TREE SPECIES RICHNESS AND CIRCUMFERENCE VARY BETWEEN RURAL, SUBURBAN, AND URBAN ENVIRONMENTS

Amanda Salmoiraghi, Paola Cruz, Julie Gifford, Joshua Mickens

ABSTRACT

Urbanization has produced inevitable changes for ecosystems throughout northeastern regions of the United States. Many factors influence biodiversity in ecosystems, such as tree species richness. To study this, we collected data in rural, suburban, and urban forested landscapes across New York State, measuring tree species richness within a 15m by 15m plot of land. Our results show that rural sites had the highest average for tree species richness when compared to suburban, and rural sites. Urban sites, however, showed the highest average for tree circumference, while the averages for suburban data settle amid rural and urban. Our data potentially could lead to developing more effective forest management practices, mitigate the effects of climate change, and protect threatened native tree species.

Keywords: biodiversity, deciduous trees, forested, urbanization, urban-rural gradient

---

INTRODUCTION

Urbanization, and by default, human interaction, have wide-reaching and lasting impacts on ecosystems (Cardinale et al. 2012). As people migrated into cities, terrestrial ecosystems were subsequently changed to fit the mold that humans needed for their living conditions. Humans influence a variety of environmental factors. Forest fragmentation as a factor of urbanization, the conversion of forest to other land uses, makes forests more susceptible to exotic species invasions, alters nutrient cycles, changes species composition, and affects tree species diversity (Evans and Perschel 2009). Disease can also be brought to new environments directly, or it can be influenced by pollution in the air, water, and soil. Insects and tree diseases can infest urban forests, potentially killing trees, and reducing the health, value, and sustainability of the urban forest (Nowak et al. 2018). However, studies show that tree plantings have been viewed as a key component to urban tree population's resilience to pests, diseases, and climate change (Cowett and Bassuk 2017). As a society, humans continue to grow, alter, and influence the world we live in, whether that be for better or worse.

Urbanization of land creates unavoidable environmental changes that ultimately influence biodiversity (Grimm et al. 2008). As movement into cities and creation of spaces for humans to populate increase, habitats, and ecosystems that were originally found there become fragmented and broken. This often creates edge sites, and it is difficult for species to live in these areas. This can potentially limit biodiversity and species richness in an area (Grimm et al. 2008). Urbanization can also directly affect biodiversity through invasive species, soil imbalances, climate, water use in the area, and biogeochemical processes (Kowarik 2011). Studies on biodiversity in urban areas and parks have concluded that urbanization and human disturbance are some of the leading causes of a decline in biodiversity, but it has also been found that urban cities are found to have a high concentration of biodiversity (Nielsen et al. 2014). For example, urban forests have been found to have higher amounts of invasive and/or introduced species compared to rural forests (Kowarik 2011). An increase of introduced species could influence the overall biodiversity and species richness found in urban areas (Evans and Perschel 2009). Invasive species are well-positioned to take advantage of species diversity shifts because they tend to be site generalists, mature quickly, and have successful dispersal strategies (Evans and Perschel 2008). Our research can give more insight into the controversy over the effect of urbanization on biodiversity, species richness, and abundance. Forest composition and the environment have a relationship that has weakened; the implications of this have been noticeable to us and will become apparent even centuries later (Thompson et al. 2013).

As pollution continues to grow at an alarming rate, we see the product of climate change. Climate change is an ongoing issue that negatively impacts various ecosystems and can impact humans. If environmental conditions become harsher, species lacking the appropriate stress tolerance would be more likely to go extinct, while other species that have sufficient stress tolerance would likely survive (Marks et al. 2016). Increased severe weather patterns such as droughts, hurricanes, and forest fires can impact species richness and diversity in all types of environments, including forested areas in the rural to urban gradient (Evans and Perschel 2009). Since it ultimately affects the amount of biodiversity found in terrestrial landscapes, climate change is a major issue that conservation ecologists face. Climate change can influence the range of native trees and could potentially impact distribution and species richness (Kendall et al. 2011, Nitoslawski et al. 2016).

In the Northeastern United States, forest environments vary an incredible amount in biodiversity, species, and species richness across a rural to urban gradient. To better understand the differences in biodiversity between rural, suburban, and urban forested environments, we surveyed eight 15m by 15m plots and cataloged the species of trees found trunk circumference, and the number of trees within individual plots. We hypothesized that suburban sites would have greater biodiversity and species richness compared to urban or rural sites.

METHODS

Experiment setup. Three different land-use sites (urban, suburban, and rural) were chosen to perform our tree abundance, diversity, and species analysis experiment. The collection sites were chosen on an urban to rural gradient and all within temperate and mostly deciduous environments typical in the Northeast, United States (Fig. 1). Data was collected Oct. 15-Nov. 4th, 2020. Leaf senescence occurs in the fall when the chlorophyll is lost in the leaves due to declining temperatures and decreased day length. This process was nearly complete at the rural collection site, the suburban collection site was at its peak, but only just beginning at the urban collection site. Urban collection sites included New York City as the most southerly at Pelham Bay Park in the Bronx, NY (PBPK). Suburban collection sites included a backyard landscape in Middletown, NY, and Five Islands Park in New Rochelle, NY. Rural collection sites were in Deposit, NY, located about 150 miles northwest of the urban site and westward of Catskill State Park. If needed, we requested permission from private landowners if the collection site was on their property. Standard safety protocol was used: not sampling alone and wearing bright colors since it was hunting season. We chose collection sites with a common tree density for each of our land-use types. To begin the analysis, all four of us measured out two 15m x 15m plots (two plots for urban and rural, four plots for suburban) with standard 100' construction grade measuring tape with metric centimeter units on it. Each intersect was perpendicular to the last tape ensuring a square was being set up.

Figure 1. Aerial map of the NY region shows an overview of the data collection sites from the rural, suburban, and urban plots. Green stars (Urban Sites 1 & 2), yellow stars (Suburban Sites A & B, two sites each), and pink stars (Rural Sites 1 & 2). When only one star can be seen, it is because the plots were adjacent to each other.

Data collection. First, we began by walking the length of the plot along with the measuring tape. Each tree within the plot area was measured by circumference in centimeters at chest height. We continued to walk parallel to the transect tape from end to end, this ensured all trees within the plot were measured and recorded. Only the trees greater than 3 cm were recorded on a data sheet along with their species type. Resources used to identify tree species included iNaturalist and Google image search.

Statistical analysis. Aerial photos from Google Earth of each plot were provided for visual analysis (Fig. 2). As well as a regional area map with plots identified with a star (Fig. 1), Google Earth Pro was used for this. Upon completion of our data collection, we individually used Microsoft Excel to create box and whisker graphs to analyze the mean circumference of the trees measured per plot, including standard error. All individual collection site graphs were compiled for group data analysis by tree species richness by land use (Fig. 3A), tree species richness by plot (Fig. 3B), average tree circumference by collection site (Fig. 4A), average circumference by plot (Fig. 4B), biomass (total circumference added up in cm) of each plot (Fig. 5B), biomass of each per collection site (Fig. 5A). For the suburban collection sites, A & B were averaged.

Figure 2. Panel figures reflect Google Earth aerial photos of all rural, suburban, and urban plots.

RESULTS

Figure 3A demonstrates that the rural sites had the highest average tree species richness with an average of 4 different species per collection site. The suburban sites had an average of 3.75 species per collection site and the urban sites an average of 3.5 species per collection site. Figure 3B indicates suburban site 1-B had the overall lowest tree species richness with 2 per plot.

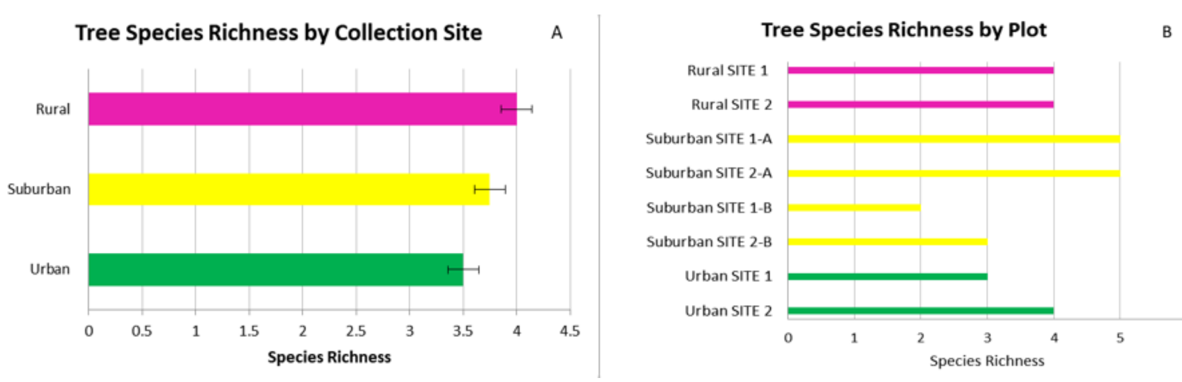

Figure 3. Tree Species Richness. A) Average tree species by collection site: rural had the most tree species richness while urban had the least. B) Tree species richness by plot: Suburban Sites 1A and 2A had the most species richness, while Suburban Site 1B had the least.

Our data reflected that the urban sites had the highest average tree circumference, 176 cm, compared to the rural and suburban. The suburban sites had an average of 96.26 cm and the rural site had an average of 65.07 cm. The rural sites had the overall smallest average tree circumference in cm. The difference between the plot means is demonstrated in Figure 4A, which shows that the difference between the urban sites and the other two sites is more significant than the difference between the suburban and rural sites. As depicted in Figure 4B, suburban site A had a lower average tree circumference, 55.92 cm, compared to suburban site B which had an average tree circumference of 136.61 cm, which is 80.69 cm more than suburban site A.

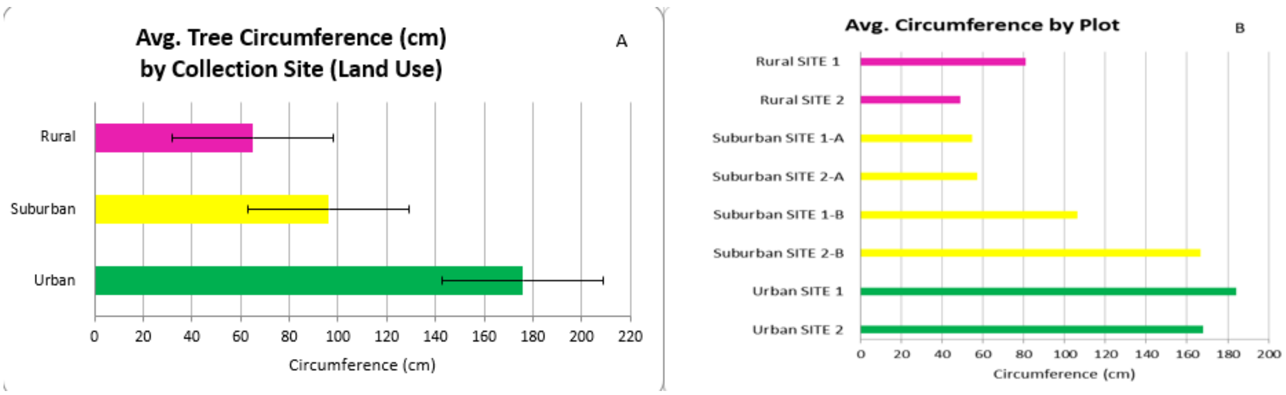

Figure 4. Average Tree Circumference in cm. A) Average tree circumference in cm by collection site. Urban has the highest circumference, while rural had the least. B) Average tree circumference in cm by plot. Urban Site 1 has the highest average circumference, while Rural Site 2 had the lowest.

Figure 5A shows the urban sample site had the highest total biomass, 1593.5 cm, out of all the sample sites. The rural site was close in the total biomass with 1536.53 cm. The suburban site had the lowest total biomass, 808.27 cm. Suburban site A had the overall lowest total biomass, 320.04 cm, which is seen in Figure 5B.

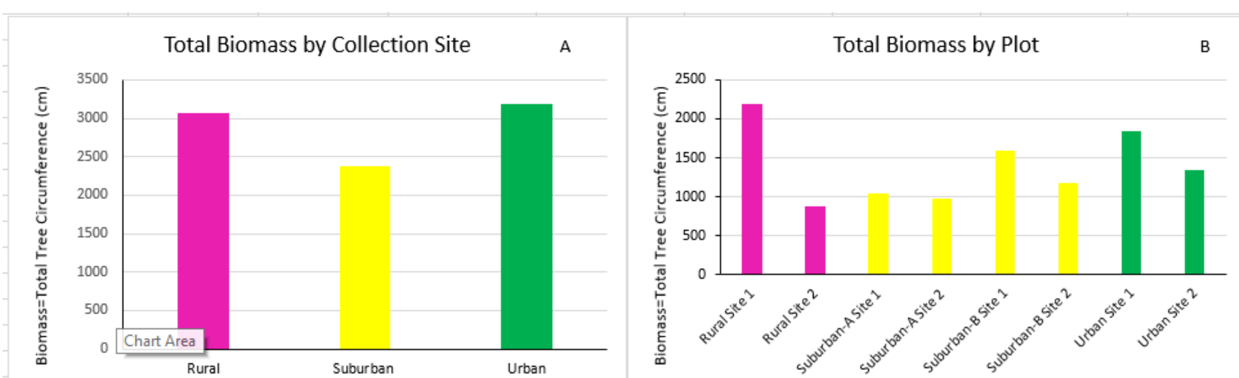

Figure 5. Total Biomass in cm. A) Total biomass in cm in rural, suburban, and urban sites. The Urban Site has the largest total biomass and suburban had the least. B) Total biomass in cm by plot. Rural Site 1 has the highest total biomass, and Rural Site 2 has the least.

DISCUSSION

This study looked at the differences in tree species richness and abundance across the three types of communities: rural, suburban, and urban across New York State. We hypothesized that suburban collection sites would have a greater tree species richness and abundance than rural and urban sites. Because of a decline of biodiversity seen on a rural to urban gradient, we anticipated less tree species richness in urban areas. We predicted that the rural environment would not have the highest tree species richness because of logging in rural environments during recent decades. Our results showed that there is a higher amount of tree species richness and abundance in the rural site compared to the suburban and urban sites. Although the rural site had the highest tree species richness, there was only a minor difference between the tree species richness from all of the sites. There was a 0.25 difference in species richness between the rural and suburban and a 0.5 difference between the rural and urban sites. This data can possibly contribute to biodiversity and forest management studies and practices.

Many aspects could have affected the results of this experiment, which may have influenced the trends found in the data. Having two suburban sites could have impacted our results because we averaged the measurements between the two sites to be able to compare it to the rural and urban sites equally. When looking at the raw data, before averaging the two suburban sites, site A has on average the lowest scores in each measurement which could have affected the overall representation of the suburban category. Site A was located in a more northern part of New York, and site B was located closer to the urban areas of New York, almost near the urban site which is shown in Figure 1. According to Ricklefs and He (2016), there are three sources of variation that are statistically associated with tree species richness in a local sense: the biogeographic region, the sample size, and the local climate.

Our data collection sites are all located in the Northeastern United States, and the climate in the areas are relatively similar. All of the plots we surveyed were 15m by 15m, however, the number of trees sampled within those plots varied. Understandably, fewer trees would be sampled in urban environments when compared to a rural environment. The location for the Urban Site was collected in an area of PBPK in the Bronx, NY, where the trees could have been an anthropogenic addition to the park's landscape. That could be the cause of more habitat fragmentation because the trees could be strategically planted making the space between them much larger. That makes it much more difficult for biodiversity and species richness to thrive. There was a previous study conducted at the urban site, PBPK, by Robert DeCandido. DeCandido's study (2004) was a census of all the plant species found at PBPK conducted from 1994-1998, which was a follow-up to a previous study done by H.E. Alhes from 1947-1948. This follow-up study found that during 50 years the park lost 19.5% of its flora, and specifically lost 25.5% of native species and 12.8% of nonnative species, and also found that invasive species have settled at a rate of 2.7 species per year during that period. The results of his study highlight that as urbanization increases so does the decrease in species diversity. There is also an increase in invasive species which could account for some of the "biodiversity" observed in urban areas. Our study could be used to extend other investigations of urban areas to compare the flora from different periods.

While our preliminary research yielded interesting results, it would be suggested to conduct this research on a larger scale. The data collected in our research and the results concluded are useful to assess if biodiversity decreases as we move into the urban territory. In the future, we would increase the size of the plots surveyed from 15m by 15m, which could potentially further our understanding of the biodiversity of the area surveyed. There could be more species richness within a larger area. We would also increase the number of plots surveyed. A factor that influenced data collected was there were two suburban data collection sites compared to one rural and one urban. This may have influenced the variation in our data. Our data was collected during the mid-autumn season, where many leaves were falling. This caused trouble in identifying trees in an area that had very few leaves left. A suggestion for future studies would be to conduct investigations during the late spring or summer months when the trees still have an abundance of leaves.

Having a larger sample size will help determine whether or not our hypothesis is being supported. Since our study was contained to the Northeast of the United States, future studies could expand upon our results by conducting surveys in other areas of the United States to see if the pattern continues. Studies performed in Japan by Yuta Kobayashi indicate the need for expansive research to be performed on the service of mixed-species forests. Their research concluded the ecological and economic benefits of mixed-forest management on a broad climatic scale. Indicating new evidence that mixed-species management is worthwhile to face climate uncertainty (Kobayashi and Mori 2017).

More variables could be added to the experiment to get a better insight into the biodiversity of the different locations because different factors can affect tree species diversity. Geography and climate, resource availability, and even income and economic status of homeowners in the area are some examples of drivers that can potentially affect tree species diversity (Nitoslawski et al. 2016). Additionally, species assemblages vary depending on overall ecosystem health and their proximity to a densely populated urban environment. The topography of an area can also greatly contribute to forest diversity (Diggins and Catterlin 2014). Incorporating sociological aspects could give a unique and more accurate view of an area's biodiversity. Light intensity, pH level, and levels of belowground organic matter are also factors that affect biodiversity. Measuring and comparing these factors for each location could lead to a better understanding of the ecosystem's services. It is important to study each component to qualify how biodiversity functions altogether, and how it is affected by each of these potential variables.

The results and expansion of this study can be useful for further investigation of biodiversity in different environments including rural, suburban, and urban. Biological systems have many components that influence each other and studying one component can help understand another. According to Cardinale et al. (2012), the efficiency of an ecological community is tied to its biodiversity; as biodiversity decreases, so does the efficiency of the community. Discovering and studying those factors can give insight on how to promote and protect biodiversity and community efficiency in these ecosystems. Research on urban biodiversity has become popular in the last few years due to the effects of urbanization on natural ecosystems. Recognition that urban ecosystems can be used in new ways to promote biodiversity has increased (Neilson et al. 2014). Our analysis could potentially help future studies investigating the urban forests controversy, as to whether or not urban forests have high biodiversity or not, and why. Focusing on promoting biodiversity in urban forests is a prospective form of land management to maintain the species richness.

Studies such as ours could contribute to conservation and biodiversity efforts. Doing this can also aid in the conservation of endangered species (Alvey 2006). Since climate change increases the likelihood of catastrophic rain events, recent findings indicate that tree diversity can reduce the growing risk of natural disasters such as landslides (Kobayashi and Mori 2017). Calculating the relationship between tree canopy cover and the density of stems has been found to predict tree species richness in urban forests (Gillespie et al. 2017). Investigating the predictors of species richness and knowing what affects the components that make up and influence the function of biological systems can aid in protection and restoration efforts. Our study can contribute to other studies that are looking into the individual components of biodiversity that affect one another and biodiversity as a whole.

CONCLUSIONS

Our findings concluded tree species richness was the greatest at the rural collection site, there was <.5 species difference from suburban. Species richness was lowest in urban environments. However, the urban collection site had the greatest average tree circumference, with rural areas having the smallest. With urbanization increasing at significant rates, preserving forested land and old park systems is essential in maintaining green-space accessibility for urban populations (Evans and Perschel 2009). Protecting forested urban green space is a key factor in continuing to preserve urban ecosystem benefits. Through improved urban forest management practices and decreasing homogeneity in urban environments, such improvements can lead to increased resilience to non-native invasive species, improved ecosystem function, and improve the health and wellbeing of the entire community (Nock et al. 2016). The large biomass of an urban forested plot will have lasting impacts on mitigating the urban heat island effect and climate change. This data in conjunction with further carbon capture ability of deciduous forested areas on a rural to urban gradient will be crucial in proactively adapting to ever changing environments.

ACKNOWLEDGEMENTS

As a group, we would like to thank Allyson Jackson, Ph.D., for her help and support during this research, and also Tiffani Rushford for her help. I would like to thank Miss Willy, for providing hours of lap snuggles during this process (JG).

AUTHOR CONTRIBUTIONS

Conceptualization (all), Data Collection (all), Data Curation (all), Formal Analysis (all), Methodology (JG), Project Administration (AS), Resources (all), Visualization (JG, AS), Writing - Intro (AS), Writing - Methods (JG), Writing - Abstract (JM), Writing - Results (PC), Writing - Discussion (AS, PC), Writing - Conclusion (JG), Writing - review & editing (all).

LITERATURE CITED

Alvey, A.A. 2006. Promoting and preserving biodiversity in the urban forest. Urban Forestry and Urban Greening 5(4): 195–201.

Cardinale, B.J., E.J. Duffy, A. Gonzalez, U.D Hooper, C. Perrings, P. Venail, A. Narwani, G.M Mace, D. Tilman, A.D Wardle, P.A. Kinzig, C.G. Daily, M. Loreau, B.J Grace, A. Larigauderie, S.D Srivastava, and S. Naeem. 2012. Biodiversity loss and its impact on humanity. Nature 486(7401):59-67.

Cowett, F.D. and N. Bassuk. 2017. Street tree diversity in three Northeastern U.S States. Arboriculture and Urban Forestry 43(1): 1-14

DeCandido, R. 2004. Recent changes in plant species diversity in urban Pelham Bay Park, 1947-1998. Biological Conservation 120(1): 129-136.

Diggins, T., and R. Catterlin. 2014. Topographic patterns in forest composition and diversity on slopes of Zoar Valley Canyon, Western New York. Northeastern Naturalist 21(3): 337–350.

Evans, A.M., and R. Perschel. 2009. A review of forestry mitigation and adaptation strategies in the Northeast U.S.. Climatic Change 96: 167-183.

Gillespie, T. W., J. de Goede, L. Aguilar, G.D. Jenerette, G.A. Fricker, M.L. Avolio, S. Pincetl, T. Johnston, and D.E. Pataki, 2017. Predicting tree species richness in urban forests. Urban Ecosystems 20(4): 839–849.

Grimm, N.B., H.S. Faeth, E.N. Golubiewski, L.C. Redman, J. Wu, X. Bai, and M.J Briggs. 2008. Global change and the ecology of cities. Science 319(5864): 756–760.

Kendal, D., N. Williams and K. Williams. 2011. A cultivated environment: exploring the global distribution of plants in gardens, parks and streetscapes. Urban Ecosystems 15: 1-16.

Kowarik, I., 2011. Novel urban ecosystems, biodiversity, and conservation. Environmental Pollution 159(8–9): 1974–1983.

Kobayashi, Y., and A.S. Mori. 2019. The potential of tree diversity reducing shallow landslide risk. Environmental Management 59: 807-815.

Marks, C.O., H. Muller-Landau, and D. Tilman. 2016. Tree diversity, tree height and environmental harshness in eastern and western North America. Ecology Letters 19(7): 1-9.

Nielsen, A.B., M. van den Bosch, S. Maruthaveeran, and C.K. van den Bosch. 2014. Species richness in urban parks and its drivers: A review of empirical evidence. Urban Ecosystems 17(1): 305–327.

Nitoslawski, S.A., N.P. Duinker, and P.G. Bush. 2016. A review of drivers of tree diversity in suburban areas: research needs for North American cities. Environmental Reviews 24(4): 471–484.

Nock, C.A., M. Follett, C. Messier, D.J. Nowak, and A. Paquette. 2016. Effects of tree species functional diversity in eastern North America. Ecosystems 16: 1487-1497.

Nowak, D.J., A.R. Bodine, R.E. Hoehn III, E. Alexis, S. Hirabayashi, C. Robert, N. Auyeung, N.F. Sonti, R.A. Hallett, M.L. Johnson, E. Stephan, T. Taggart, and T. Endreny. 2018. The urban forest of New York City. Resource Bulletin 117: 82.

Ricklefs, R.E., and F. He. 2016. Region effects influence local tree species diversity. Proceedings of the National Academy of Sciences 113(3): 674.

Thompson, J.R., D.N. Carpenter, C.V. Cogbill, and D.R. Foster. 2013. Four centuries of change in Northeastern United States Forests. PloS One 8(9): 1-15.