominate Ballantine Woods sugar maple (*Acer* saccharum) and white ash (*Fraxinus* americana) making it lowest in species diversity.

Seventeenth and Fee did not have a witness to tell its story or recorded history about the site, however when collecting data a well and foundation were found, making it possible to conclude that the site previously had a house and given the history of the other nearby areas, it may have been a part of a farm.

Discussion

This study found no significant relationship between the distance from a continuous patch of rural forest and species diversity nor area of the patch and diversity, other studies have found that species richness has a positive relationship with area (Hobbs 1988, Godefroid and Koedam 2003); however, this study has not been able to confirm that relationship.

This study found no relationship with species diversity or richness and the area of the area of the urban forest patches. According to other studies, there are positive relationships between area and richness.

This study found that distance from the rural forest to the urban patch only slightly affects species richness. Proximity to a rural forest has little effect compared to the influence of the species that are being planted in the neighborhoods directly surrounding the urban forest patches (Dzwonko and Loster 1988).

Maximum DBH of the largest tree was used as a proxy for the relative age of each site since a complete and accurate historical background or site age was not available. As the relative age decreases, tree density increases (figure 18), although the site Fess and 12^{th} (figure 3) did not fit this trend. This may be due to the presence of invasive species in the form of herbaceous groundcover, woody shrubs, and trees. These three forms of invasive species are suppressing the capability of the urban forest to regenerate. Individually they may not pose a problem to the regeneration of the urban forest, however together they are causing enough damage that may decrease the density of the trees significantly.

The histories of a few sites altered their diversity. The site 17th and Fee (figure 5) may have not had any documented past, however a few uncommon species on the site helped increase its Shannon diversity and richness. The site was covered in native trees and trees that would normally grow on the site, although it also contained Canadian hemlock (*Tsuga canadensis*), ginkgo (*Ginkgo biloba*), and fir (*Abies*). These species are not native to Indiana yet they are commonly planted in urban areas within the state. The site Atwater and Rose (figure 7) had a single family home at one time and it also has trees that are outside of their native ranges, such as bald cypress (*Taxodium distichum*). These two sites have trees species that have been planted, and this is a factor that may have altered them to artificially inflate their species diversity. These trees may help increase the species diversity, nonetheless they may not impact the health of the site. These species may be taking away from the native species in the landscape altering some of the urban forest ecological services.

Latimer Woods (figure 10) and Dunn's Woods (figure 9) were sites with the oldest known histories and they both had evenness numbers that were average compared with all the other sites, although it had higher species richness. The largest three sites in area also had the three largest maximum tree diameter.

The problem of invasive species is not new and is a growing concern. The community is frequently introducing new invasive species to the urban forest, such as the Asian long-horned beetle (*Anoplophora glabripennis*) and the emerald ash borer (*Agrilus planipennis*) causing damage to urban forest. Management for invasive species is imperative for the health of the urban forest (Sakai et al. 2001). Figure 13 shows that the sites Latimer Woods (figure 10) and Dunn's Woods (figure 9), have an ongoing invasive species removal program and they have the highest species richness, while the site with the worse invasive species problem, Fess and 12th (figure 3) has a decrease in tree density, an increase in species evenness and a decrease in species richness. Findings indicate that where the presence of invasive species increases, they reduce the species richness as well as abundance and growth (Richardson et al. 1989, Loomis and Cameron 2014).

This study found no substantial relationship between size, area, history and determining the diversity of the urban forests. However, this study has found that the presence of invasive species is affecting the urban forest. Invasive species may be hindering the generation of the young urban forest causing a decrease in the density of trees. The maps of the sites give a potential clue to why their diversity may not have any positive correlations with the area. The shape of the site may play a more critical role in the urban forest than area (Bastin and Thomas 1999). These forest patches are fragmented ecosystems and have high edge-to-interior ratio, which will influence the vegetation that the site is comprised (Matlack 1992). Edge-to-interior ratios may be a better indicator for species diversity than just the area. Figure 2 is a site comprised of all edge habitats and it is not able to have an interior. This may restrict the types of vegetation that is able to thrive in this environment.

In conclusion, urban forest patches are complex subjects to analyze. There is not a single variable that can be measured to predict factors as complicated as species diversity (Bastin and Thomas 1999). There are a large number of factors that come into play when exploring a complex system such as the urban forest. The presence of invasive species is one driving force that maybe decreasing native species diversity and the management of these species is paramount to the health of these urban forest patches. Further research in how invasive species are affecting the regeneration of urban forests is needed to help define the dominant factors that influence species diversity of urban forest patches.

Figures

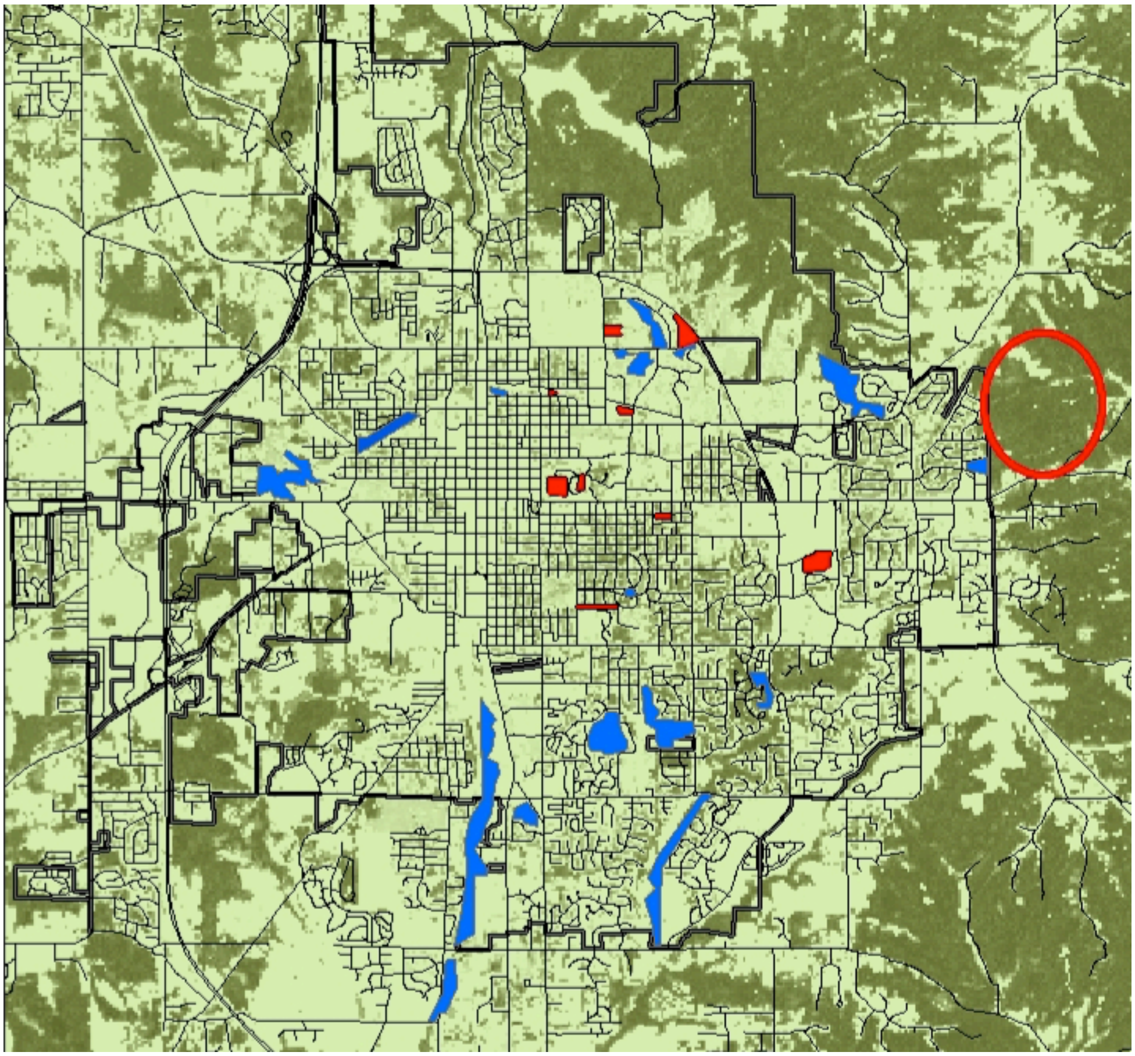

Figure 1: A site map of all possible sites indicated by the City of Bloomington Urban Forester, Lee Huss. Sites in red are sites studied; the sites in blue are areas that were considered but not chosen. The red circle is the patch of rural forest used to measure all distances from.

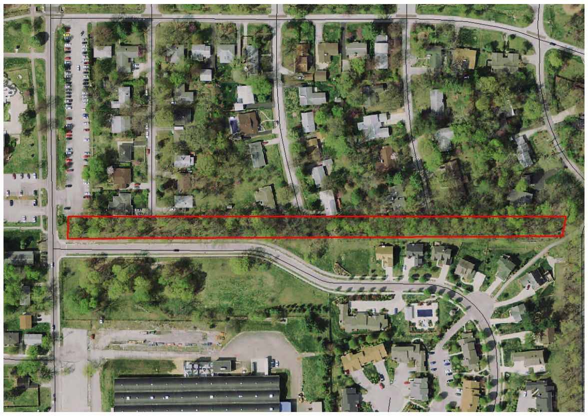

Figure 2: Woodlawn and Weatherstone is classified as a small site.

Figure 3: Fess and 12th is classified as a small site.

Figure 4: Ballantine Woods is classified as an intermediate sized site.

Figure 5: 17th and Fee is classified as a intermediate sized site.

Figure 6: SPEA woods is classified as a intermediate sized site.

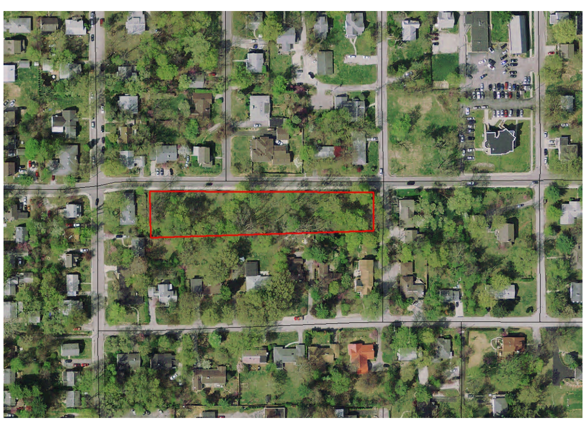

Figure 7: Atwater and Rose has a mowed understory and is classified as a small site.

Figure 8: State Road 45 46 and 17th is classified as a large site.

Figure 9: Dunn Woods is classified as a large site.

Figure 10: Latimer Woods is classified as a large site.

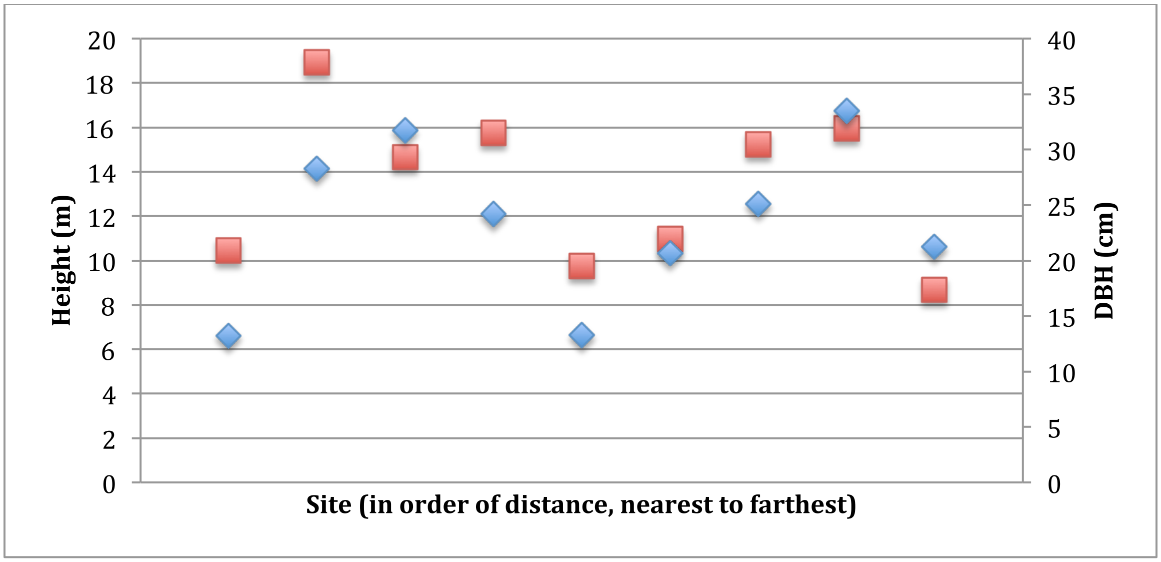

Figure 11: The blue diamonds are the average DBH according to the distances from left to right. The red squares are the average heights according to the distances from left to right.

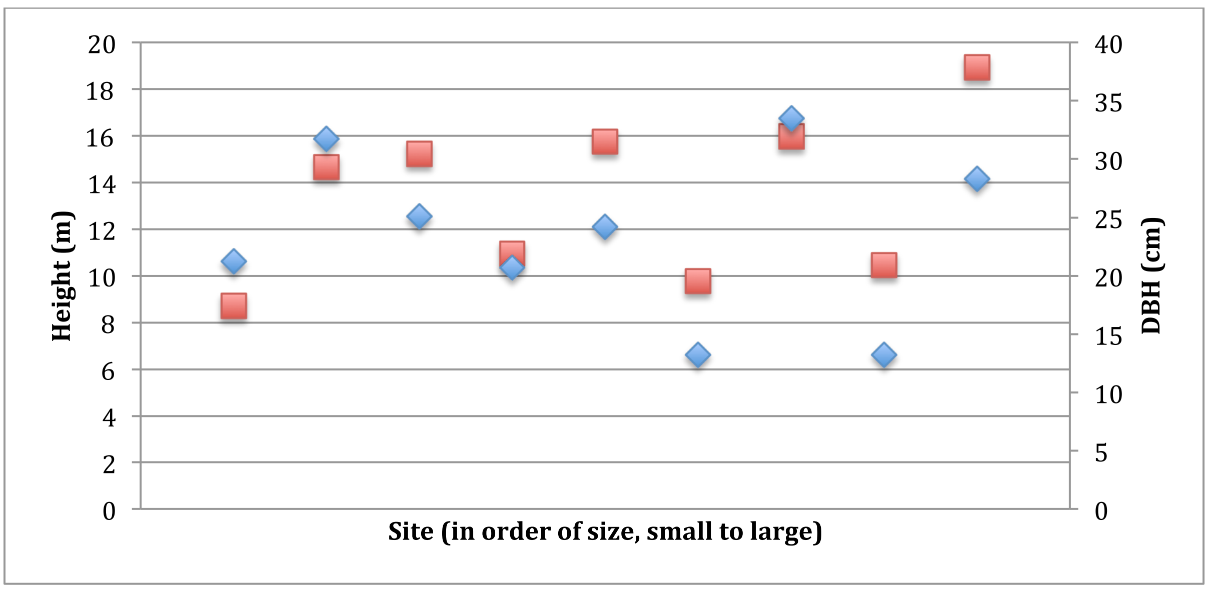

Figure 12: The blue diamonds are the average DBH of trees according to site size from left to right. The red squares are the average heights according to the size from left to right.

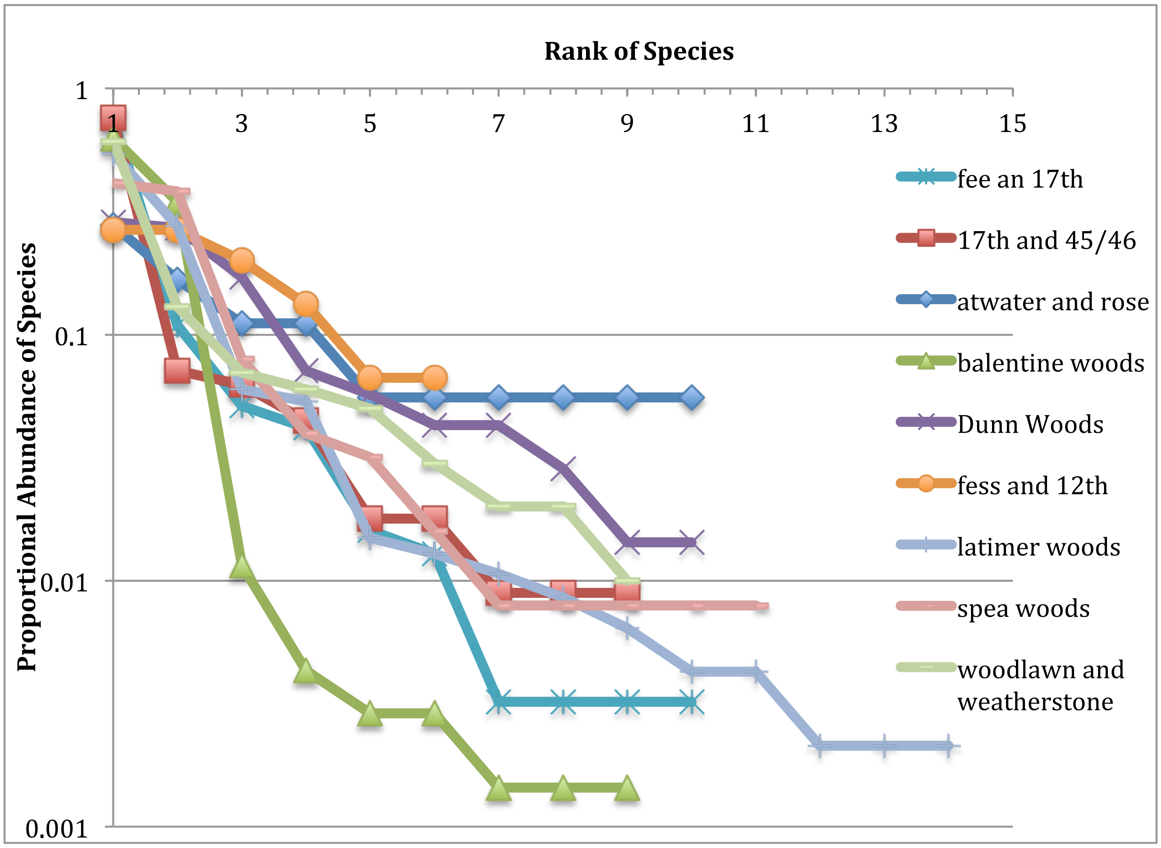

Figure 13: A ranked landscape proportional abundance using a log scale on the y-axis. The red boxes represent 17th and 45/46, the blue diamonds represent Atwater and Rose. The green triangles represent Balentine woods. The purple line represents Dunn woods. The orange circles are Fess and 12th. The blue crosses represent Latimer woods. The red dash lines represent SPEA woods and the green dash lines represent Woodlawn and Weatherstone.

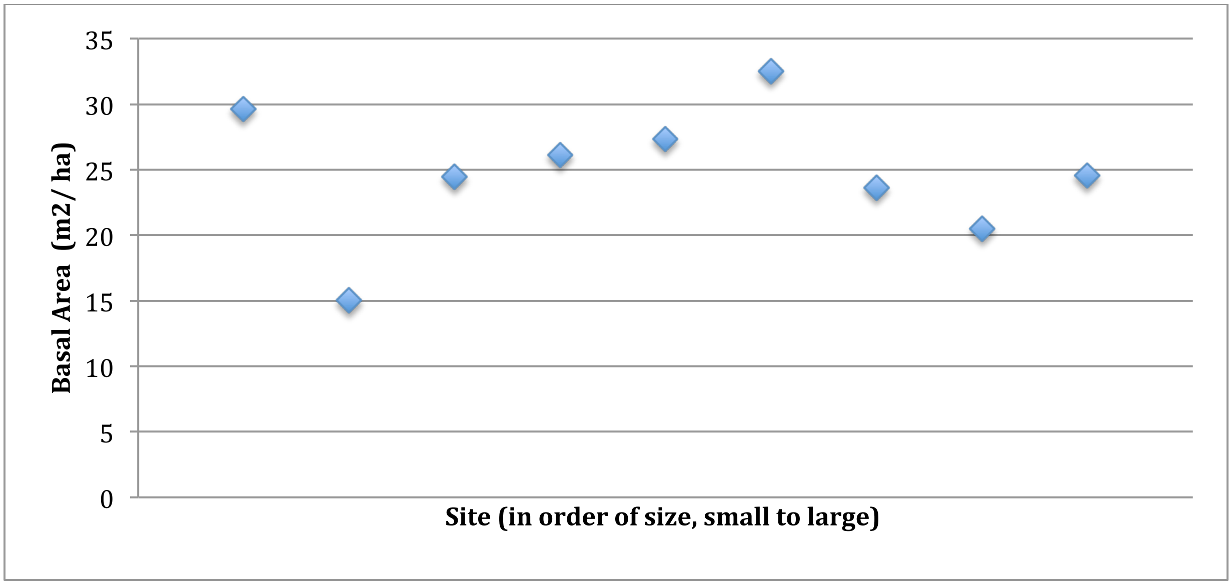

Figure 14: Basal Area in m^2/ ha. The blue diamonds are oriented with the smallest in area on the left and the largest on the right.

Distance

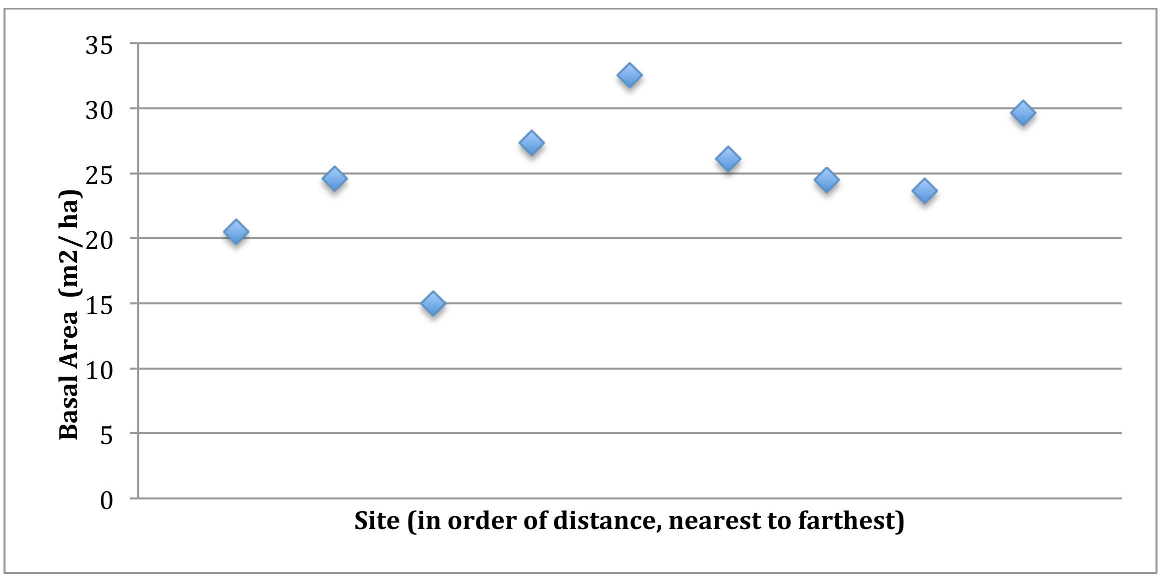

Figure 15: Basal Area in m^2/ ha the blue diamonds are oriented with the closes to the rural forest on the left and the farthest on the right.

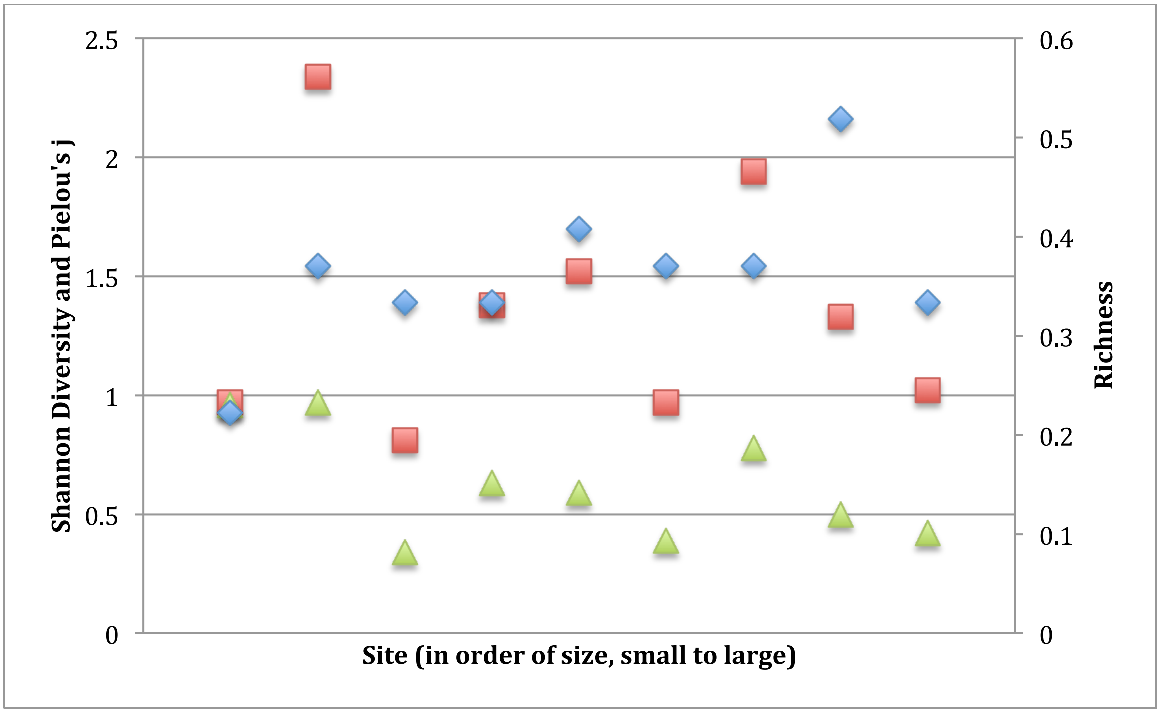

Figure 16: landscape richness (blue diamonds), Shannon diversity index (Red squares), and Pielou's j species evenness (green triangles) by site size.

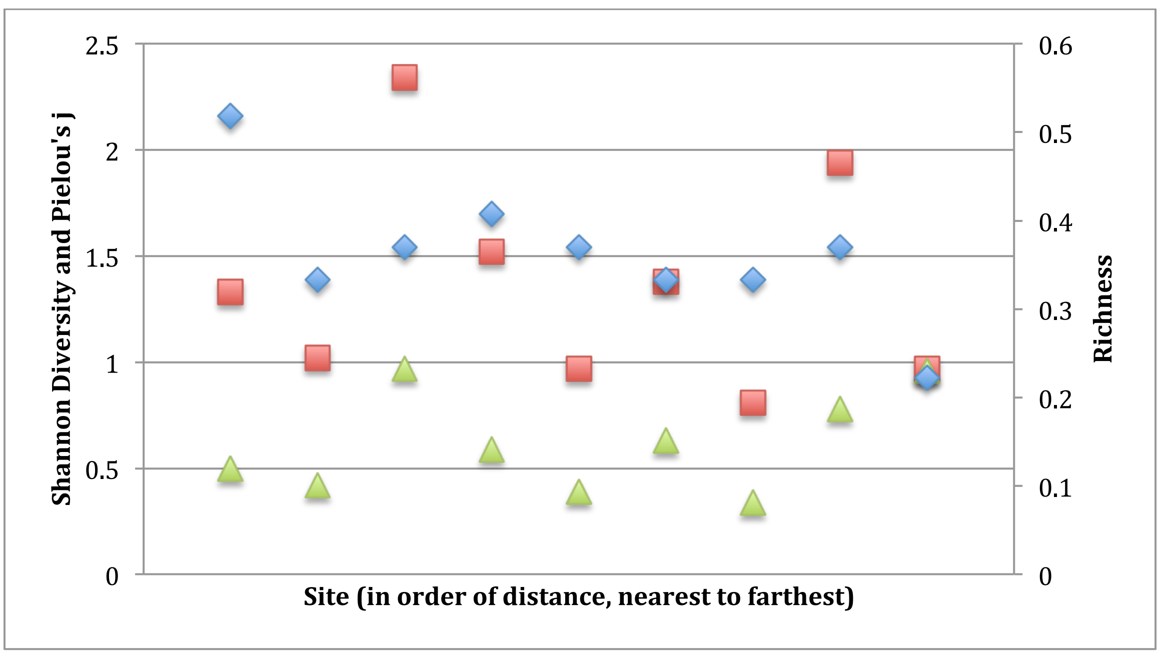

Figure 17: The right vertical axis has blue diamonds that indicate landscape richness. Red squares are the Shannon diversity index and green triangles indicate the Pielou's j species evenness and are located on the left axis. The graph is ranked according to site size with the closest on the left and the farthest on the right.

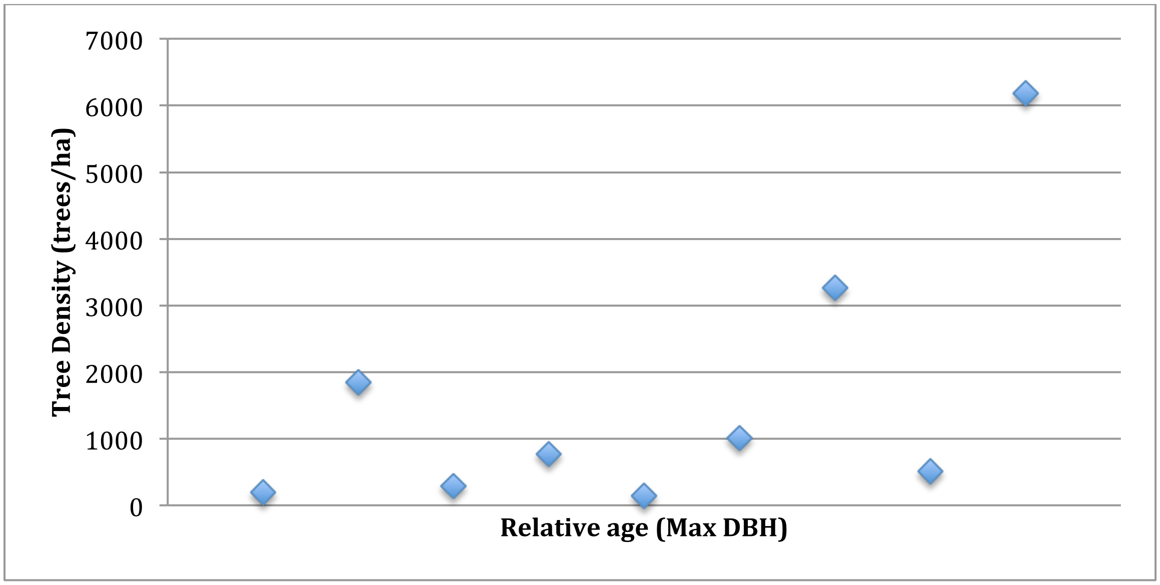

Figure 18: Tree density arranged by relative history of the sites. The maximum DBH at each site is used a proxy for history. The site with the largest tree DBH is to the left and the site with the smallest max DBH to the left.

Table 1: A complation of all the data from the 9 sites.

	Area (ha)	Area surveyed (ha)	Percent of Total Site Area Surveyed	Distance from Forest (km)	Tree Composition	Shannon Diversity	Pielous j	Tree density (trees/ ha)	Basal Area (m/ ha)	Top 3 genera Percent abundance		Max DBH (cm)	Max Height (m)
Atwater and Rose	0.5	0.13	27.8	3.41	9 species in 9 genera	2.34	0.97	151	15.01	Celtis Quercus Acer All others	29% 18% 12% 41%	Tuliptree (Liriodendron tulipifera) 68.0	Tuliptree (Liriodendron tulipifera) 28.2
Balentine woods	0.7	0.11	15.7	4.30	9 genera in 10 species	0.81	0.34	6,181	24.47	Fraxinus Acer Cercis All others	63% 35% 1% 1%	Sugar maple (*Acer* saccharum) 48.3	Sugar maple (*Acer* saccharum) 25.4
Dunn Woods	3.5	0.36	10.4	4.49	13 species in 10 genera.	1.94*	0.78*	197*	23.63*	Acer Prunus Fagus All others	29% 27% 17% 27%	Tuliptree (Liriodendron tulipifera) 103.1	Tuliptree (Liriodendron tulipifera) 31.9
Fee and 17th	1.3	0.09	7.5	4.13	10 genera in 11 species	0.97	0.39	3,270	32.54	Acer Fraxinus Prunus All others	76% 11% 5% 8%	Canadian hemlock (*Tsuga canadensis)* 57.3	Tuliptree (Liriodendron tulipifera) 29.4
Fess and 12th	0.2	0.03	14.9	4.63	genera in 8 species	0.97	0.96	510	29.65	Acer Fraxinus Prunus All others	76% 11% 5% 8%	Elm (Ulmus) 56.8	Elm (Ulmus) 18.8
Latimer woods	4.1	0.25	6.2	1.88	14 genera in 14 species	1.33	0.50	1,851	20.49	Acer Asimina Sassafras All others	28% 54% 6% 12%	Tuliptree (Liriodendron tulipifera) 92.3	Beech (Fagus grandifolia) 38.8
SPEA woods	0.9	0.13	13.9	3.83	11 generas in 12 species	1.52	0.59	1,011	27.35	Acer Fraxinus Carya All others	41% 38% 8% 13%	Black walnut (Juglans nigra) 62.7	Black walnut (Juglans nigra) 27.4
State Road 45/46 &17th	4.1	0.38	9.1	3.33	10 species in 9 genera.	1.02*	0.42*	294*	24.58*	Acer Juglans Liriodendron All others	76% 7% 6% 11%	White ash *(Fraxinus* Americana) 90.4	White ash *(Fraxinus* Americana) 36.5
Woodlawn and Weatherstone	0.7	0.13	17.5	4.23	9 genera in 9 species	1.38	0.63	772	26.13	Acer Celtis Ulmus All others	61% 13% 7% 19%	Sugar maple (*Acer* saccharum) 69.5	Sugar maple (*Acer* saccharum) 23.0

*Data only contains DBH's of 10 cm and greater

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