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2021

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December 2021

Abstract

Increasing urban heat island effects and atmospheric greenhouse gas concentrations with climate change require cities to develop plans to ameliorate these anthropogenic factors. Street trees and urban forests are possible global warming mitigation strategies as trees sequester carbon. Urban street trees and rural forests sequester carbon at different rates for the same species due to environmental and site conditions. The purpose of this study is to understand how urban street trees and forests compare in tree composition, growth rates, and carbon sequestration rates. In Northfield, Minnesota, urban street trees and rural forest trees were sampled and size and growth rate data were compared by species and by site. I found that street trees were on average larger with higher growth rates than the forest trees. City blocks were also more species diverse and age diverse than the forest trees. While urban trees will sequester carbon more quickly, rural forest trees of the same species will sequester more carbon overall due to a longer life span. Current literature predicts that all species experience a higher growth rate due to increased temperatures from the historical norm making this study even more relevant. These results confirm that street trees are as effective as forest trees and should be seen as a mitigation strategy for cities to reduce air pollution, heat island effects, and sequestering carbon. The results of this study will be useful for urban planners, foresters, and environmental health practitioners in understanding tree ability to absorb carbon and the potential for mitigating climate change.

Keywords: Green infrastructure, trees, street trees, carbon sequestration, growth rates, maple-basswood forest, Climate Change

Introduction

As urban areas contribute to over 70% of the CO_2 emissions globally, it is important to find ways to mediate these emissions (WHO 2021). People in cities use 1000 times more energy than that consumed by forests, amounting to 75% of the world's energy resources being used by cities (Madlener and Sunak 2011). Street trees and urban forests can majorly reduce the ambient pollution and emissions (Abhijith et al. 2017; Nowak et al. 2017; Churkina 2012). In particular, large urban parks and dense street tree areas can mitigate urban heat island effect through carbon sequestration, shading, and transpiration (Nowak et al. 2013). Street trees or boulevard trees are city-owned trees between walkways and roads.

Urban trees provide ecosystem services that benefit human welfare such as carbon sequestration, air purification, reducing stormwater runoff, urban heat island effect reduction, providing shade, aesthetically increasing curb appeal for walkability and bike-ability (Pincetl et al. 2013, Bastin et al.

2019). Forests are the most powerful nature-based solution to address climate change. As climate change is bringing more frequent heat waves, tropospheric ozone, and storms, increasing street trees and urban forests would enable greater cooling through transpiration and shade, filter pollutants cleaning the air, and act as shelter and blocks for storms (Curtis and Gough 2018; Millar and Stephenson 2015). Bastin et al. (2019) looked at the potential for tree restoration globally and found that 4.4 billion hectares of land could support trees and forest canopy which would create an additional 205 gigatons of carbon storage. Cities of all sizes need to improve their green infrastructure to do their part in addressing climate change.

As cities are primary sources of carbon emissions that contribute to increasing temperatures and to the positive feedback loop of climate change, trees can help mitigate these emissions through carbon sequestration. Carbon sequestration is the process of taking in atmospheric carbon through photosynthesis and absorption and using it for growth (Nowak et al. 2013). Tree carbon sequestration is one of the most important climate mitigation strategies in order to reduce the greenhouse gas effect and global warming. Trees sequester carbon in the form of biomass which varies by tree species, size, health, and growth rate (Nowak et al. 2017). Carbon storage is higher for larger trees that are less shaded (Weissert et al. 2017). A case study in Tshwane, South Africa, showed that street trees sequestered 200,000 tons of carbon and saved $3 million (Stoffberg et al. 2010). A study of four main parks in Rome revealed that the trees sequestered 3.6% of the total GHG emissions for the country which is worth an estimated $24,000 per hectare (Grantai et al. 2016). Street trees and forest trees of the same species have different growth rates which can be impacted by environmental factors of growing locations (Nowak et al. 2002, Stoffberg et al. 2010). Hyvonen et al. (2006) conducted a review looking at the impact of increasing CO_2levels on temperate and boreal forests and found that this increase will magnify carbon sequestration and lengthen the growing season, meaning that trees will be even more beneficial as carbons stores.

Climate change will bring more frequent heat waves, storms, and tropospheric ozone, and both trees in urban and rural areas are going to experience elevated CO_2levels (Churkina et al. 2015 as cited by Pearlmutter et al. 2017). In Minnesota, temperatures are, on average, 1.5℃ warmer now than in 1900 which will increase to 2-2.5℃ by the end of the century (NOAA 2021 as cited by Huttner 2021). Forests and street trees play a crucial role in the environmental health of a location. There is a lack of literature and reviews on carbon sequestration rates of street trees compared with forests for the same tree species. Many studies, that cite a difference in street tree and rural forest growth rates, had to estimate allometric equations for specific species based on broad categories of tree organization like deciduous and coniferous (Revelli and Porporato 2018, Hyvonen et al. 2006, Nowak et al. 2013). There are not comparative studies on the effect of abiotic environmental factors on tree growth and carbon sequestration in street trees vs forest trees. This paper seeks to generate an analysis of street trees as compared to rural forests in composition and carbon sequestration.

In southeastern Minnesota, the dominant deciduous forest is maple-basswood forest, also known as Big Woods. 90% of the original forest has experienced land-use change as trees were cut down for agriculture and development starting at the time of European settlement in the 1800s (Shea 1993). The remaining 10% of Big Woods is fragmented which reduces biodiversity and increases edge species such as ticks and invasive plants (Milbert 1994, Halos et al. 2010). Biodiversity loss often results from forest fragmentation which also results in more edge species (Fahrig 2003, Wilson et al. 2016). Species diversity affects resistance and resilience of a forest to disturbance; in fact, Hughes (2010) suggests that there may be a reciprocal interaction between diversity and disturbance. Within the remaining forest, species composition may be impacted by site area, microclimate, slope, and soil. Historically, oak (*Quercus spp.*) and elm (*Ulmus spp.*) were the dominant species in this area, but presently this land is dominated by *Acer saccharum*, sugar maple (Shea and Helgeson 2018). On the St. Olaf College campus, there is a remnant of Big Woods forest called Norway Valley.

The City of Northfield conducted a tree survey in 2016 which determined the city has 8965 street trees and 2825 park trees for a total of 11,790 city trees (City of Northfield). Of the 40 tree genera and 75 tree species, the public trees are dominated by maple (34%) and ash (23%), and 90% of trees by biomass are represented by eight species: maple, ash, linden, spruce, hackberry, oak, honey locust, and pine. According to the Climate Action Plan, increasing tree diversity is a priority for the city of Northfield as 60% of the canopy is maple and ash. The City of Northfield has identified an environmental justice area of concern which is a census tract where the median income was $40,000 compared to $70,000 or higher in all other tracts in the city (Census.Gov, 2021). A tree survey conducted by the city of Northfield in 2016 determined that this census tract had lower tree canopy density than the other tracts (City of Northfield 2016). The City manages 12,000 urban trees of which 59% are maple and ash trees.

Through comparing the species composition and growth rates of trees in urban and rural sites, this study aims to understand the abiotic and biotic factors influencing variation in tree species composition and, thus, carbon sequestration at both sites. I hypothesize that there will be a difference in carbon sequestration both by trees and by plot type: tree species that are native to colder climates (i.e. some of the coniferous pines species) will have a slower growth rate in cities (with urban heat island effect) than in forests. Additionally, I propose that carbon sequestration will be higher in the younger (smaller) trees than in the older (larger) trees of the same. I anticipate the city site will be more species diverse and age diverse than the rural site. Specific objectives were (1) determine the growth rates of tree species in urban vs rural settings in Northfield, MN, USA, (2) analyze the composition of street blocks compared to Norway Valley maple-basswood forest, (3) propose overall carbon sequestration for each plot, and (4) compare diameter class composition in urban to rural sites and of the same species.

Methods

Study Site

This study took place in the City of Northfield in southeastern Minnesota. The urban location is the environmental justice area of the city spanning from 5th St (44.45587, -93.17662) to highway 3 (44.45510, -93.16433) to North Ave (44.47134, -93.17010) and back on Cedar Ave (44.47119, -93.18083). For comparison to the rural location, three sites of the environmental justice area were selected based on similar tree count and biomass to the rural sites; the three urban sites are 2, 3 and 28 as shown in Figure 1. Of the 1,300 street trees analyzed for this study, the three sites selected resulted in 160 street trees for a more adequate comparative analysis to the 130 trees in the rural site. The area of the three urban sites is approximately 0.56ha (20x40m). The rural site is Norway Valley (44.45809, -93.18098) which measures 6 ha and is the oldest maple-basswood forest in the St. Olaf College Natural Lands. Three sites within the forest, Obelisk, Path, and Slope, that were used for sampling are pre-existing plots (set up by students and faculty for experiments since at least 2012) located in the center of the forest with little disturbance and no walking paths. Each of the three plots has been divided into a 4x4 (20m by 20m) grid, with the number given to each tagged tree being placed in the respective location from the plot to the grid.

Tree Measurements

All street trees within the city blocks and all trees within the Norway Valley site were surveyed. In Norway Valley in 2012, each tree measuring at least 2.5 cm DBH was marked where measured, given a number in the plot, and tagged accordingly while recording the species. I measured at these marked locations to ensure consistent measurements over time. In the environmental justice area of the City of Northfield, we recorded the numeric identifier, species, genus and diameter at breast height (DBH, 1.37m) for each mature tree. The mature trees (>2.5cm DBH) are tagged with unique numbers for each plot in Norway Valley and georeferenced with unique numbers for the entire city of Northfield for the street trees. I measured the DBH of the Norway Valley trees to the nearest millimeter while the street trees were measured to the nearest inch and needed to be converted to centimeters (due to this, the margin of error is +/- 3cm). These DBHs were compared to previous years of data (2016) to calculate the growth rates for each tree and species overall. Using the growth calculations, I calculated the potential carbon sequestration for each tree, the species overall, the sites, and extrapolated to estimate each location’s carbon storage as a whole. These calculations were done using an equation for aboveground biomass (Jerkins et al. 2003).

$$\text{Biomass} = \text{Exp}(\beta_0 + \beta_t \ln [\text{DBH}]) \text{ where } \beta_0 = -2.0127 \text{ and } \beta_t = 2.4342$$

After averaging the biomass, that value was converted to carbon intake using a carbon sequestration equation for broadleaf deciduous trees (Kuers et al. 2011).

$$\text{Carbon sequestered} = \text{biomass} * 0.45$$

Data Analysis

All data analyses were performed using Microsoft Excel (Version 2111) and RStudio (Version 3.6.0). The data were not normally distributed, so I performed non-parametric statistical analyses. To understand if the diameter at breast height (DBH) measurements from 2016 and 2021 were done similarly enough to use for biomass calculations, I ran a correlation analysis. I tested the relationship between location and size and location and growth using Welch Two-Sample T-tests. To determine the impact of tree genus on growth rates and the effect of site on growth rates, I used Kruskal-Wallis rank-sum tests. I calculated importance values of the species for each location using methods from the Field Ecology Forest Ecology Manual (Shea 2021). Frequency is by the proportion of sampling points at which a species is present, and importance values are the combined proportional values of tree frequency, basal area, and relative density.

Commented [KS1]: How did you determine frequency? Need to explain what importance values are.

Results

The correlation analysis showed a strong significant positive relationship between measurements in 2016 and 2021 (Figure 3, p-value <0.0001, R = 0.88). In comparing mean tree size between urban and rural locations, I found the urban mean DBH was 46.91cm which was significantly larger than the rural mean diameter at 13.69 (Figure 4 Left, Welch Two Sample t-test, T = 14.90, df = 272.33, p-value < 0.0001, 95% CI = 28.83, 37.61). The city location was also more species diverse overall compared to the rural location which was dominated by sugar maple (Figure 3 Right). I ran a Kruskal-Wallis rank sum test on DBH by tree genus and found significant differences between species; mean tree size was largest for *Fraxinus spp.*(ash) (Figure 4, X^2 = 73.61, df = 21, p-value < 0.0001). Mean tree growth was significantly higher for the city location, 13.23cm/yr, than the rural location, 0.31cm/yr (Figure 5, Welch Two Sample t-test: T = 10.94, df = 168.44, p-value < 0.0001, 95% CI = 10.54, 15.18). In comparing the growth rates for each site, a Kruskal-Wallis rank sum test showed that the growth rate means are significantly different by site; in the city location, site 28 had the highest growth rate, 18.2cm/yr, while in the rural location, site Path had the highest growth rate, 5cm/yr, (Table 2, X^2 = 162.9, df = 5, p-value < 0.0001). The city sites have a greater spread of growth rates while the rural sites are more uniform (Figure 6). I calculated the carbon sequestration totals using the biomass and carbon sequestration equations presented in the methods. The urban location had higher carbon sequestration (144,140.83 tons) than the rural locations (17,187.37 tons) and, by genus, maple, ash, and basswood/linden had the highest overall carbon sequestration (Table 3). Maple was the most important tree genus for both locations (Urban 0.90 and Rural 1.88) followed by ash and basswood for urban and basswood and elm for rural (Table 4). The growth rates by diameter class for maple trees increased with diameter class for both locations (Table 5).

Discussion

Tree Size and Composition

Urban mean DBH was larger than rural, and urban was shown to be more species diverse than the rural area (Figure 4). The finding that trees are larger in urban areas concurs with my hypothesis and the current literature. With less competition and shading, urban spaces are ideal growing locations for trees that can tolerate urban conditions such as air pollution, soil compaction, and salt (Pearlmutter et al. 2017). Cities intentionally plant diverse species and while the city sites were more diverse in comparison to Norway Valley, Northfield is not as species diverse for street trees as other nearby cities or as the literature suggests is appropriate for a healthy resilient canopy. Canopies are recommended to follow the 10-20-30 rule which means 10% of a species, 20% of a genus, and 30% of a family (Kendal et al. 2014). The city of Northfield canopy is 60% ash and maple species which breaks the resilient forest canopy rule (City of Northfield 2016). Rural area was dominated by maple trees (Figure 3, Right). Vadnais (2016), Bray (1956) and Wood (1995) also found maple to be dominant in maple-basswood forests which Shea (2018) explains as sugar maples being especially tolerant of shade which may be an advantage allowing maples to dominate forests.

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I found a significant difference in tree size by species with ash having the largest mean DBH (Figure 4). With the emergence of the emerald ash borer, the fact that ash trees were the largest trees overall in the study is concerning. The city canopy will be even more impacted by ash tree loss because of these trees being the largest on average. Trees grew more rapidly on average for the urban site than the rural sites (Figure 5). Larger trees that are less shaded were found to have a higher growth rate and carbon sequestration than smaller trees in the same circumstances (Weissert et al. 2017). The urban sites were mainly in the open with full sun all day which are ideal conditions for trees that can tolerate urban conditions. Another thing that I noted during data cleanup was incorrect identification of trees. I measured trees in early October and late October; with the early measurements, I could see the leaves on the trees and am confident in my identification while the later measurements happened after the leaves fell off all of the trees. Even so, the 2016-2012 data had a couple of trees that were identified as different species than what I identified them as. I removed trees that were not reported in 2021 or 2016 to have full comparison and growth rates for all. Some unique trees have strange patterns such as going from 6cm DBH to 46cm from 2016 to 2021. These may be the wrong trees being identified in the city cases. In the rural plots, I infrequently saw the reverse: a 30cm DBH tree became a 4cm tree from 2016-2021. I expect that this may be due to an old tree dying and a new sapling growing in its place. The same numeric identifier may have been used for the two different trees.

I analyzed tree size, growth rate, and species composition in an urban vs rural location to determine the difference that environment makes on tree success and growth. I found 2016 and 2021 measurements of tree DBH were strongly correlated (Figure 3). This is what I expected to see if the measurements were done accurately and consistently between years and sites. At 0.88, the correlation is not as strong as it could be, which may be due to the city plots being measured differently from the rural plots. There was a difference in measurements for city vs rural (+/- 3 cm) DBHs in that city trees were measured to the nearest inch while rural trees were measured to the nearest mm. This could have impacted the biomass and carbon sequestration calculations. The city measurements would need to be redone to assure the accuracy of my findings. The correlation graph reveals that the measurement technique differences were likely not enough to completely alter the findings of the study.

Each site had significantly different growth rates in comparison with each other (Table 2) which makes me curious about the site-specific abiotic conditions influencing these differences. I think, in a future study, it would be great to compare the tree growth rates to the abiotic conditions of each site. I would measure soil characteristics, moisture, temperature, and sunlight for 8-10 spots for each site. Revelli and Porporato (2018) analyzed the effects of abiotic factors on individual tree success and growth, and they found that the potential of trees for ecosystem services is connected to the soil, water, carbon, and nutrient composition as well as the impervious surface often encompassing street trees. They suggest that the ecohydrological and biogeochemical processes can hinder or enhance carbon sequestration and other ecosystem services through proper design of urban spaces to minimize plant water stress and maximize nutrient sequestration (Revelli and Porporato 2018). The city sites had greater variety of growth rates than the rural sites which were quite uniform (Figure 6). The environmental conditions of a location can impact the growth rate of a species such that trees in urban conditions may have different growth rates than those trees of the same species in rural/forest areas (Nowak et al. 2002, Stoffberg et al. 2010). The results from my study suggest that abiotic factors are contributing to significantly different growth rates for the locations on a large scale.

Carbon Sequestration

City carbon sequestration for the three sites was 144,140tons compared to 17,187tons for the three rural sites (Table 3). While the city sites were larger than the rural sites, both locations totaled to similar amounts of trees (160 to 130 respectively). With the range of growth rates and generally larger trees for the city location, it does not surprise me that the urban location had so much higher carbon sequestration than the rural location. Hyvonen et al. (2006) found that young forest stands are better carbon stores than old forest stands. Maple, ash and basswood/linden had the highest biomass overall and the most carbon sequestration (Table 4). Nowak et al. (2017) suggested that carbon sequestration differs by tree species, size, health, and growth rate. When zooming into maples, I found that the growth rate increased with diameter meaning that older trees were sequestering higher rates of carbon than younger trees (Table 5). I did not see a difference in growth rates by diameter class for location. This means that maples are not the major difference between city and rural locations for overall carbon sequestration.

Conclusion

I found significant differences in tree species composition, tree growth rate and size between urban and rural locations of approximately similar size and tree abundance in Northfield, MN. Carbon sequestration was higher overall in the urban than the rural location. Due to these findings, I postulate that city street trees are as effective as carbon stores as trees in rural forests of similar size and tree count. While the city is much more diverse than the rural maple-basswood forest, the city can still increase the diversity of the canopy to meet the 10-20-30 rule. My study found maple and ash to be the most prevalent by count and biomass in the urban locations which means urban planting initiatives are even more important now. As maple trees are not heat tolerant and ash trees will be wiped out by the emerald ash borer, the city of Northfield could lose up to 60% of the canopy. The maple-basswood forest also may be vulnerable to the increasing heat waves with climate change; however, the forest is more protected and insulated from heat waves than the isolated street trees.

Trees are the most powerful nature-based solution to address climate change. Forests and street trees are critical to the environmental health of an area with ecosystem services including air purification, cooling, carbon sequestration, and storm water retention. With global warming bringing more frequent heat waves, drought, storms, floods, and tropospheric ozone, trees are a critical mitigation and protection strategy. Study after study has shown how valuable trees are, and Bastin et al. (2019) determined that globally there is a potential to plant 4.4 billion ha of land with trees. Based on the $17-$50 value range on carbon per ton, planting all of this land would be worth $3.49- $10.25 trillion dollars in carbon costs. Not only is planting trees good for ameliorating climate change but also for saving lives. Planting trees to the full potential of space available for planting in a city could reduce seasonal summer temperatures between 0.5 and 2°C which reduces heat related mortality by 5-28% (Chen et al. 2014). Investing in trees is investing in the economy, the health of current and future citizens, and the longevity of the planet.

Acknowledgments

I would like to thank Dr. Kathy Shea for all of her guidance and support on this project. Thank you also to Beth Kallestad, Dr. Diane Angell, and the Ecological Principle class. I would also like to thank my classmates in Field Ecology, especially Clay Wilkens for assistance collecting data, Madelyn Wood for proofreading my papers, and Miranda Lentz for talking me through Rstudio analyses.

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Tables and Figures

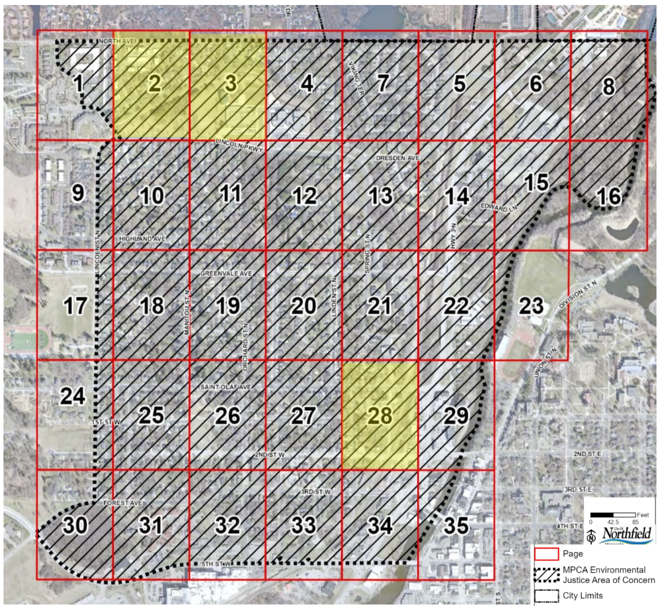

Figure 1: Environmental Justice area of concern for the City of Northfield, MN, outlined in red where trees were sampled for the urban conditions. Highlighted in yellow are the specific sites used for comparative analysis with the rural sites. *Map sourced from the City of Northfield.*

Figure 2: Norway Valley Forest in the St. Olaf Natural Lands used for tree sampling in rural forested conditions. Outlined in yellow are the approximate size and locations of the three 20x20m rural plots: Obelisk, Path, and Slope.

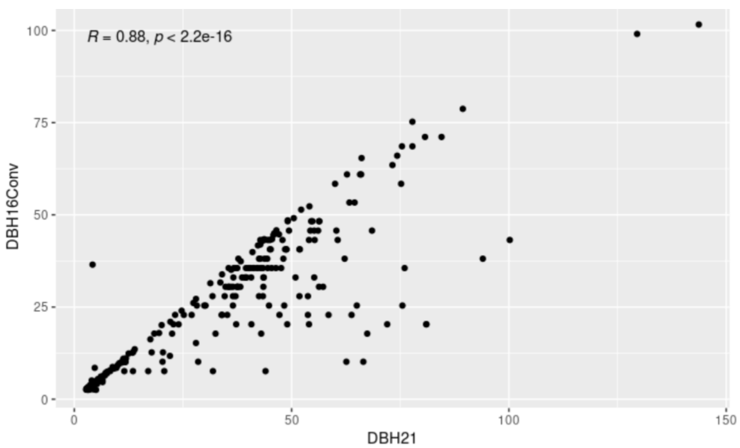

Figure 3: Correlation test for diameter at breast height measured in 2016 and 2021 in Northfield, MN, reveals positive significant correlation (R = 0.88, p-value < 0.0001).

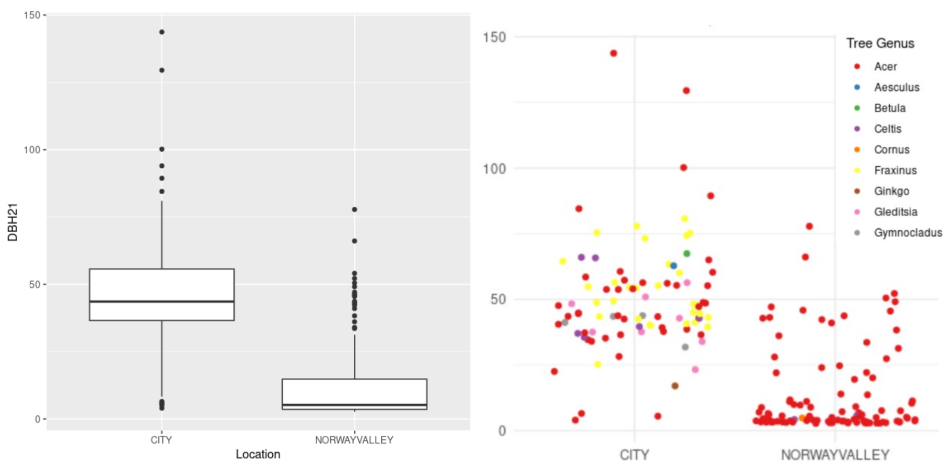

Figure 4: Comparing mean tree size between urban (city) and rural (NorwayValley) locations in Northfield Minnesota. **Left**, urban (mean 46.91cm) and rural tree (mean 13.69 cm) sizes are significantly different as confirmed by a Welch Two Sample t-test (T = 14.90, df = 272.33, p-value < 0.0001, 95% CI = 28.83, 37.61). **Right**, the city location is more diverse in tree species and size while the rural location is dominated by Maple (*Acer spp.*).

Table 1: Summary statistics of tree diameter at breast height for urban and rural locations in Northfield, Minnesota. The means (cm) are combined for both urban and rural sites. DBH by tree genus differs significantly as presented by the Kruskal-Wallis rank sum test ($X^2 = 73.61$, df = 21, p-value < 0.0001).

TreeGenus	**min**	**Q1**	**median**	**Q3**	**max**	**mean**	**sd**	**n**
Acer	2.70	3.70	10.40	43.00	143.70	24.67	26.28	143
Celtis	4.20	28.08	38.30	48.54	66.00	37.08	23.17	8
Fraxinus	25.20	43.10	49.40	63.30	80.70	53.76	14.19	29
Gleditsia	23.20	36.60	40.20	48.95	56.30	41.31	10.55	8
Gymnocladus	31.80	38.85	42.35	43.58	43.80	40.08	5.64	4
Malus	13.5	36.38	53.30	63.58	66.50	46.65	24.18	4
Ostrya	3.30	3.75	4.10	4.45	4.90	4.10	0.67	4
Phellodendron	27.0	29.13	31.25	33.38	35.50	31.25	6.01	2
Picea	20.3	31.90	43.50	49.0	75.50	41.70	16.11	9
Pinus	17.8	33.58	36.30	39.13	62.20	37.0	12.15	12
Quercus	22.8	33.75	42.00	47.0	51.90	39.74	11.03	7
Tilia	3.30	17.95	40.75	54.05	94.00	40.72	25.01	31
Ulmus	3.20	5.20	8.20	10.20	11.90	7.74	3.56	5

Commented [KS3]: Are the means combined from urban and rural or just one?

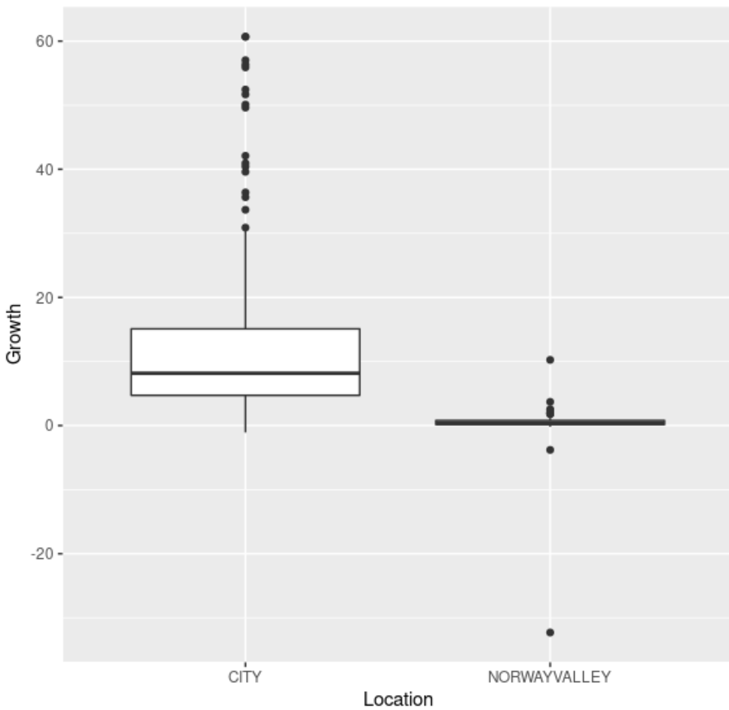

Figure 5: Comparing mean tree growth between urban (city) and rural (NorwayValley) locations in Northfield, Minnesota. Urban (mean 13.23cm/yr) and rural tree (mean 0.37cm/yr) growth rates from 2016 to 2021 are significantly different as confirmed by a Welch Two Sample t-test ($T = 10.94$, $df = 168.44$, p-value < 0.0001, 95% CI = 10.54, 15.18).

Table 2: Comparison of tree growth rates (cm/yr) for each site (2, 3, 28 are Urban and Obelisk, Path, and Slope are Rural) in Northfield, Minnesota. Kruskal-Wallis rank sum test shows statistically significant differences in the means between sites ($X^2 = 162.9$, $df = 5$, p-value < 0.0001).

Block	min	Q1	median	Q3	max	mean	sd	n
2	-0.06	5.64	8.26	12.71	57.02	12.12	11.84	67
28	-1.08	1.79	9.38	25.81	60.68	16.22	18.20	41
3	-0.38	4.83	8.04	12.09	56.34	12.12	12.40	43
Obelisk	-0.20	0.08	0.35	0.93	10.25	0.91	1.87	31
Path	-32.30	0.30	0.53	0.71	3.70	-0.13	5.00	44
Slope	-3.80	0.15	0.40	0.80	2.40	0.48	0.84	49

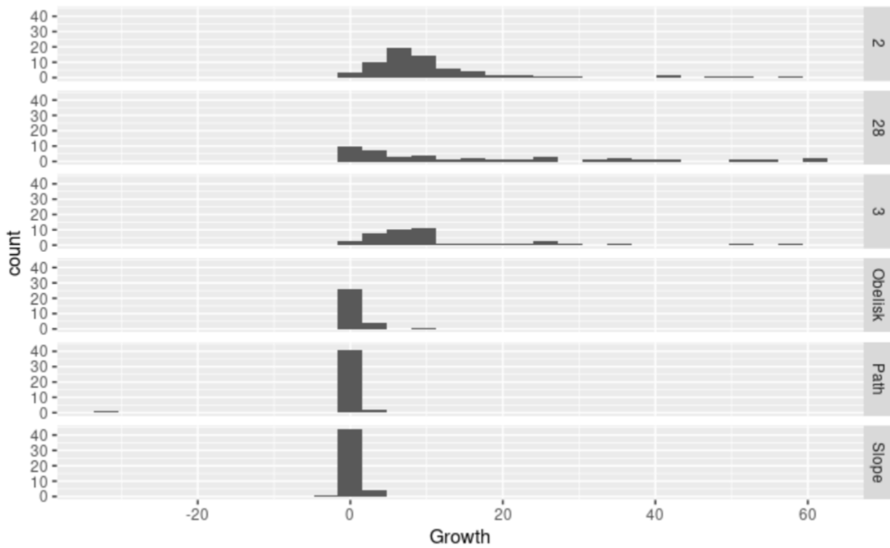

Figure 6: Distribution of tree growth (cm/yr) compared by city (2, 28, 3) and rural (Obelisk, Path, Slope) sites reveals greater spread for city sites and narrow range for rural sites. Kruskal-Wallis rank sum test shows statistically significant differences in the means between sites ($X^2 = 162.9$, df = 5, p-value < 0.0001).

Table 3: Comparing city and rural (Norway Valley) carbon sequestration totals by tree genus. Carbon sequestration (tons) was highest for *Acer* (Maple), *Fraxinus* (Ash), and *Tilia* (Linden/Basswood) overall, and city location had greater carbon sequestration over rural location (Norway Valley), in Northfield, MN.

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Sum of Carbon Sequestration	CITY	NORWAYVALLEY	Grand Total
Acer	55014.70	14209.64	69224.34
Aesculus	1428.43		1428.43
Betula	1699.93		1699.93
Celtis	4996.15	6.32	5002.47
Cornus		2.74	2.74
Fraxinus	31804.42		31804.42
Ginkgo	59.47		59.47
Gleditsia	4537.83		4537.83
Gymnocladus	1966.92		1966.92
Juglans	685.09		685.09
Malus	3701.27		3701.27
Ostrya		7.72	7.72
Phellodendron	540.38		540.38
Picea	5894.59		5894.59
Pinus	5566.35		5566.35
Prunus	3.02		3.02
Quercus	3661.65		3661.65
Sorbus	96.04		96.04

Syringa	4.71		4.71
Thuja	22.96		22.96
Tilia	22456.92	2904.41	25361.33
Ulmus		56.54	56.54
Grand Total	**144140.83**	**17187.37**	**161328.20**

Table 4: Importance of each tree genus by location based on relative density, coverage, and frequency in Northfield, MN. *Acer spp* was most important to both the urban (0.90) and rural sites (1.88).

	Urban				Rural			
Tree Genus	**Relative Density**	**Relative Coverage**	**Relative Frequency**	**Importance Value**	**Relative Density**	**Relative Coverage**	**Relative Frequency**	**Importance Value**
Acer	0.28	0.53	0.09	**0.90**	0.81	0.80	0.27	**1.88**
Aesculus	0.01	0.00	0.03	0.04	0.00	0.00	0.00	0.00
Betula	0.01	0.00	0.03	0.04	0.00	0.00	0.00	0.00
Celtis	0.04	0.01	0.09	0.14	0.02	0.01	0.18	0.21
Cornus	0.00	0.00	0.00	0.00	0.01	0.00	0.09	0.10
Fraxinus	0.19	0.28	0.09	**0.56**	0.00	0.00	0.00	0.00
Ginkgo	0.01	0.00	0.03	0.04	0.00	0.00	0.00	0.00
Gleditsia	0.05	0.01	0.06	0.12	0.00	0.00	0.00	0.00

Gymnocladus	0.03	0.00	0.06	0.09	0.00	0.00	0.00	0.00
Juglans	0.01	0.00	0.03	0.04	0.00	0.00	0.00	0.00
Malus	0.03	0.00	0.06	0.09	0.00	0.00	0.00	0.00
Ostrya	0.00	0.00	0.00	0.00	0.03	0.01	0.09	0.13
Phellodendron	0.01	0.00	0.03	0.04	0.00	0.00	0.00	0.00
Picea	0.06	0.02	0.09	0.17	0.00	0.00	0.00	0.00
Pinus	0.08	0.02	0.06	0.16	0.00	0.00	0.00	0.00
Prunus	0.01	0.00	0.03	0.04	0.00	0.00	0.00	0.00
Quercus	0.05	0.01	0.09	0.15	0.00	0.00	0.00	0.00
Sorbus	0.01	0.00	0.03	0.04	0.00	0.00	0.00	0.00
Syringa	0.01	0.00	0.03	0.04	0.00	0.00	0.00	0.00
Thuja	0.01	0.00	0.03	0.04	0.00	0.00	0.00	0.00
Tilia	0.13	0.11	0.09	**0.33**	0.10	0.16	0.18	**0.44**
Ulmus	0.00	0.00	0.00	0.00	0.04	0.02	0.18	**0.24**
Grand Total	**1.00**	**1.00**	**1.00**	**3.00**	**1.00**	**1.00**	**1.00**	**3.00**

Table 5: Growth rates (cm/yr) of maple (*Acer Spp.*) trees by diameter class and location shows that tree growth rate generally increases with diameter class for both locations.

Maple Diameter Class	CITY	NORWAYVALLEY
2.5-5	-0.33	0.23
5.1-15	1.42	0.58
15.1-30	2.8	2.43
30+	16.48	1.10