Spring 2016

Studying the Effect of Urbanization on Tree Growth Surrounding Streams in Lincoln, Nebraska

Benjamin Heusinkvelt
University of Nebraska - Lincoln

STUDYING THE EFFECT OF URBANIZATION ON TREE GROWTH SURROUNDING STREAMS IN LINCOLN, NEBRASKA

By

Benjamin Heusinkvelt

AN UNDERGRADUATE THESIS

Presented to the Faculty of
The Environmental Studies Program at the University of Nebraska-Lincoln

In Partial Fulfillment of Requirements

For the Degree of Bachelor of Science

Major: Environmental Studies

With the Emphasis of Geography

Under the Supervision of Shannon Moncure

Lincoln, Nebraska

Date: May 4th, 2016

Table of Contents

Abstract

Urban forests are important to many functions of not only the city itself but also the citizens that live there. They provide carbon storage, shade, invaluable erosion control and can act as barriers to flash floods. This thesis was completed inside the municipality of Lincoln, Nebraska and at Spring Creek Prairie Audubon Center. Its purpose was to determine the effect urbanization has on tree growth in specific areas, in this case alongside stream banks. Data was collected from two test sites and analyzed to determine any differences. The results indicate that urban environments affect many characteristics of trees. This comparative study shows how urbanization affects tree growth and can help future landowners and scientists develop more sustainable ways to combat these problems.

Introduction

Nebraska is naturally a grassland prairie. It was historically dominated by natural grasses and shrubs. The only trees in the area could be found alongside rivers, creeks springs or in water abundant valley areas. As seen in Raymond (2012), there are many pictures that clue us into our past. The landscape was vastly different than we see today. Pictures of Nebraska show that much of the area was hilly grassland, only populated by trees in small patches scattered through the landscape. It is more than likely that the trees that were present naturally were those which thrive along water ways. In the homesteading days, settlers searched for thick groves of trees when looking for a place to live because on the plains this almost always meant water. Even back then, trees played a valuable part in the lives of the settlers and in the ecosystem itself. Understanding how trees interact with the ecosystem around them and how they are managed inside of cities is important to studying what affects them.

Nobody can deny that urbanization has had an effect on tree growth. We see studies of deforestation and rapid urbanization everywhere we look. There are thousands of trees occupying the city limits of Lincoln Nebraska. It is true that there are several creeks and marshes that occur in the Lincoln area, so there were more than likely naturally occurring trees in the area before any of it was settled or developed. People began settling in the Lincoln area in the early 1800's (Raymond, 2012). With these people came the earliest form of urban sprawl. Houses, buildings and everything at that time came from wood. Therefore, maintaining trees was a necessity. In the United States, tree planting, along with the tradition of city parks, is arguably one of the oldest efforts to improve the quality of life in the city (Voget et al, 2012). Not only did they provide shelter, but they also gave shade and served as a wind block along with many other benefits.

The trees inside the city of Lincoln make up what is known as an urban forest. A sustainable urban forest is the naturally occurring and planted trees in cities which are managed to provide residents with a continuing level of economic, social, environmental and ecological benefits both now and in the future (Clark, 1998). These trees are maintained and managed by the city and its residents. In most cities, these trees appear on city property, and are therefore considered public. There are select cities around the country that treat both public and private trees the same, meaning they provide maintenance and support for trees on private land and consider them to be part of the city's urban forest. Clark and Matheny (1998) conducted a study to interpret different communities view on urban forests. In cities with urban forest management plans (64% of respondents), such plans were largely restricted to public trees. One city, Sioux Falls South Dakota, had an urban forest management plan that considered all trees in the community, in the public and private areas (Clark et al, 1998). The study also focused on how people interacted with their city governments regarding the urban forests. They have many functional uses and services that they can provide. In urban areas in particular, promoting sustainable development can significantly affect the overall environmental impact and long-term sustainability of a city (Voget et al, 2012). Urban forests can clean the air and even reduce the urban heat island effect. They are capable of storing carbon from the air, and even adding more into the ground. Carbon sequestration is the process by which CO2 is transformed into above- and belowground biomass and stored as carbon (McPherson, 2008). Developing and maintaining urban forests is an important part of living in a community.

Urbanization can also have many negative effects on tree growth. This is commonly and widely occuring in the Amazon Rainforest where thousands of acres of native forests have been destroyed do to city expansion. Municipalities clear native vegetation that was once thick and

dense and plow under the ground cover. It is not only cities that are responsible for this, but people in general. Developing the Amazon into a major provider of internationally traded mineral and food commodities has dramatically transformed broad expanses of tropical forests to farm and pasturelands and to mining sites. The environmental impacts of this transformation are devastating (Richards and VanWey, 2015). Forests are threatened by cities unless careful management is practiced. Cities rely on trees for many reasons. As stated above, they provide lumber, shade and recreation areas.

Trees, both inside and outside of municipalities, play a very important role in the environment. They also provide ecological services. Trees filter water and can provide invaluable erosion prevention. Land-cover change (urbanization, deforestation, and cultivation) results in increased flood frequency and severity. Mechanisms of flooding include reduced infiltration capacity, lower soil porosity, loss of vegetation, and forest clearing, meaning lower evapotranspiration (Tollan, 2002). Trees found around streams provide all of these functions and more. Urban forests, especially those around streams and drainage ways, are most important because they provide the city their first line of defense against natural disasters such as flooding and mudslides. Cities must be mindful of these areas and how they are managed.

The question that will be researched in this study is: What is the effect of urbanization on tree growth surrounding streams in Lincoln, Nebraska? It is important to learn the effect that Lincoln has had on trees around streams encompassed by the city. The objective of this study is to explore the relationship between the expansion of Lincoln and the growth and health of the urban forests in semi-untouched areas along streams. Determining how trees respond to the expansion of the city around them compared to similar areas outside of Lincoln will help in understanding how to better manage Lincoln's urban forests. This thesis has some limitations,

however. I will be using a small sample size for my research. Ideally, a larger sample size would be used for more efficient data. However given the time and the means that it would take to complete multiple sites, it is simply not possible right now. Another limitation to my research is that I am taking a "snapshot" of the trees in their current state. This means that I am only taking into account what has happened in the past with regards to growth and management practices and I am not collecting any data to determine the expansion over time. I do not feel that this is a problem since I am concerned with the history of city growth to the present, and cannot predict future actions or development.

This thesis is based on a comparison of two locations, inside and outside of Lincoln. The effect of urbanization will be determined by comparing tree size, density, type and current management plans of the two areas. Data collection will be done in both of these sites and then a comparative analysis will be done to determine the effect, if any, that urbanization has on tree growth using sources of literature and peer reviewed articles for references.

Literature Review

The study by Voget and Fischer (2012) provides a guideline for excellent survey work. In their study, they recognize that there is a considerably longer history of people improving urban forests and planting trees than urban forest sustainability programs have existed. For that reason, they are confident that there will be a positive correlation between urban forest programs and sustainability programs. They use Tree City USA cities as trial places, hoping to find a strong relationship in a community that has actively embraced the Tree City USA concept. Since a strong tree planting program indicates such things as environmental awareness (even if for just the aesthetic value), the authors anticipate an increased interest in these communities for more

developed sustainability programs. According to the results of this study, there is a strong correlation between participation in Tree City USA and other sustainability programs.

McPherson (2008) describes the direct impacts that urban forests have on levels of carbon in a community. He points out and describes many different ways that urban forests are able to use the carbon that is produced from urban environments. Some uses include biological processes such as using carbon in the process of photosynthesis and turning the carbon into glucose. Other means include more physical ways, such as urban forests producing shade which can reduce the need for cooling and electricity bills in the summer. Although this is not my thesis's area of study, it can be useful by showing people the benefits of expanding their urban forests and planting more trees in their yards.

Nowak and Greenfield (2010) inspect the tree density and land cover/vegetation of different states. The study discussed the benefits that urban forests have on urban areas, such as reduced energy usage, carbon storage, increased property value and also an increase in human psychological health. Overall, results of the study will help the growth of urban forests, increase the variation in forests and also help to introduce more positive policies in government when it comes to making decisions about urban forests. This study provides much structure for helping create a positive image of urban forests. Because it seeks to improve policy, it is not a one size fits all solution. Therefore, because they address several different states their model can be used as framework for developing such a plan in Nebraska, and more specifically the city of Lincoln.

In another study done by Clark and Matheny (1998) they looked at what constitutes a sustainable model for urban forest care. To gather their information, they sent out surveys to cities over the country that were to be filled out by proper heads of the city government e.g. city planner, city forester, landscape architect etc. Through this study, they developed a plan for

urban forestry initiatives that are specific to the cities that responded to the study. Questions on the survey take into account things like knowledge of existing trees, the cooperation and interest in groups already related to urban forestry and the cities current programs regarding urban forests. Lincoln, Nebraska was not one of the cities that was covered in the survey, though the process behind finding a suitable plan for urban development could be beneficial to the area.

Miller (2012) explored Atlanta, Georgia's forests in and around the city. He focused on the effects that urban forests have on areas as it is seen through city development. He pointed out that urban sprawl can take away urban forests that provided things such as habitat for species as well as runoff prevention and carbon storage. For this reason, all urban areas should have some sort of development plan that ties urban development and urban forest care together. This is what my study is hopefully going to achieve, so it is important that I use what Miller has already found for a basis for my research.

The study by Sanders, Grabosky and Cowie (2013) looked at data regarding tree size and tree age in urban forests. The study specifically looked at whether or not where the tree is at in the urban area had any effect on tree size. This has significant applications because of safety and property reasons. If it is known that a certain type of tree will get too big to be safe if planted in a certain area, then property damage or severe injury can be prevented by not planting the tree. There is also potential of it being used for reasons of replacement and routine care. The authors found a strong correlation between site location and tree growth. This is significant for my purposes because it allows me to see what kind of trees can thrive in which areas of a city.

In 2005, the mayor of Los Angeles declared his plan to plant 1 million trees in the city to make it "greener". In response to this plan, McPherson (2008) combined a study of both survival and the future benefits of these trees. He first put together a model for tree growth by measuring

several parts of trees and recording them over time. He then looked into the benefits of these trees, such as energy reduction for nearby buildings, the air quality and the amount of runoff that they prevented. The study found that a much higher percentage of trees survived than expected, and the records for things like air quality and carbon storage were significantly higher than anticipated. This study supports my work by giving me an idea of the survival rate of trees based on their planting location. This can be extremely helpful in determining the long term well-being of urban forests in Lincoln, Nebraska.

A study conducted by Nowak and Walton (2005) focused on the growth of urban areas and the potential and existing depletion of forests, both urban and natural. The authors found that through analyzing urban forests, urban expansion will indeed have an effect on natural forests. This means that urban forests will become more invaluable as resources for habitat and carbon sinks. Urban areas need to be aware of this so that proper urban forest policies can be made.

Berg (2015) pointed out how things such as the emerald ash borer, disease and severe weather have taken their toll on urban forests. He addressed certain areas and certain times that work best for replacing trees on private lots and neighborhoods. This is a great resource for my thesis because it is a "plan" that is specific for Lincoln's urban forests.

A study by Nowak et al (2010) explored the issue of keeping forests alive in cities and towns. They described proper care and management as being key in helping and also developing urban forests. There are countless positives that come from urban forests including everything from carbon sinks, runoff preventers to habitat for urban wildlife. Nowak et al say it is important to learn what kind of trees a given area is able to support before beginning to plant. This is significant for my study, because it helps people realize the benefits of urban forests, which may

mean an increase in trees in urban areas. It also informs the general public on urban forest issues such as the health of trees and the management and care for them.

Tollan (2002) goes into detail and describes the importance of vegetation. He says interventions like construction and land use change can lead to increased floods, mudslides, lower soil porosity, and a greater risk of flash floods. His paper describes modeling tools for using vegetation and ground cover for helping predict floods based on the land use in the area. He concluded his paper describing the importance of efficient land use and utilizing natural ground cover so that serious natural disasters can be avoided. This is relevant to this thesis since I have chosen areas of vegetation bordering streams, which are potential high erosion areas. It is important to understand the vital role that trees play in keeping soil in place in these areas and learning how urbanization affects these trees which in turn affects the area as a whole.

Methods

The original project was to study aerial photographs of Lincoln from the past decades to get a big picture look at how the growth of Lincoln has influenced the growth of trees. Conclusions were then going to be drawn to see if a relationship could be found between urban growth and urban forests. The study, however, needed a more researchable question, one with an end result that could be presented to the public that could be useful to the city currently and to future generations. Still keeping with the original idea, the information was laid out in a sequence of researchable items. This system allowed narrowing down what was to be looked at, and also to define specific areas and not just the entire city.

Since this thesis is based on a comparison, two areas were chosen that contained similar characteristics. I located an area of natural growth for my test plot 15 miles outside of Lincoln at

the Spring Creek Prairie Audubon Center. This plot was chosen because it contained an area of ground that has been undeveloped. This ground was never tilled or plowed under, and no purposeful planting of any kind has been done on it. Limited management plans have taken place in this area to remove unwanted trees. This will be discussed later on in this research paper. Spring Creek was selected so that I could have an area of trees to study to compare the tree characteristics of the test plot inside the urban area of Lincoln.

The second plot was chosen inside the city of Lincoln in order to determine an effect of urbanization. This area was located next to a drainage stream in the Holmes Lake area. It was chosen using Google Maps while searching for stream areas in Lincoln that were not man-made that contained vegetation. It displayed similar characteristics as the first rural plot including stream size, location to the stream and remoteness. This plot was chosen to compare tree characteristics to the test plot outside of the urban area, and in this way, will provide information on how, or at all, an urban environment has affected tree growth.

My hypothesis when considering tree age in the two plots is that the Holmes Lake plot will show younger trees because of the urban environment. These trees are not provided with as many nutrients and room to grow as the trees out at Spring Creek. Therefore, that is why I expect to see a difference in the tree ages between the plots. An independent samples t-test analysis will be done on the data to determine any statistical significance.

Based on a study done by Lin et al. (2013) I used an area of twenty square meters or .05 ha, for my test plots. This was done to not only have a manageable area to work with, but Lin et al. states that smaller plot sizes give a more accurate representation of a large area. Each tree in the test plot was cataloged and measured. Information including tree type, the age of the tree (tree size), and the number of trees in the test plot will be collected. Tree type was identified by

leaves, tree appearance and bark characteristics. The tree age will be determined by obtaining the circumference of the trunk at 4.5 feet from the ground, roughly chest height (Kalliovirta & Tokola, 2005). This was done using a tape measure in the inches/feet scale. Tree diameter can be calculated using the equation diameter = circumference / pi. The diameter was used to find the age of the tree based on tree type using a standard chart (Figure 1).

The Spring Creek test plot was located on the Hanes Branch of the Spring Creek. The creek was approximately 5 meters wide and bordered my test plot on the North side. It curved around to the East where it was 20 meters from the test plot. The location of the plot was chosen due to the proximity to the stream and appeared to have an accurate representation of the trees in the area. The Holmes Lake test plot also bordered the stream in a similar way. The north boundary of the test plot was confined by the stream, while the east side was approximately 10 meters away from it. In both test plots, a 20 meter^2 area was marked with flags on the corners. The tree data was then collected and logged. Each tree in the test plot was identified and measured, after which a ribbon was tied onto the trunk to mark it as recorded. After collecting the data, the information was charted and compared. The hypothesis was tested by conducting independent samples t-tests. Factors including location, tree type, size, age, and management practices will be reviewed and discussed for accurate comparisons.

Results

The results of the study included the tree type, age (size), and number of trees in the plot in order to effectively observe any effect of urbanization. Figures 2 and 3 contain the data of tree type, size and number found in the plots, respectively. The trees have been accurately identified based on bark and leaves. The circumference of the trees was taken at 4.5 feet off the ground to

gain the best measurement for estimating age (Kalliovirta & Tokola, 2005). The measurements were taken accurately and all trees in the plots were accounted for. An analysis using an independent samples t-test indicated no statistically significant difference between the circumference of Spring Creek trees (M = 23.09, SD = 23.60) and the circumference of Holmes Lake trees (M=29.17, SD = 14.59).

Discussion

The objective of this thesis was to compare two different areas of tree growth along streams, one inside the city of Lincoln and the other outside. In this way, the different effects of urbanization on trees would be determined. Data was collected at both sites to determine observable differences.

The first site was the Spring Creek Prairie location. Here, 60 trees were identified and cataloged in the 20 meter^2 test plot. Of these 60 trees, 55 of them were Red Oak of varying sizes. There were four Honey Locust and one Red Cedar. The age of the trees was calculated by determining the diameter from the circumference and using the Growth Factor Chart (Figure 1). The ages of the Spring Creek Prairie plot are listed in Figure 4. Similarly, the ages for the Holmes Lake Stream are listed in Figure 5 which were calculated in an identical manner. There were a total of 18 trees in this area, Silver Maples, Red Oaks, Cottonwoods, Lindens and Ashes.

First we will discuss the tree type and density. The Spring Creek plot had almost three times the amount of trees that the urban plot had, while the Holmes Lake area had 2 more unique specie types as well as a higher percentage of variation. Ninety two percent of the trees in the Spring Creek plot were Red Oaks, a native tree to Nebraska. The Holmes Lake area had much more variation in tree type, including trees that are not native to Nebraska. Overall, we see that

the Holmes Lake area has less trees, but has a greater variety. This result can be seen likely because of urbanization. Red Oaks are the most common native Nebraska tree found in this part of the state so it is not unusual that we would find them both inside and outside of the city. However, the urban environment allows for the introduction of new tree species that would not have been there otherwise. Lindens for example, are native to the area around the Missouri River, so without people to plant and care for them they would not be found in such great numbers here. Several other trees are this way that were found in the Holmes Lake site. The Silver Maple as well as the honey locust are not native to these areas of Nebraska. Similarly, in the natural area of Spring Creek, we see an abundance of Red Oak trees. This is because they are native to the low valley areas of the state where there is rich soil and plenty of water. This can be seen in the Native Vegetation map of Nebraska (Figure 6).

The different land uses in the areas play a significant role in tree size and density. The area of Spring Creek Prairie is managed as a natural prairie, with the only development on the land being unobtrusive nature trails. As a result, the trees are able to grow thick and unregulated. Certain management plans are in place to keep out invasive trees such as the Honey Locust and the Eastern Red Cedar. Selective thinning is done occasionally to prevent the spread of noxious weeds and plants. Natural forces such as forest fires, soil type and water table keep the spread of the trees from pushing into the Prairie, so no other thinning takes place. No development or plowing has ever occurred on the land. The native trees such as the cottonwoods and the oaks are allowed to grow as they will. The area of Holmes Lake however is noticeably thinner, due to the urban area that it is in. The area selected is located along a popular hiking trail. Therefore, thinning practices have taken place to prevent the overgrowth of the trail. The area is also in the

flood zone of Holmes Lake, and therefore must be well maintained and controlled. This leads to thinning of trees, but also keeps the area from being too developed or plowed under.

The independent samples t-test analysis of the tree ages in the two plots showed that there was not a statistically significant difference between the ages in the two plots. Therefore, the hypothesis was not confirmed. This means that based on the data collected, it cannot be determined that urbanization had any effect on tree growth in the Holmes lake plot. Likewise, it cannot be determined that trees grow larger and older in a natural undisturbed setting like the Spring Creek Prairie. More plots with larger data sets would be necessary in determining any statistically significant differences between tree ages in different locations.

Not only do current land uses play a role in the trees present there, but past land use as well. Spring Creek Prairie has never been plowed and has consistently maintained a natural state thus allowing for a better growing environment than in the city. Figure 7 shows that this even back in 1955, the area of my study in the top of the picture is still very much a wooded area similar to today. The area of Lincoln, however, has had development around it and therefore it creates an environment not as suitable for healthy tree growth.

This study considers two different areas of similar characteristics, both minimally maintained with different uses. One is inside the city of Lincoln and the other is outside. However, through collected data of tree type, size and density illuminates an obvious difference in the two plots. The main question was not able to be answered however. While the mean tree size in the urban forest was twenty three percent higher than the mean size in the natural forest, this difference was not statistically significant. It is clear that being in an urban environment has a significant effect on tree growth in that area.

Summary/Conclusion

The objective of this thesis was to find an effect of urbanization on tree growth surrounding streams in Lincoln, Nebraska. This was done by collecting tree characteristics in two plots, one outside of Lincoln and one inside the city of Lincoln. The plots were 20 meters^2 in size to obtain an accurate representation of the area (Lin et al, 2013). These characteristics included tree type, age (size) and density. The age was determined by obtaining the circumference of the tree at chest height (Kalliovirta & Tokola, 2005), and then using the growth factor chart to estimate their age. A comparison of the two areas was then done to determine any effect the urban environment had on tree growth around the stream areas. It was found that the trees in the urban setting were fewer in number while displaying more variety.

It can be seen that urban environments affect trees growing near streams in Lincoln Nebraska. The urban environment affects the number of trees as well as the age that the trees are allowed to mature to along with providing more variety into the biosphere. This can be seen in the data collected in Figures 2 through 5. When compared to the natural area outside of the city of Lincoln, an obvious difference can be seen. The natural forest was much denser than the regular forest. The t-test analysis showed no significant difference between the tree ages in the two plots. Through many peer reviewed articles used in reference to this thesis, we see that urban environments have effects on trees. In Sanders et al (2013) article we see that trees grow differently in urban environments. References used in this thesis support the hypothesis that urban development has had an effect on tree growth. Perhaps this study may be utilized by further researchers to help show evidence of urban effects on trees. For further research into this thesis, it would be more effective to use multiple test plots in both environments. Collecting data from more areas both inside and outside of Lincoln would provide more conclusive evidence of

urban effects. Setting test areas up for ongoing study will also be helpful in monitoring effects in the future, instead of in the past as this thesis has done. Based on what has been learned through this thesis study, recording data from multiple plots in both the past and the present may lead to a better understanding of the urban environment on tree growth.

Appendix 1

Tree Type	Growth Factor	Tree Type	Growth Factor
Red Maple	4.5 x diameter	Pin Oak	3 x diameter
Sugar Maple	3 x diameter	Locust	4 x diameter
Silver Maple	5 x diameter	American Elm	4 x diameter
River Birch	3.5 x diameter	Iron Wood	7 x diameter
White Birch	5 x diameter	Cottonwood	2 x diameter
Shagbark Hickory	7.5 x diameter	Scotch Pine	4 x diameter
Green Ash	4 x diameter	White Pine	6 x diameter
Black Walnut	4.5 x diameter	Eastern Red Cedar	5 x diameter
Black Cherry	5 x diameter	Redbud	7 x diameter
Red Oak	4 x diameter	Dogwood	7 x diameter
White Oak	5 x diameter	Aspen	2 x diameter
		Linden	6 x diameter

Figure 1. Growth Factor Chart (Morton Arboretum 2015; Nix 2015)

Red Oak	144	Red Oak	37
Red Oak	84	Red Oak	6
Red Oak	10	Red Oak	12
Honey Locust	65	Honey Locust	9
Red Oak	19	Red Oak	6
Red Oak	46	Red Oak	6
Red Oak	29	Red Oak	5
Red Oak	36	Red Oak	3
Honey Locust	17	Red Oak	20
Red Oak	17	Red Oak	17
Red Oak	12	Red Oak	24
Red Oak	18	Red Oak	15
Red Oak	9	Red Oak	39
Red Oak	5	Red Oak	57
Red Oak	6	Red Oak	15
Red Oak	18	Red Oak	17
Red Oak	6	Red Oak	27
Red Oak	16.5	Red Oak	18
Red Oak	26	Red Oak	8
Red Oak	12	Red Oak	33
Red Oak	12	Red Oak	33
Red Oak	9	Red Oak	56
Red Cedar	12	Red Oak	72
Red Oak	9	Red Oak	24
Red Oak	7	Red Oak	39
Red Oak	9	Red Oak	32
Red Oak	5	Red Oak	23
Red Oak	11	Red Oak	16.5
Red Oak	9	Honey Locust	22
Red Oak	9	Red Oak	6

Figure 2. <u>Spring Creek Prairie Audubon Center Natural Forest Tree Size</u>

Tree Type	Circumference (inches)
Linden	22
Linden	21
Red Oak	33
Red Oak	36
Red Oak	52
Cottonwood	67
Red Oak	38
Red Oak	25
Red Oak	45
Red Oak	21
Red Oak	16
Elm	27
Cottonwood	13
Red Oak	24
Ash	10
Silver Maple	29
Silver Maple	32
Red Oak	14

Figure 3. Holmes Lake Stream Urban Forest Tree Size

Tree Type	Age (years)	Tree Type	Age (years)
Red Oak	183.34649	Red Oak	47.109863
Red Oak	106.95212	Red Oak	7.6394373
Red Oak	12.732395	Red Oak	15.278875
Honey Locust	62.070428	Honey Locust	11.459156
Red Oak	24.191551	Red Oak	7.6394373
Red Oak	58.569019	Red Oak	7.6394373
Red Oak	36.923947	Red Oak	6.3661977
Red Oak	45.836624	Red Oak	3.8197186
Honey Locust	21.645072	Red Oak	25.464791
Red Oak	21.645072	Red Oak	21.645072
Red Oak	15.278875	Red Oak	30.557749
Red Oak	22.918312	Red Oak	19.098593
Red Oak	11.459156	Red Oak	49.656342
Red Oak	6.3661977	Red Oak	72.574654
Red Oak	7.6394373	Red Oak	19.098593
Red Oak	22.918312	Red Oak	21.645072
Red Oak	7.6394373	Red Oak	34.377468
Red Oak	21.008452	Red Oak	22.918312
Red Oak	33.104228	Red Oak	10.185916
Red Oak	15.278875	Red Oak	42.016905
Red Oak	15.278875	Red Oak	42.016905
Red Oak	11.459156	Red Oak	71.301415
Red Cedar	19.098593	Red Oak	91.673247
Red Oak	11.459156	Red Oak	30.557749
Red Oak	8.9126768	Red Oak	49.656342
Red Oak	11.459156	Red Oak	40.743665
Red Oak	6.3661977	Red Oak	29.28451
Red Oak	14.005635	Red Oak	21.008452
Red Oak	11.459156	Honey Locust	28.01127
Red Oak	11.459156	Red Oak	7.6394373

Figure 4. Spring Creek Prairie Audubon Center Urban Forest Tree Age

Tree type	Age (years)
Linden	42.016905
Linden	40.107046
Red Oak	42.016905
Red Oak	45.836624
Red Oak	66.208456
Cottonwood	42.653525
Red Oak	48.383103
Red Oak	31.830989
Red Oak	57.29578
Red Oak	26.73803
Red Oak	20.371833
Elm	34.377468
Cottonwood	8.276057
Red Oak	30.557749
Ash	12.732395
Silver Maple	46.154934
Silver Maple	50.929582
Red Oak	17.825354

Figure 5. Holmes Lake Stream Urban Forest Tree Age

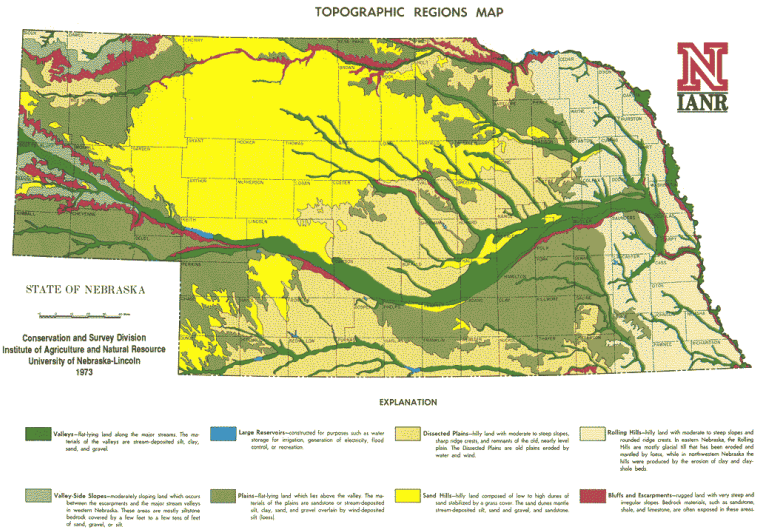

Figure 6. <u>Native Vegetation Map of Nebraska</u>

Figure 7. <u>Spring Creek Prairie Arial View</u>

References

Berg, E. (2015). Trees: Planting to replace. *UNL Extension.* http://acreage.unl.edu/enews-april-2015#Trees.

Clark, J., & Mathany, N. (1998). A Model of Urban Forest Sustainability: Application to Cities in the United States. *Journal of Arboriculture* 24:2 112-120.

Kalliovirta, J., & Tokola, T. (2005). Functions for estimating stem diameter and tree age using tree height, crown width and existing stand database information. *Silva Fennica*, *39*(2), 227-248.

Lin, D., Lai, J., Mi, X., Ren, H., & Ma, K. (2013). Spatial variation in community structure of a subtropical evergreen broad-leaved forest: Implications for sampling design. *Chinese Science Bulletin*, *58*(10), 1181-1186.

McPherson, G. (2014). Monitoring Million Trees LA: Tree Performance During the Early Years and Future Benefits. *Arboriculture and Urban Forestry, 40*(5), 286-301. Retrieved from Arboriculture Urban Forestry.

McPherson, G. (2008). Urban Forestry and Carbon: What the reporting protocol means to you. *Arborist News,* 17(6), 31-33.

Miller, M. (2012). The impacts of Atlanta's urban sprawl on forest cover and fragmentation. *Elsevier, 34,* 171-179.

Nowak, D.J., Stein, S., Randler, P.B., Greenfield, E.J., Comas, S., Carr, M., & Alig, R.J. (2010). Sustaining Americas Trees and Forests. *United States Dept. of Agriculture.* General Technical Report-62.

Nowak, D., & Greenfield, E. (2010). Urban and Community Forests of the South Central East Region. *General Technical Report,* (NRS-58)

Nowak, D., & Walton, J. (2005). Projected Urban Growth (2000– 2050) and Its Estimated Impact on the US Forest Resource. *Journal of Forestry,* 383-389.

Raymond, E. (2012). Prairie Settlement: Nebraska Photographs and Family Letters. 1862-1912 (Book Review). *Journal of American History.* 99(2), 691-692.

Richards, P., & VanWey, L. (2015). Where Deforestation Leads to Urbanization: How Resource Extraction Is Leading to Urban Growth in the Brazilian Amazon. *Annals Of The Association Of American Geographers*, *105*(4), 806-823.

Sanders, J., Grabosky, J., and Cowie P. (2013). Establishing Maximum Size Expectations for Urban Trees with Regard to Designed Space. *Arboriculture and Urban Forestry.* 39(2), 68-72

Tollan, A. (2002). Land use change and floods: what do we need most? Research or management?. *Water Science and Technology*. 45(8), 183-190.

Voget, J., & Fischer, B. (2012). Explaining the Relationship Between the Urban Forestry and Community Sustainability Programs of Tree City USA Municipalities in Indiana. *School of Public and Environmental Affairs. Bloomington Urban Forestry Research Group White Paper,* 1-23.